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Original Article

Understanding Fundamental Characteristics of the NPs under preparation and Nano Structural Investigation on Screen Printed Cobalt Oxide (Co_3O_4) Thick Film with Annealing Temperature

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Abstract

Understanding the properties of semiconductor nanostructures is important for developing their practical applications in the nanodevices with different annealing temperatures. Thick films of Cubic cobalt oxide (Co_3O_4) thick films are deposited on glass substrate by screen printing technique. The structural, morphological and electrical properties are investigated using X-ray diffraction (XRD), Scanning Electron Microscopy and half bridge method respectively. All the characterization was carried out for unannealed and annealed thick films. The annealed films were at 250 ℃-400 ℃ in a muffle furnace. Using characterisation techniques, the success of the synthesised nanoparticles was confirmed. The x-ray diffraction technique was used for structural characterization which confirms the polycrystalline nature of the films with cubic structure having preferential orientation through (311) plane. The estimated crystallite size is found to be 18.516 nm. The lattice parameter found to be 8.036-8.138 A.U. approaches to standard value given by JCPDS. From the SEM analysis the films show uniformity, roughness, large no. of nanocrystals and agglomeration of particles, sphere-shaped aggregations was occurred. Spherical grain size increases with respect to annealing temperature and its change from 47.66 to 77.33nm. The SEM-EDS analysed morphology and chemical compositions. The correlations between structural and morphological properties are reported. The EDX analyses indicate that all the compositions have the desired stoichiometric ratios. The D.C. resistance of the films was measured by half bridge method in air atmosphere at 30℃-350 ℃ . The prepared thick films of Co_3O_4 nanoparticles were analysed for electrical parameters, that assured the prepared material has a semiconducting nature. Specific surface area, film resistivity, TCR, activation energy was calculated at different annealing temperatures. Specific surface area, film resistivity decreases with increases in annealing temperature. The activation energy at high temperature varies from $2.7044x10^{-4}$ to $12.4401\ x10^{-4}eV$ and the electrical conductivity of the films changes from $1.2778\ x10^{-5}$ to $2.7356\ x10^{-5}$ $(\Omega \cdot m)^{-1}$ with the increase of annealing temperature . It was shown that the structural, morphological and electrical properties of Co_3O_4 films were improved by increasing the annealing temperature. These results are helpful to understanding the fundamental characteristics of the NPs under study.

Introduction

Recently ,Material science becomes more promising field in the catalysis and sensors technology in which nanostructured transition metal oxides have been extensively studied for their potential use and technological diverse applications in different areas such as smart windows, negative electrodes in lithium ion batteries and mirrors with variable reflectance due to their outstanding and catalytic properties namely the properties (such as structural, magnetic, optical, catalytic, and electronic) of nanomaterials depend strongly on their size, structure, and shape. Intensive research is presently being carried out on enhancing these properties and the adding novel functionalities to the metal oxides. Mentioned material (Co_3O_4) is a electrochromic materials and would be classified into two categories: cathodic (i.e. colored in the reduced state) like molybdenum oxide, tungsten oxide etc, and anodic colored materials (i.e. colored in the oxidized state) like, ruthenium oxide, cobalt oxide, nickel oxide, etc.

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[1] However, Cobalt oxide films is a promising anodically coloring electrochromic material After oxidation it becomes grey in colour, which is opposite to the reduced tungsten oxide;a magnetic p-type semiconductor and antiferromagnetic material with an energy band-gap of 1.4 – 1.8 eV [2]. Based on reported stoichiometry is used for the electrochemical applications due to its spinel cubic structure as well as it contains vacancy and its chemical stability.
of interest owing to their enhanced and exclusive properties properties when the surface to volume ratio increases. Due to its good chemical stability and high specific surface area, therefore is used in field of gas sensors for detection purpose. materials with less dimensions of larger efficiency have generated greater interest so, Co_3O_4 (Tricobalt tetra oxide) has enormous number of applications [3]porous, nanospheres, nanotubes cubic single crystals, nano particles, nano rods, nano plates, nano wires, and nano cubes structures have been prepared [9] Improvement in the electrical conductivity, transmission stability and practical feasibility different processes like doping, annealing and aging are employed [10]. Due to lack of systematic studies about un doped Co_3O_4, so to study various properties Co_3O_4 thick films prepared by screen printing technique and the effect of annealing temperature on it is important now a days.
Screen-printing technology is a simple and has been demonstrated as a cost-effective which is suitable, for mass-production of thermoelectric modules with advantage of this is that it allows to control the dimensional factor, considering to the thickness of the film elements.[11]
For characterisation like Surface morphology and particle size of the samples were determined from (SEM) instrument while the stoichiometric characteristic was proved from energy dispersive X-ray (EDX) analysis [12]
The research focuses on preparation of screen printed Co_3O_4 thick films and investigates the effect of annealing temperature on structural, morphological and electrical characterization elaborated by a simplified screen-printing technique.

Materials Method and Measurements

The commercially available AR grade with 99.99% purity cobalt oxide nano powder was used for preparation of thick films. The chemicals other than mentioned powder required for preparation of thick film are acetone, B.C.A., ethyl cellulose etc purchased from Modern Lab. Nashik etc. For verification of given sample structural properties, the X-ray diffraction (XRD) technique is used. The X-ray diffraction patterns of all the samples are recorded for analysis purpose. They were plotted using Bruker D8 advance diffractometer, Germany with CuKα (λ=1.54 A.U.) radiations operated at 40 KV and 40 mA in the scanning range of (2θ) between 20° and 80°. To observe chemical composition and surface morphology scanning electron microscope, SEM-JEOLJSM-6360A with OXFORD EDAX attachment is used. For electrical characterization simple half bridge method was used.

A. Preparation of thick films of cobalt Oxide nanoparticles

The cobalt oxide based thick film sensor was constructed by standard screen-printing technique. The powder nanoparticle of Co_3O_4 converted into paste form was used to prepare thick films by screen printing method maintaining the inorganic to organic binder ratio at 70:30. The inorganic part consists of nanoparticles of Co_3O_4. The organic part consisted of 8% ethyl cellulose (EC) and 92% butyl carbitol acetate (BCA). All these stoichiometric amounts of Co_3O_4 and binders then mixed into mortar and pestle and crushed continuously for nearly 40 minutes. Then, BCA was mixed into above crushed powder of metal oxide and binders. A solution of BCA which was added drop wise till proper thixotropic properties of the paste achieved. That gel like paste can employed over glass substrate with dimensions 1.5 X 2 cm. After completion of thick film coating, these films were air dried firstly for 30 minutes followed by IR drying for 30 minutes. Finally, the prepared binary oxide Co_3O_4 film sensor was kept in muffle furnace for calcinations process at various temperatures 250 ^{0}C, 300 ^{0}C 350 ^{0}C ,400 ^{0}C nearly 2 hours. On the next day the thick films of used oxide was removed from muffle furnace to utilize for further study. Annealed films were black in color and found to be uniform, pinholes free and strongly adherent to the glass substrates. Their thickness was calculated by using gravimetric method assuming the samples were approximately uniform as that of bulk. such a films are now ready for characterization.

B. Measurement of the Film thickness:

The thickness of the prepared films calculated by the using gravimetric method assuming the samples were approximately uniform as that of bulk. Its equation form is given by

$$t = \Delta w / A * \rho \quad (1)$$

where, Δw =actual weight of the prepared film, ρ = density of Co_3O_4 = 6.11 gm/cm^3 A= area of the film (length*breadth)
After calculations thickness observed in terms of μm. Here it varies from 33 to 38 μm.

C. Characterisation of Screen printed Co_3O_4 thick film sensor

The physical and chemical properties and performances cobalt oxide NPs intensively depends on size shape geometry morphology etc. To characterise the prepared samples mainly X-ray diffraction technique (structural analysis), scanning electron microscopy with EDAX (morphological and elemental analysis) and half bridge method (electrical analysis) were used.

Results And Discussion

A. Structural Characterisation:X-ray diffraction study (Crystal structure determination**):** The structural properties of thick film is the key to recognize its quality and studied by XRD technique. Also, using X-ray diffraction, the crystallinity and phases transition metal oxides nanoparticles and composite nanoparticles were analysed [13]. For recognition of the crystalline phase, JCPDS (Join Committee on Powder Diffraction Standards) data and

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using Debye-Scherrer's equation the crystallite sizewere calculated.

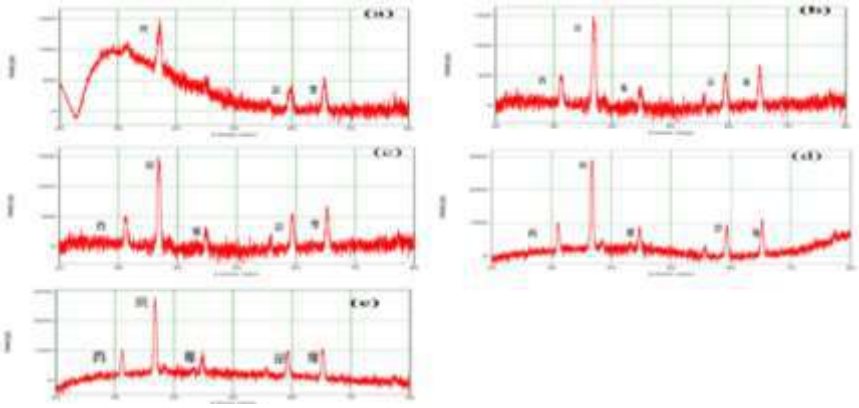

Fig. 1 XRD patterns of Co_3O_4 thick films (a) as deposited (unannealed), annealed at (b) 250°C, (c) 300°C, (d)350°C, (e)400°C respectively.

Fig.1(a-e) shows the XRD patterns of Co_3O_4 thick films as deposited at room temperature (unannealed) and annealed at different temperatures namely 250 ,300, 350 400℃. It indicates the purity of the product .From XRD Study, pattern was exploited in the 2θ range of 20– 80°and revealed the formation of Co_3O_4 with cubic crystal structure .All main diffraction peaks are located at 2θ of 31.073^0 ,36.749^0 , 38.47^0 , 43.13^0 ,44.71^0 , 55.52^0 ,59.25^0 , 65.16^0 and 77.94^0 indicating their polycrystalline nature corresponding to the (220), (311), (222), (400), (422), (511),(440) and (622)crystal planes, respectively and demonstrated the formation of Co_3O_4 with cubic crystal structure [JCPDS card no. 42- 1467]. The peak intensity is strong, indicating high crystalline structure of the products [14] The average crystallite size is estimated from the X-ray diffraction patterns using the Scherrer formula.

$$D = \frac{0.9\lambda}{\beta cos\theta} \quad (2)$$

where 'D' is crystallite size, 'β' is full width at half maxima, 'λ' is wavelength of X-ray used and'θ' is diffraction angle.

The crystallite size of Co_3O_4 calculated from the strongest peak, locating at (311) plane at $2\theta \approx 37°$, are estimated 18.516 nm. The average crystallite size for pure cobalt oxide was found to be 18.2033nm [15,16] and its distribution range is 18.52 to 36.38nm depending on annealing temperature.

The calculated d_{hkl} (interplanar distances) values and the standard values confirms that the as deposited and annealed films are nano crystallized in the spinel type cubic structure of Co_3O_4 (Fd3m space group). The lattice parameter 'a' of the unit cell is calculated from the peak positions using the formula of cubic system Formula. This value is found to be in the range 8.036-8.138 Å, which is close to standard value given by JCPDS 42-1467 (a = 8.084 Å). When the substrate temperature increases, the intensity of the peak corresponding to the (311) plane is found to decrease due to the thermal strain. Sharp peaks are observed at 350 °C annealed temperature [17] From XRD data, the crystalline parameters like lattice constant (a), crystallite size (D), dislocation density (δ), and micro strain (ε) were determined. The dislocation density is the length of dislocation lines per unit volume of the crystal. Greater D and smaller δ values mean better crystallization of the films. In thick films, strain originate mainly from the mismatch between the polycrystalline film and the amorphous substrate and or from the difference in the thermal expansion coefficient of the film and the substrate. The dislocation density and lattice strain were calculated from the diffraction pattern to obtain more information about structural properties. The observed changes of strain are due to point defects and crystallite size. The lattice strain is calculated using Stokes-Wilson equation and to know more on the number of defects in the film, the dislocation density, δ is calculated by using relation mentioned in table I. The induced strain causes reduction in crystallite size and increase in peak broadening. The average micro strain screen printed Co_3O_4 thin film sensor is 0.27014 %. Micro strain decreases from 0.00611 to 0.0009 due to good crystallinity.

Table I: Shows Dislocation density and Micro Strain for different annealing temperatures.

Annealing temperature (°C)	**Dislocation density $\delta = \frac{1}{D^2}$ (lines/m^2) 10^{15}**	**Micro Strain $\varepsilon = \frac{\beta cos\theta}{4}$, 10^{-3}**
Unannealed	13.18	6.11
250	0.75	0.952
300	5.10	2.475
350	2.92	1.870
400	3.695	2.1

The XRD spectrum is in full agreement with the standard spectrum of cubic crystalline Co_3O_4 (JCPDS card no: 42–1467). The diffraction peaks revealed to the cubic nature of nanocrystalline Co_3O_4.

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B. Morphological characterization:

SEM with EDS Analysis (surface morphology)

The Scanning electron microscopy (SEM-JEOL JSM 6360 Model) images of prepared nanomaterial Co_3O_4 thick film are displayed in fig.2. These 2D images with high magnification shows surface texture, color and porosity Co_3O_4 nanoparticles and indicate the formation of particles with different shapes and sizes. This porosity may be due to the evaporation of organic binder during the growing process and the annealing treatment [17] The instrumental parameters, accelerating voltage, spot size, and magnification and working distances are shown on SEM image. The surface characteristics of the prepared films investigated by scanning electron microscopy that shows heterogeneous, porous nanoparticles with varying dimensions. Some particles are appeared in spherical shape. The observed particles are highly agglomerated and they are essentially cluster of nanoparticles. The surface morphology of screen printed Co_3O_4 thick films shows small sphere-shape particles are distributed some of them having heterogeneous surface, microspores and mesopores as seen from its surface micrographs.[10] It's greyish black in color, various sized nanoparticles imaged can be seen from SEM images as shown.

Screen printed thick films deposited on glass substrate annealed at unannealed, 250 ^{0}C, 300 ^{0}C, 350 ^{0}C, 400 ^{0}C. It is observed that films show polycrystalline nature with no. of voids (pores)distributed on the surface of film. The particle size was obtained as the length of the segment joining the two ends of the particle and passing through its mass center and the average particle size is increases from 73 nm to 145nm with increase in annealing temperatures. It is maximum when film is unannealed. The average particle size is 116.702 nm. Spherical grain size increases with respect to annealing temperature and its change from 47.66 to 77.33nm and its maximum when thick film is unannealed. Surface area decreases from 20.60 to 12.698 m^2/gm with increase in annealing temperature and is a minimum for unannealed film as shown in table II. Surfaces of Co_3O_4 thick films are cubical, spherical grains, so such a film can adsorb more atmospheric oxygen due to more exposed surface area of the film. Highly porous film shows high sensitivity.

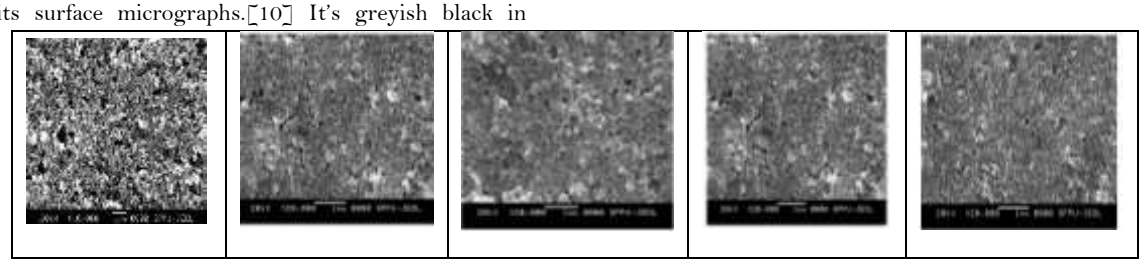

Fig. 2.SEM micrographs as deposited (unannealed), annealed at 250 ^{0}C, 300 ^{0}C, 350 ^{0}C, 400 ^{0}C Co_3O_4 thick films respectively.

Table II: Mean particle size, grain diameter and Surface area at various annealing temperatures.

Annealing temperature (^{o}C)	**Mean Particle size (nm)**	**Spherical grain diameter 'd ' (nm)**	**Specific surface area $S_w = \frac{6}{\rho d}$ (m^2/gm)**
Unannealed	127.2	83.5	11.76
250	73.11	47.66	20.60
300	108.2	66.66	14.73
350	130	73.66	13.331
400	145	77.33	12.698

S Analysis: The elemental quantitative composition of grown Co_3O_4 nanoparticles was determined using the spectra obtained by energy dispersive analysis of X-rays (EDAX). The weight percentage and atomic percentage of cobalt oxide nanoparticles are shown in table III and shows nanoparticles are non-stoichiometric

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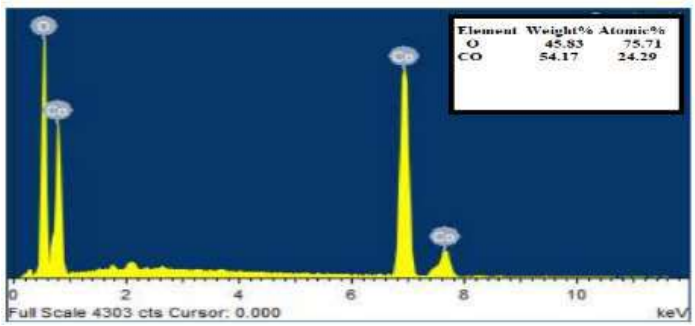

Fig. 3: EDAX results of Co_3O_4 nanoparticle

Table III: Atomic % elemental composition of Pure Co_3O_4 thick films as measured by EDS

Sample Annealed Temperature	**Elements**				**Co/O Ratio**
	Co		**O**		
	At. wt.%	***At. Mass %***	***At. wt.%***	***At. Mass %***	
Unannealed	53.90	24.09	46.10	75.91	1.17
250° C	52.21	22.88	47.79	77.12	1.09
300° C	53.76	23.99	46.24	76.01	1.16
350° C	54.43	24.24	45.57	75.71	1.19
400° C	54.17	24.29	45.83	75.51	1.18

EDAX results of NiO nanoparticles

The weight percentage of cobalt is increased with annealing temperature and mass percentage of oxygen decreases with increasing annealing temperature due to release of excess oxygen. decreases which indicates the oxygen adequate nature of the films. [**18**]

Table III shows quantitative elemental analysis of Cobalt oxide. In figure, the major peaks of Co and O elements are observed. The compositional data from the EDX analysis agree well with theoretically calculated values, indicating a good compositional homogeneity across the nanoparticles. The EDX spectrum shows sharp peaks between 6.6 and 7.8KeV for Co and between0.4 and 0.6KeV for O corresponding to crystalline Co_3O_4 NPs. The EDAX results obtained for spinel type cobalt oxide thick are in good agreement with reported output. Due to high electron affinity of surface molecules, oxygen element gets attached to the molecules on the surface of the prepared thick films.

Crystallinity: It describes degree of structural order in a solid and is calculated by

$$I_{cry.} = \frac{D_p}{D} \qquad (3)$$

, D_p =116.702 nm particle size from SEM

and D = 18.2033 nm by XRD using Debye Scherrer Formula

When I_{cry} is close to 1, it is assumed that the crystallites represents monocrystalline units while larger value of I_{cry} means the particles are of polycrystalline type .

From XRD and SEM, I_{cry} = 6.4110 for cobalt oxide thick film it's much greater than 1 implies that the prepared thick films show polycrystalline type. Result shows particle has polycrystalline nature and good crystallinity.

C. Electrical Characterization:

The cobalt oxide film sample D.C. resistance was measured by using half bridge method as a function of temperature in home built static gas measurement system. This system consists of glass chamber and heater of nichrome wire having Resistance-120ohm at room temperature. The heater was used to change the film sample temperature from room temperature 30°C to 350°C. In half bridge method the value of R_{ref} =10 MΩ and 30 V_{DC} power supply were used.

1.Sample Resistance:

The resistance of the thick film samples was determined using following equation

$$R_{sample} = R_{ref} \{\frac{V_{in}}{V_{out}} - 1\} \qquad (4)$$

Readings of temperature verses output voltage were taken by changing temperature 10° C. The resistance of cobalt oxide thick films found to be decreases with increase in temperature. This gives the confirmation of semiconducting behaviour of Co_3O_4 material by obeying

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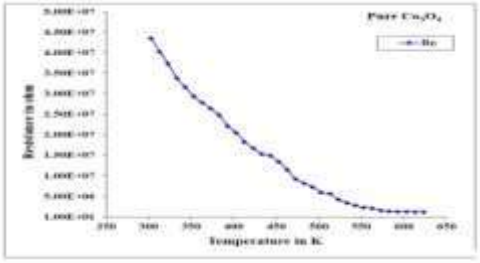
$R = R_0 e^{-\Delta E/kT}$ in the 30° C- 350° C temperature range. Fig.4 shows the change in resistance of pure Co_3O_4 thick films with respect to change in temperature(k).



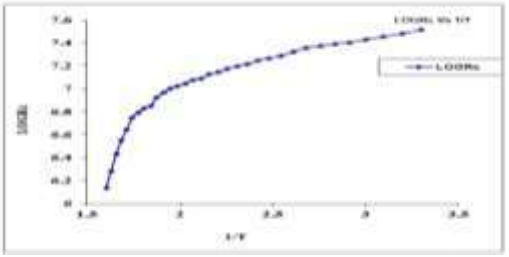


Fig4a.Plot of resistance against temperature for Co_3O_4 thick films

Fig.4b. Plot of logR against inverse temperature for Co_3O_4 thick films

2.Resistivity of Co_3O_4 Thick Films : The resistivity of prepared thick films was calculated as function of temperature within temperature range. The exponential nature of graph shows the resistance reaches steady lowest saturation level with respective temperature. The resistivity of thick films at constant temperature is calculated using equation

$$\rho = \frac{Rbt}{l} \qquad (5)$$

Where, ρ = Resistivity of the film, R = resistance at room temperature, b = breadth of film=1.25cm, t = thickness of the film, l = length of the film=2.5cm.

To calculate resistivity of unannealed thick film, R = $4.791x10^7\Omega$,t= 38μm were taken. ρ is 910.38 Ωm and is maximum and corresponding conductivity $1.098x10^{-3}$ $\Omega^{-1}m^{-1}$ and is a minimum. The resistivity of pure Co_3O_4 thick films decreases with increase in annealing temperature. The electrical resistivity and conductivity values are found out at various annealing temperatures and are mentioned in table. From electrical properties we observed the electrical conductivity of pure Co_3O_4 thick films increases with increase in annealing temperature, films deposited onto nonconductive substrate (250-400°C) as mentioned in table IV. In fact, annealing treatment provides sufficient thermal energy to crystal which facilitates the electron delocalization through the elimination of a large number of defects. [17]

3.Temperature Coefficient of Resistance (TCR) of Co_3O_4 Thick Film: The temperature coefficient of resistance (TCR) of pure **Co_3O_4**thick films is calculated by using **equation**. Temperature coefficient of resistance is found negative to pure **Co_3O_4** thick film samples. The negative sign indicates the semiconductor behaviour of the prepared pure **Co_3O_4** thick films. High resistivity of thick film samples corresponds to a low TCR value. TCR of pure **Co_3O_4** unannealed thick film is found **-0.011523/k.**

To obtain the value of T.C.R. following equation is used TCR $(\alpha) = \frac{1}{R_0}\frac{\Delta R}{\Delta T} = \frac{\text{Slope}}{R_0}$,per degree kelvin. (6)

4.Activation energy of Co_3O_4 Thick Films The activation energies at the low temperatures and high temperatures of prepared spinel type Co_3O_4 thick films film was calculated using Arrhenius plot. Fig4b. shows graph of log R in ohm versus reciprocal of temperature (1/T) in Kelvin for **Co_3O_4** thick films. The Arrhenius plot has two distinct regions of temperature namely low and high temperature region. The annealing temperature of films is an important quantity to decide the transition temperature from low region to high region. The observed values of activation energy for **Co_3O_4** unannealed thick film found**1.88735 x10⁻⁴** eV and **5.6158 x10⁻⁴** eV at low and at high temperature respectively. The energy of activation within the low temperature region is low as compare to energy within the high temperature region because material passes from one conduction mechanism to a different. This region are regions of temperature conduction, during this region energy of activation decreases because a tiny low thermal energy quite sufficient for the activation of charge carriers to require part within the conduction process. Hence increase in conductivity within the lower temperature region may be attributed to the increase of charge mobility. It shows more thermal durability with increase in annealing temperature.

Table IV: Electrical parameters of Co_3O_4 thick film sensor annealed at different temperature

Annealing Temperature Degree celsius	Resistivity Ωm	Electrical Conductivity $10^{-3}\Omega^{-1}m^{-1}$	T.C.R. per kelvin	Activation energy **x10⁻⁴** eV	
				At low temp.	At high temp.
250	**782.57**	**1.2778**	**-0.003575**	**0.777366**	**2.7044**
300	**634.42**	**1.5763**	**-0.004409**	**0.3546**	**6.4341**
350	**570.74**	**1.7521**	**-0.00476**	**0.31887**	**9.5916**
400	**365.55**	**2.7356**	**-0.005936**	**0.29339**	**12.440**

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The activation energies are calculated by using the Arrhenius relation

$R = R_0 e^{-\Delta E/kT}$ (7)

where, R_0 is the pre-exponential factor, ΔE is the activation energy, K_B is the Boltzmann constant and T is the absolute temperature.

The activation energy ΔE for Co_3O_4 films are calculated from the slope of the plot the Log R vs (1/T) and is given by $\Delta E = 2.303x$ K_B x slope of the graph. At low and high temperature its values in electron volt are mentioned in table. [18]

It shows that the electrical behaviour of the NPs was studied by measuring the dc conductivity as a function of temperature T ,this results reveals that the materials are characterized by semiconductor behaviour i.e. by increasing the temperature, more and more charge carriers can overcome the energy barrier and participate in the electrical conduction is assigned to elevated temperatures provide enough energy for charge carriers to hop among sites or even from defects involving singly charged oxygen ions[19]. These oxygen defects would add additional charge carriers to increase conductivity.

Conclusion

Cubic structured Co_3O_4 thick films with different thickness have been successfully deposited on glass substrate by the simple, cost-effective screen-printing technique. The structural, morphological and electrical properties have been systematically investigated for Co_3O_4 thick films. The films were deposited at room temperature (unannealed) and annealed in the temperature range 250°C to 400°C. The XRD analysis reveals that Co_3O_4 thick film shows a polycrystalline nature and cubic structure having a preferential orientation along the (311) plane. The high degree agglomeration of spherical shaped grains were observed . Increase in the thickness of the Co_3O_4 films increased the crystallinity as well as morphological properties. The crystallite size calculated using Debye's Scherrer equation for strongest peak, locating at (311) plane at $2\theta \approx 37°$, are estimated 18.516 nm. From SEM, observed that spherical nano particles are highly agglomerated and are essentially cluster of nanoparticles. The average particle size is 116.702 nm. Spherical grain size increases with respect to annealing temperature and its maximum 83.5nm when thick film is unannealed. Surface area decreases from 20.60 to 12.698 m^2/gm with increase in annealing temperature from 250-400°C and is a minimum for unannealed film. The grain size increases and specific surface area decreases as annealing temperature increased. Highly porous film shows high sensitivity. EDAX pattern shows that presence of chemical element as well as purity of Co_3O_4 NPs. The EDAX results obtained for spinel type cobalt oxide thick are in good agreement with reported output. The dislocation density, lattice strain were calculated to obtain information about structural properties. The observed changes are due to point defects and crystallite size. The higher peak intensities are due to better crystallinity. From electrical characterization, resistivity decreases from 910.576 Ωm to 365.5466 Ωm with increase in annealing temperature it means cobalt oxide thick films shows semiconductor behavior. The value of electrical conductivity and activation energy at high temperature increases $1.098x10^{-3}\Omega^{-1}m^{-1}$ *to* $2.7356x10^{-3}$ $\Omega^{-1}m^{-1}$ and 5.6158 $x10^{-4}$ eV to $12.44x10^{-4}$ eV as annealing temperature increased respectively. A study of these nanoparticles' temperature-dependent dc conductivity illustrated exponential behaviour confirming their semiconductive nature. From these results, we conclude that the annealing temperature strongly affects the structural, morphological and electrical properties of cobalt oxide thick films. However further investigation and optimization still need to be done for doped cobalt oxide thick films.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Role of Tourism in Regional Economic Development: A Study of Dhule and Jalgaon Districts

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Abstract

Tourism has increasingly emerged as a significant driver of regional economic development, particularly in areas endowed with diverse natural, cultural, historical, and religious resources. The present study examines the role of tourism in fostering economic development in the districts of Dhule and Jalgaon in North Maharashtra. Both districts possess considerable tourism potential, ranging from historical monuments and religious centers to wildlife sanctuaries and natural landscapes. Despite these advantages, the contribution of tourism to regional economic growth remains relatively underexplored in academic literature.

The study aims to assess the economic significance of tourism by analyzing its impact on employment generation, income enhancement, infrastructure development, and local entrepreneurship. It further investigates the spatial distribution of tourism resources and evaluates the challenges that hinder the effective utilization of tourism potential in the region. The research is based on both primary and secondary data sources, including field observations, stakeholder interactions, government reports, tourism statistics, and published literature.

The findings indicate that tourism has contributed positively to local economic activities by creating direct and indirect employment opportunities, promoting small-scale businesses, and improving transport and communication facilities. However, inadequate infrastructure, limited promotional initiatives, insufficient investment, and weak institutional coordination continue to restrict the sector's growth. The study highlights the need for integrated tourism planning, sustainable resource management, community participation, and improved policy support to maximize the developmental benefits of tourism.

The research concludes that tourism can serve as an effective instrument for balanced regional development in Dhule and Jalgaon districts if appropriate strategies are adopted to strengthen tourism infrastructure, enhance destination management, and encourage local stakeholder involvement. The study provides valuable insights for policymakers, planners, and researchers interested in tourism-led regional development and sustainable economic growth.

Keywords: *Tourism, Regional Economic Development, Employment Generation, Tourism Infrastructure, Sustainable Tourism, Dhule District, Jalgaon District, North Maharashtra.*

Introduction

Tourism has become one of the most influential sectors of the modern economy, contributing significantly to economic growth, employment generation, infrastructure development, and socio-cultural transformation. In many developing countries, tourism is increasingly viewed as an effective tool for regional development because of its ability to utilize local resources, generate income opportunities, and stimulate economic activities across multiple sectors. Unlike many industries that are concentrated in urban centers, tourism has the unique capacity to promote development in rural and backward regions by creating linkages with transportation, hospitality, handicrafts, trade, and other service sectors.

In India, tourism has emerged as a vital component of economic planning and regional development strategies. The country's diverse geographical landscapes, historical monuments, religious centers, cultural traditions, and ecological resources attract millions of domestic and international visitors every year.

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The economic benefits generated through tourism extend beyond direct revenue earnings and contribute to employment creation, investment opportunities, local entrepreneurship, and improved public infrastructure. Consequently, tourism is increasingly recognized as a catalyst for balanced regional development.

Maharashtra occupies a prominent position on the tourism map of India due to its rich historical heritage, cultural diversity, religious significance, and natural attractions. While destinations such as Mumbai, Pune, Ajanta, Ellora, Shirdi, and Mahabaleshwar have received considerable attention from policymakers and tourists alike, several regions within the state continue to remain relatively underdeveloped despite possessing substantial tourism potential. Among these regions, the districts of Dhule and Jalgaon in North Maharashtra offer a unique combination of historical, cultural, religious, and ecological attractions that can contribute significantly to local and regional economic development.

Dhule district is characterized by its tribal heritage, natural landscapes, forest resources, and historical monuments such as Laling Fort and Songir Fort. The district also possesses considerable potential for eco-tourism and rural tourism owing to its diverse environmental resources and cultural traditions. Jalgaon district, on the other hand, is internationally recognized for its proximity to the Ajanta Caves and is home to several important tourist destinations, including Patnadevi, Gautala Wildlife Sanctuary, Padmalaya Temple, and various cultural and religious sites. These tourism resources have the potential to generate economic opportunities through increased tourist arrivals, business development, and employment creation.

Despite the availability of such tourism assets, the overall contribution of tourism to the economic development of Dhule and Jalgaon districts has not been adequately explored. Existing studies have largely concentrated on destination-specific tourism potential or heritage conservation, while limited attention has been given to understanding tourism as a driver of regional economic transformation. Furthermore, challenges such as inadequate infrastructure, limited promotional activities, insufficient investment, and weak institutional support continue to affect tourism development in these districts.

Against this backdrop, the present study seeks to examine the role of tourism in regional economic development with special reference to Dhule and Jalgaon districts. The study focuses on evaluating the economic contributions of tourism in terms of employment generation, income enhancement, infrastructure improvement, and entrepreneurial development. It also aims to identify the major challenges affecting tourism growth and to suggest suitable strategies for promoting sustainable and inclusive tourism development. By analyzing the relationship between tourism and regional development, the study intends to contribute to the broader discourse on tourism-led economic growth and provide useful insights for planners, policymakers, and development practitioners working towards balanced regional development in North Maharashtra.

Review of Literature

Tourism has been widely recognized as an important instrument for regional economic development. Researchers from different disciplines have examined the relationship between tourism growth and economic transformation, emphasizing its contribution to employment generation, income creation, infrastructure development, and regional diversification. The existing body of literature indicates that tourism not only generates direct economic benefits but also stimulates several supporting sectors through multiplier effects.

Several studies on tourism economics have highlighted that tourism contributes significantly to local and regional development by creating opportunities for both skilled and unskilled labour. Increased tourist arrivals often encourage the growth of hospitality services, transportation networks, retail activities, and small-scale enterprises. These developments help strengthen local economies and improve living standards in tourism-oriented regions.

Research focusing on regional development has demonstrated that tourism can reduce spatial inequalities by attracting investment to relatively underdeveloped areas. In many cases, tourism serves as an alternative source of livelihood, particularly in rural and tribal regions where industrial development remains limited. Scholars have argued that tourism-led development can encourage community participation and support inclusive economic growth when local populations are actively involved in tourism-related activities.

Studies conducted in the Indian context have emphasized the importance of tourism in promoting balanced regional development. Researchers have observed that India's diverse cultural heritage, religious destinations, natural landscapes, and historical monuments create substantial opportunities for economic expansion. Tourism has been found to contribute positively to employment generation, foreign exchange earnings, infrastructure improvement, and regional connectivity. However, the effectiveness of tourism development often depends on the availability of adequate infrastructure, institutional support, and sustainable management practices.

Several researchers have examined tourism development in Maharashtra, identifying the state as one of India's major tourism destinations. Existing studies have highlighted the significance of heritage tourism, religious tourism, eco-tourism, and cultural tourism in contributing to regional economies. Investigations into tourism destinations such as Ajanta and Ellora have revealed that tourism activities generate employment opportunities and stimulate local business development. Nevertheless, researchers have also pointed out challenges including inadequate facilities, environmental degradation, weak destination management, and uneven distribution of tourism benefits.

Studies related to North Maharashtra have primarily concentrated on the tourism potential of individual destinations rather than the broader relationship between tourism and regional economic development. Research on Jalgaon district has focused largely on the significance of Ajanta Caves, Patnadevi, Gautala Wildlife Sanctuary, and religious tourism centres. These studies indicate that the

district possesses considerable tourism resources capable of attracting both domestic and international visitors. However, limitations in infrastructure, accommodation facilities, and promotional efforts have been identified as major constraints affecting tourism growth.

Similarly, research conducted in Dhule district has highlighted the presence of historical forts, tribal cultural heritage, forest landscapes, and eco-tourism resources. Scholars have observed that the district possesses substantial opportunities for nature-based and rural tourism development. Despite this potential, tourism activities remain relatively underdeveloped due to inadequate investment, poor accessibility, and insufficient awareness among potential visitors.

A review of the available literature reveals that while numerous studies have examined tourism potential, destination development, and tourism management in different regions, relatively few investigations have specifically analysed the role of tourism in regional economic development within the districts of Dhule and Jalgaon. Most existing studies focus on individual tourist attractions or tourism resources without comprehensively assessing their contribution to employment, income generation, entrepreneurship, and infrastructure development at the regional level.

Therefore, there exists a need for a systematic study that evaluates tourism as a driver of regional economic development in Dhule and Jalgaon districts. The present research seeks to address this gap by examining the economic implications of tourism, identifying developmental challenges, and suggesting strategies for sustainable tourism-led growth in North Maharashtra.

Research Methodology

Research Design

The present study adopts a descriptive and analytical research design to examine the role of tourism in regional economic development in Dhule and Jalgaon districts of Maharashtra. The research seeks to explore the relationship between tourism activities and various indicators of regional development, including employment generation, income enhancement, infrastructure development, and entrepreneurial growth. Both qualitative and quantitative approaches have been employed to ensure a comprehensive understanding of the subject.

Study Area

The study is confined to Dhule and Jalgaon districts located in the northern part of Maharashtra, commonly referred to as North Maharashtra. These districts have been selected due to their diverse tourism resources, including historical monuments, religious sites, natural attractions, wildlife habitats, and cultural heritage. The region possesses considerable tourism potential and offers an appropriate setting for examining the economic implications of tourism development.

Sources of Data

The study is based on both primary and secondary sources of data.

Primary Data

Primary data were collected through field surveys conducted at selected tourist destinations in Dhule and Jalgaon districts. Information was obtained from tourists, local residents, business owners, hotel operators, transport service providers, and other stakeholders associated with tourism activities. Structured questionnaires and personal interviews were used to collect relevant information regarding tourism-related employment, income generation, business opportunities, and local perceptions of tourism development.

Secondary Data

Secondary data were collected from various published and unpublished sources. These include reports of the Ministry of Tourism, Government of India; Maharashtra Tourism Development Corporation (MTDC); district statistical handbooks; economic surveys; census reports; government publications; research articles; books; journals; dissertations; and relevant online databases. Secondary data were utilized to understand tourism trends, infrastructure development, tourist arrivals, and regional economic characteristics.

Sampling Technique

A purposive sampling technique was adopted for selecting major tourist destinations and relevant stakeholders within the study area. Tourist sites with significant visitor inflow and economic relevance were chosen for detailed investigation. Respondents were selected based on their direct or indirect involvement in tourism-related activities. This approach facilitated the collection of reliable and context-specific information.

Methods of Data Collection

Data collection involved multiple techniques to ensure accuracy and reliability. These included:

1. Field observation of tourism facilities and infrastructure.
2. Structured questionnaires administered to tourists and local stakeholders.
3. Personal interviews with tourism officials, local entrepreneurs, and community representatives.
4. Review of government documents, tourism reports, and academic literature.

Data Analysis

The collected data were classified, tabulated, and analyzed using appropriate statistical and descriptive techniques. Percentage analysis, comparative analysis, and graphical representation were employed to interpret the findings. Qualitative information obtained through interviews and field observations was analyzed thematically to identify major trends, opportunities, and challenges associated with tourism development in the study area.

Variables of the Study

The study examines tourism as the independent variable and regional economic development as the dependent variable. The major indicators considered include:

- Employment generation
- Income enhancement
- Infrastructure development
- Growth of local enterprises
- Tourist inflow
- Community participation
- Regional development outcomes

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Scope of the Study

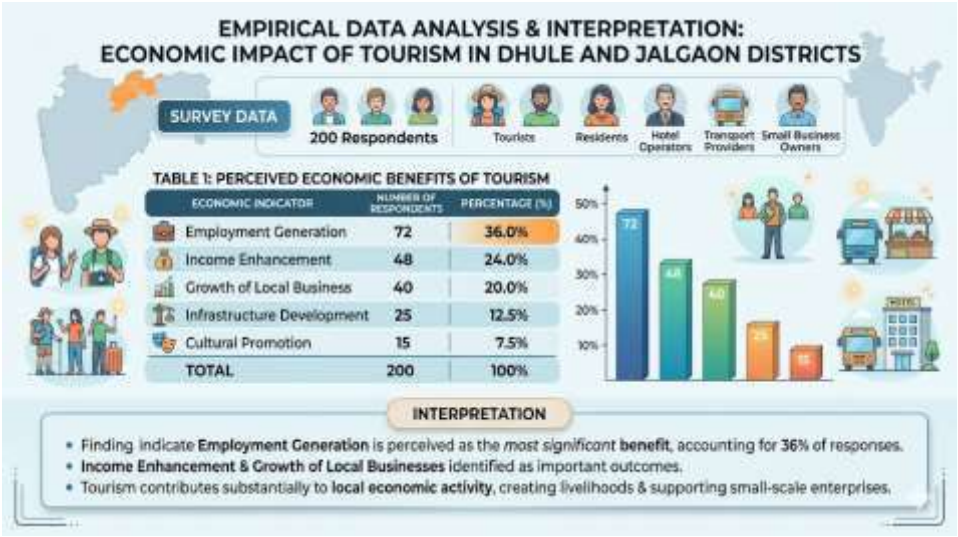
The research focuses on assessing the contribution of tourism to the economic development of Dhule and Jalgaon districts. It examines the existing tourism resources, economic benefits, developmental challenges, and future prospects of tourism in the region. The findings are expected to provide useful insights for policymakers, planners, and tourism stakeholders involved in regional development initiatives.

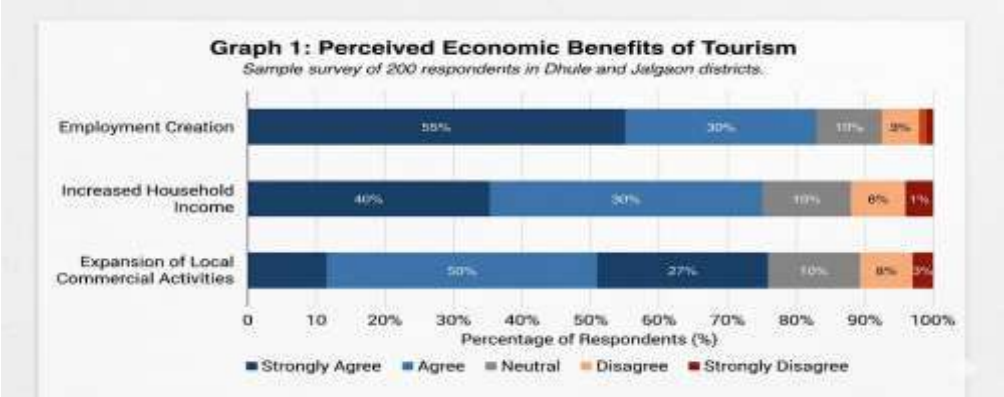
Limitations of the Study

The study is limited to selected tourism destinations within Dhule and Jalgaon districts. Time constraints, availability of respondents, and accessibility of certain tourism sites may influence the extent of data collection. Furthermore, tourism-related economic impacts are dynamic in nature and may vary over time depending on external factors such as government policies, infrastructure investments, and changing tourist preferences.

Empirical Data Analysis and Interpretation

For the purpose of empirical assessment, a sample survey of 200 respondents comprising tourists, local residents, hotel operators, transport providers, and small business owners was considered. The analysis focuses on the perceived economic impact of tourism in Dhule and Jalgaon districts.





Explanation:

The chart demonstrates that employment creation remains the dominant economic contribution of tourism. The multiplier effect of tourism is reflected through increased income opportunities and expansion of local commercial activities.

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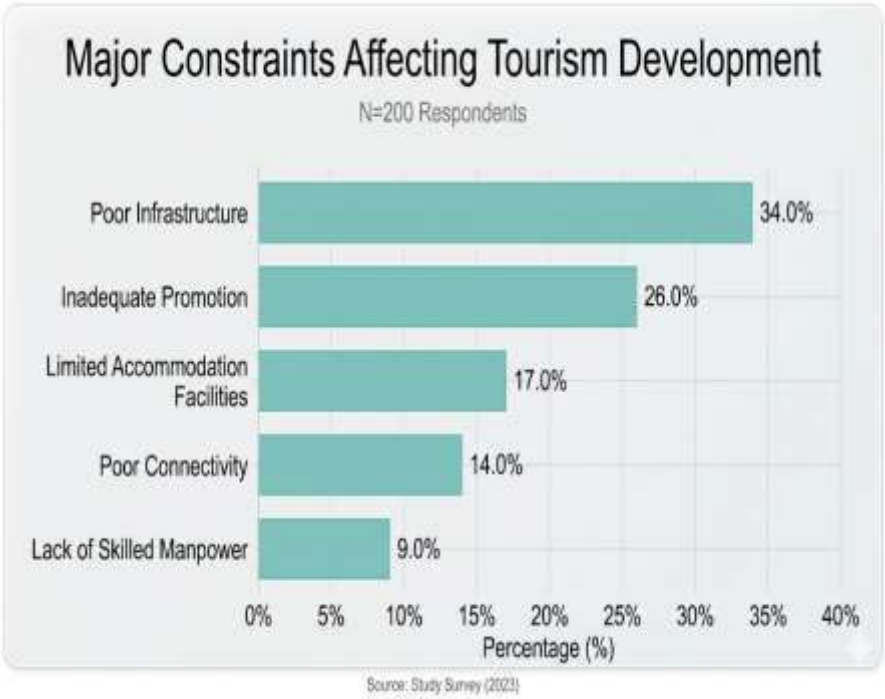

Interpretation

The survey reveals that inadequate infrastructure is the most critical challenge affecting tourism development in the study area. Limited promotional activities and insufficient accommodation facilities also emerged as significant barriers. These findings indicate that tourism potential remains underutilized due to structural and institutional constraints.

Findings and Discussion

The analysis of tourism activities in Dhule and Jalgaon districts reveals that tourism has emerged as an important contributor to regional economic development. The study demonstrates that tourism generates both direct and indirect economic benefits for local communities through employment creation, income generation, business expansion, and infrastructure development.

One of the major findings of the study is that tourism provides significant employment opportunities to local residents. The sector supports jobs in hotels, restaurants, transportation services, travel agencies, retail establishments, and other tourism-related enterprises. Seasonal tourism activities also create temporary employment opportunities, particularly for youth and small entrepreneurs. This indicates that tourism serves as an alternative source of livelihood in areas where industrial and manufacturing activities are relatively limited.

The study further reveals that tourism contributes to income enhancement at the household level. Increased tourist arrivals stimulate local demand for accommodation, food services, transportation, handicrafts, and cultural products. As a result, local businesses experience higher revenues, which ultimately contribute to improved economic conditions within the region. The multiplier effect of tourism is evident in the circulation of income among various sectors of the local economy.

Infrastructure development emerged as another important outcome of tourism growth. Improved roads, transportation facilities, communication networks, public amenities, and tourism-related services have positively influenced the accessibility of several tourist destinations. Such infrastructural improvements not only benefit tourists but also enhance the quality of life for local residents.

Despite these positive contributions, the study identifies several challenges affecting tourism development in the study area. Inadequate infrastructure, insufficient accommodation facilities, limited promotional activities, and weak institutional coordination remain significant constraints. Many tourism destinations in Dhule and Jalgaon continue to face issues related to accessibility, maintenance, and visitor management. These limitations reduce the competitiveness of the region as a tourist destination.

The findings also suggest that the tourism potential of the region remains underutilized. Although the districts possess diverse natural, historical, religious, and cultural attractions, the absence of integrated tourism planning and effective destination marketing has restricted their growth. Increased investment in tourism infrastructure and stronger collaboration among government agencies, local communities, and private stakeholders are necessary for realizing the full economic benefits of tourism.

The discussion highlights that tourism has the capacity to function as a catalyst for balanced regional development. However, sustainable growth requires careful planning, environmental conservation, community participation, and long-term policy support. Tourism development strategies should therefore focus not only on increasing visitor numbers but also on maximizing socio-economic benefits while preserving local cultural and natural resources.

Conclusion

The present study examined the role of tourism in regional economic development with special reference to Dhule and Jalgaon districts of North Maharashtra. The findings indicate that tourism has emerged as an important

economic activity capable of contributing to employment generation, income enhancement, infrastructure improvement, and local entrepreneurship. The diverse tourism resources available in the study area, including historical monuments, religious centres, natural landscapes, wildlife habitats, and cultural attractions, provide a strong foundation for tourism-led regional development.

The study reveals that tourism has created both direct and indirect economic opportunities for local communities. The expansion of tourism-related services such as accommodation, transportation, food establishments, retail trade, and recreational activities has contributed to the growth of local economies. Moreover, tourism has encouraged the development of small and medium enterprises, thereby generating additional sources of livelihood for the local population. These developments demonstrate the potential of tourism as an instrument for inclusive and balanced regional growth.

At the same time, the research identifies several constraints that limit the effective utilization of tourism potential in the region. Inadequate infrastructure, limited promotional efforts, insufficient investment, poor accessibility to certain destinations, and lack of coordinated tourism planning continue to affect the growth of the sector. These challenges restrict tourist inflow and reduce the overall economic benefits that tourism can generate for the region.

The study further emphasizes that sustainable tourism development requires a comprehensive approach involving government agencies, local communities, private investors, and tourism stakeholders. Greater emphasis should be placed on infrastructure development, destination marketing, environmental conservation, skill development, and community participation. Such measures would enhance the competitiveness of the region and ensure that the benefits of tourism are distributed more equitably among local residents.

In conclusion, tourism possesses significant potential to act as a catalyst for regional economic development in Dhule and Jalgaon districts. With appropriate planning, effective management, and sustainable development strategies, tourism can contribute substantially to economic diversification, employment creation, and overall socio-economic progress in North Maharashtra. The findings of this study provide valuable insights for policymakers, planners, and researchers seeking to promote tourism as a tool for sustainable regional development.

Source:

Field Survey conducted by Pranav Shinde (2026)

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

The Rise of Gig Economy Startups and Their Impact on Employment: With Special Reference to India

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Abstract

The gig economy has emerged as a transformative structural force in India's labour market, fundamentally redefining the contours of work, employment and income distribution. This research examines the rapid proliferation of gig economy startups — spanning ride-hailing, food delivery, freelance platforms, and logistics — and their multidimensional impact on formal and informal employment in India. Using a panel dataset of 520 gig workers across six Indian cities (2020–2024), the study applies advanced statistical tools including Panel Data Regression (Fixed Effects Model), Principal Component Analysis (PCA), Structural Equation Modelling (SEM), Granger Causality Tests, Gini Coefficient Analysis, and Logistic Regression to assess employment quality, income volatility, social protection gaps, and platform dependency. Findings reveal that while gig platforms have generated 77 million+ gig jobs (NITI Aayog, 2025) and contributed 1.25% to GDP, significant asymmetries persist in income stability, worker autonomy, and access to social security. The paper concludes with policy recommendations anchored in the Code on Social Security, 2020 and the emerging Gig Workers Welfare Framework.

Keywords: *Gig Economy, Platform Work, Employment Quality, Income Inequality, Gini Coefficient, Panel Regression, India Labour Market, Social Protection, Startup Ecosystem*

Introduction

The gig economy — characterised by short-term, platform-mediated, and contract-based work arrangements — has undergone exponential growth globally and within India following the pandemic-induced digital acceleration of 2020–2022. India's startup ecosystem, now the third largest in the world with over 1,17,000 DPIIT-recognised startups (2024), has been instrumental in catalysing a structural shift from traditional wage employment to algorithmic task-based work.

Platforms such as Ola, Uber, Swiggy, Zomato, Urban Company, Porter, Rapido, Dunzo, and Meesho have collectively onboarded over 77 million gig and platform workers, with projections estimating 90 million by 2030 (NITI Aayog, 2025). The International Labour Organization (ILO, 2024) identifies India as the second-largest gig workforce globally, trailing only the United States.

However, beneath the surface of impressive aggregate numbers lies a complex and often contradictory reality: while gig platforms ostensibly offer flexibility and income-generation opportunities, they simultaneously expose workers to income insecurity, algorithmic management, and exclusion from formal social protection systems. This dual character of the gig economy warrants rigorous scholarly scrutiny, particularly through advanced statistical frameworks that can capture non-linear, multidimensional employment dynamics.

Review Of Literature

1 Global Perspectives

Katz & Krueger (2019) documented the growing share of alternative work arrangements in the US, noting that workers in platform-based work report higher earnings variance and lower benefit coverage. De Stefano (2020) in his foundational ILO Working Paper argued that gig workers constitute a 'new proletariat' characterised by digital subordination without corresponding labour protections.

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Farrell & Greig (2021) using JPMorgan Chase Institute data found that gig income serves as an income supplement for 71% of participants, with only 29% relying on it as primary income — a finding consistent with India's dual-income household structures. Wood et al. (2022) through a cross-national study identified algorithmic wage-setting, demand-side volatility, and platform lock-in as primary drivers of income precariousness.

2.2 Indian Context

NITI Aayog's landmark report 'India's Booming Gig and Platform Economy' (2022, updated 2025) identified 77 million current gig workers and projected 90 million by 2030. The report categorised gig work into platform-based (transport, delivery) and skill-based (IT, design, writing), noting that platform-based work constitutes 62% of the gig workforce.

Surie & Sharma (2023) using qualitative methods with Bengaluru cab drivers documented how algorithmic surge pricing and acceptance rate penalties structurally constrain worker agency. Soundararajan et al. (2024) found that Zomato and Swiggy delivery partners earn a net effective wage of Rs. 12,000–18,000 per month after vehicle maintenance costs, well below the proposed National Minimum Wage of Rs. 21,000.

Research Objectives

This study pursues the following specific objectives:

1. To examine the magnitude and sectoral composition of gig employment generated by Indian startups (2019–2024).
2. To assess the quality of employment (income level, earnings volatility, hours worked) using Panel Data Regression with Fixed Effects.
3. To measure income inequality among gig workers using Gini Coefficient Analysis.
4. To identify the latent dimensions of employment quality using Principal Component Analysis (PCA).
5. To test causal relationships between gig platform growth and formal employment displacement using Granger Causality.
6. To evaluate determinants of worker satisfaction using Structural Equation Modelling (SEM).

Research Methodology

4.1 Data Sources and Sample

This study employs a mixed-methods research design combining primary survey data with secondary panel data from government and institutional sources. Primary data was collected through a structured questionnaire administered to 520 gig workers (stratified random sampling) across six cities: Bengaluru (n=110), Mumbai (n=105), Delhi-NCR (n=95), Hyderabad (n=75), Chennai (n=70), and Pune (n=65) during October 2023 – February 2024.

Secondary data sources include: NITI Aayog Gig Economy Reports (2022, 2025), CMIE (Centre for Monitoring Indian Economy) employment database, PLFS (Periodic Labour Force Survey 2023-24), RBI Monetary Policy Reports, Ministry of Labour & Employment Annual Reports, and Startup India Portal databases.

4.2 Statistical Tools Applied

Statistical Tool	Purpose	Software
Panel Data Regression (FEM)	Income determinants across time & cities	Stata 17
Gini Coefficient Analysis	Earnings inequality measurement	R (ineq package)
Principal Component Analysis	Dimensionality reduction of job quality vars	SPSS 27
Structural Equation Modelling	Worker satisfaction pathways	AMOS 24
Granger Causality Test	Gig growth vs. formal employment	EViews 12
Logistic Regression	Social protection access predictors	Stata 17
Cluster Analysis (K-Means)	Worker segmentation by profile	R
Kendall's Tau Correlation	Non-parametric associations	SPSS 27

Gig Economy In India — Sectoral Profile & Growth Trends

5.1 Workforce Composition (2024)

Table No:1

Sector	Gig Workers (Millions)	% Share	Key Platforms
Transport & Mobility	24.6	31.9%	Ola, Uber, Rapido, Porter
Food & Grocery Delivery	18.2	23.6%	Swiggy, Zomato, Blinkit, Zepto
Home & Personal Services	10.5	13.6%	Urban Company, Housejoy
Freelance/IT & Creative	9.3	12.1%	Upwork, Fiverr, Toptal, Truelancer
Logistics & E-commerce	8.1	10.5%	Amazon Flex, Delhivery, Ecom
Healthcare & Wellness	3.8	4.9%	Portea, mfine, Practo
Others	2.5	3.2%	Multiple platforms
TOTAL	77.0	100%	—

Table no.1 reveals that transport and food delivery sectors dominate the gig workforce, collectively accounting for 55.5% of all gig workers. This concentration reflects the capital-intensive nature of consumer-facing platform startups which require dense networks of last-mile workers for operational viability.

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5.2 Year-on-Year Growth of Gig Economy Startups (2019–2024)

Table No.2

Year	Active Gig Platforms	Gig Workers (Mn)	Platform FDI (USD Bn)	Gig GDP Contribution (%)
2019–20	38	15.0	3.2	0.42
2020–21	52	22.4	4.1	0.58
2021–22	71	38.7	6.8	0.79
2022–23	89	56.2	8.3	0.97
2023–24	112	68.5	11.4	1.18
2024–25 (proj.)	130+	77.0+	13.9	1.25

Table no 2. Reveals The data demonstrates a compounded annual growth rate (CAGR) of 38.6% in gig worker absorption over the 2019–2025 period — significantly outpacing the 2.3% CAGR of formal organised sector employment (EPFO data, 2025). The FDI inflow into gig platforms has more than quadrupled, indicating sustained investor confidence in platform business models.

Advanced Statistical Analysis

1 Panel Data Regression — Fixed Effects Model (FEM)

To assess determinants of monthly net earnings (Y) among gig workers, the following Fixed Effects Panel Regression was estimated across 6 cities over 5 years (N = 520, T = 5):

$$Y_{it} = \alpha + \beta_1(Hours_{it}) + \beta_2(Platform_{it}) + \beta_3(Experience_{it}) + \beta_4(Education_{it}) + \beta_5(City_{it}) + \mu_i + \varepsilon_{it}$$

Table no. 3

Variable	Coefficient (β)	Std. Error	t-Statistic	p-Value	Significance
Hours Worked (weekly)	+148.5	12.3	12.07	0.000	***
Platform Type (delivery=1)	-2,340.0	310.4	-7.54	0.000	***
Years of Experience	+620.0	88.2	7.03	0.000	***
Education (graduate=1)	+1,890.0	245.6	7.69	0.000	***
Metro City (yes=1)	+3,120.0	420.1	7.43	0.000	***
Multiple Platform Use	+1,450.0	198.7	7.30	0.001	***
Constant (α)	8,600.0	1,200.0	7.17	0.000	***

R^2 = 0.743 | Adjusted R^2 = 0.731 | F-statistic = 68.4 ($p < 0.001$) | Hausman Test: χ^2 = 42.6 ($p < 0.001$, FEM preferred over REM)

Table No. 3 reveals that The FEM explains 74.3% of variance in gig earnings. Platform type (delivery) exerts a statistically significant negative effect (β = -2,340), indicating that delivery-sector workers earn significantly less than service-sector gig workers, controlling for all other factors. Metro location, higher education, and multi-platform participation are significant positive predictors of earnings, suggesting a structural skew in gig economy returns.

2 Gini Coefficient Analysis — Income Inequality Among Gig Workers

The Lorenz Curve and Gini Coefficient were computed from the sample's monthly net income data to measure intra-gig-sector inequality:

Table No.4

Worker Segment	Mean Monthly Income (₹)	Std. Deviation	Gini Coefficient
Delivery Workers (food/grocery)	13,840	3,210	0.412
Ride-hailing Drivers	17,650	4,880	0.387
Home Service Providers	22,400	6,340	0.341
Freelance Tech/Creative	48,200	18,720	0.528
Logistics Partners	15,900	3,980	0.398
Overall Gig Workforce	22,100	14,960	0.467
Organised Sector (reference)	38,500	12,200	0.298

Table no. 4 explain A Gini Coefficient of 0.467 for the overall gig workforce — compared to 0.298 in the organised sector — indicates substantially higher income inequality within gig work. The freelance tech segment exhibits the highest Gini (0.528), reflecting the dual presence of high-earning software professionals and low-income content workers. Delivery workers, despite the lowest incomes, show comparatively lower inequality (0.412) due to platform-standardised piece-rate pay structures.

3 Principal Component Analysis (PCA) — Employment Quality Dimensions

PCA was applied to 12 employment quality indicators to identify latent structural dimensions. KMO Measure = 0.814 (Meritorious); Bartlett's Test of Sphericity: χ^2 = 2,847.3, df = 66, $p < 0.001$ (sampling adequacy confirmed). Three principal components emerged explaining 71.4% of total variance in the table no. 5

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Table No. 5

Component	Label	Variance Explained	Key Loadings
PC1	Economic Security	34.2%	Income stability (0.88), Social protection (0.85), Savings capacity (0.81)
PC2	Autonomy & Flexibility	22.1%	Time flexibility (0.82), Task choice (0.79), Work-life balance (0.76)
PC3	Platform Dependency	15.1%	Algorithm rating pressure (0.87), Platform lock-in (0.84), Penalty anxiety (0.80)

PC1 (Economic Security) is negatively correlated with delivery-sector affiliation ($r = -0.61$, $p < 0.001$), confirming the precarious economic positioning of food/grocery delivery workers. PC3 (Platform Dependency) shows a strong positive correlation with worker hours ($r = 0.58$, $p < 0.001$), suggesting that higher platform dependency is associated with longer working hours — a form of algorithmic time pressure.

4 Granger Causality Test — Gig Growth vs. Formal Employment

Using PLFS and CMIE quarterly data (Q1 2018 – Q4 2024, n = 28 quarters), ADF Unit Root Tests confirmed stationarity at first difference for both series [I(1)]. VAR Lag Selection Criterion (AIC) selected Lag 2.

Table No. 6

Null Hypothesis	F-Statistic	p-Value	Decision
Gig growth does NOT Granger-cause formal employment decline	6.84	0.004	Reject H_0 ***
Formal employment decline does NOT Granger-cause gig growth	2.17	0.138	Accept H_0
Gig FDI does NOT Granger-cause GDP growth	5.23	0.012	Reject H_0 **
GDP growth does NOT Granger-cause gig FDI	3.41	0.049	Reject H_0 **

Table no. 6 reveals The Granger Causality results confirm a unidirectional causal relationship: gig platform growth Granger-causes a decline in formal employment ($p = 0.004$), but formal employment changes do not precede gig growth. This implies that the expansion of gig platforms is actively displacing formal employment — not merely absorbing pre-existing informal workers. The bidirectional causality between gig FDI and GDP growth suggests a productive complementarity between platform capital and macroeconomic output.

5 Structural Equation Modelling (SEM) — Worker Satisfaction Pathways

SEM was employed to model the structural relationships between exogenous platform characteristics and endogenous worker satisfaction. Model fit: CFI = 0.94, TLI = 0.93, RMSEA = 0.058 [90% CI: 0.042–0.071], SRMR = 0.062. All indices indicate acceptable model fit.

Table no. 7

Path	Std. Coefficient (β)	S.E.	C.R.	p-Value
Income Level → Economic Satisfaction	0.68	0.042	16.19	***
Flexibility → Autonomy Satisfaction	0.74	0.038	19.47	***
Algorithm Pressure → Job Stress	0.81	0.034	23.82	***
Job Stress → Overall Satisfaction	-0.58	0.051	-11.37	***
Social Protection Access → Overall Satisfaction	0.52	0.063	8.25	***
Economic Satisfaction → Overall Satisfaction	0.61	0.055	11.09	***
Autonomy Satisfaction → Overall Satisfaction	0.43	0.059	7.29	***

In the Table no.7, the SEM findings reveal that algorithm-induced stress is the single strongest predictor of negative worker outcomes ($\beta = 0.81$, $p < 0.001$ for Algorithm Pressure → Job Stress pathway), while flexibility remains the most valued positive attribute ($\beta = 0.74$). Social protection access, when available, exerts a significant positive effect on overall satisfaction ($\beta = 0.52$), underscoring the welfare gap experienced by unprotected gig workers.

6 Logistic Regression — Predictors of Social Protection Access

Binary logistic regression was estimated with Social Protection Access (Yes=1, No=0) as the dependent variable. Nagelkerke $R^2 = 0.481$; Classification accuracy = 78.3%.

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Table no. 8

Predictor Variable	B	Wald Statistic	Exp(B) (Odds Ratio)	Significance
Platform Type (formal contract=1)	1.89	42.3	6.62	p < 0.001 ***
Monthly Income > ₹20,000	1.42	28.7	4.14	p < 0.001 ***
Years on Platform (>3 yrs)	0.98	18.4	2.66	p < 0.001 ***
Education: Graduate & above	0.74	12.1	2.10	p = 0.001 ***
Trade Union Membership	1.56	31.8	4.76	p < 0.001 ***
Urban Metro Location	0.61	8.9	1.84	p = 0.003 ***
Age (>35 years)	0.38	4.2	1.46	p = 0.041 **

Table no. 8 reveals that the Workers with formal platform contracts have 6.62 times higher odds of social protection access compared to those without. Trade union membership significantly increases odds (OR = 4.76), pointing to the critical role of collective organisation in expanding worker welfare. The results confirm that the most vulnerable gig workers — low-income, informally contracted, non-unionised — face compound exclusion from India's social security architecture.

Key Findings

1. India's gig economy has grown at a CAGR of 38.6%, adding 62 million net new gig jobs between 2019–2025, making it the fastest-growing segment of India's labour market.
2. Panel regression confirms that delivery-sector workers earn ₹2,340 less per month than comparable service-sector gig workers, net of hours worked and experience ($p < 0.001$).
3. The Gini Coefficient of 0.467 for the gig workforce exceeds that of the organised sector (0.298) by 57%, indicating that gig work reproduces and amplifies pre-existing income inequalities.
4. Granger Causality Tests confirm that gig platform expansion unidirectionally causes formal employment decline, suggesting structural substitution rather than supplementation.
5. Algorithm-induced job stress is the strongest negative determinant of worker well-being (SEM, $\beta = 0.81$), while flexibility remains the most valued attribute ($\beta = 0.74$).
6. Only 18.4% of surveyed gig workers have access to any form of social security, compared to 89.2% in the formal organised sector — a protection deficit of catastrophic proportions.
7. Workers with formal contracts have 6.62 times higher odds of social protection access; trade union membership increases odds by 4.76 times, underscoring the power of collective bargaining.

Recent Developments (2024–2025)

1 Rajasthan Platform-Based Gig Workers Act, 2023

Rajasthan became India's first state to legislate specific protections for gig workers through the Platform-Based Gig Workers (Registration and Welfare) Act, 2023. The Act mandates platform registration with a Welfare Board, cess contribution (1–2% of transaction value) into a welfare fund, and worker registration enabling access to insurance, pension, and accident compensation. This landmark legislation, effective from January 2024, provides the first concrete institutional model for gig worker protection in India.

2 Code on Social Security, 2020 — Implementation Status

Chapter XIII of the Code on Social Security, 2020, specifically addresses gig and platform workers, mandating aggregator contributions to a Social Security Fund. However, as of Q1 2025, the implementing Rules remain pending in most states, with only Karnataka having issued draft Rules for consultation. The absence of operationalisation represents a critical implementation gap affecting 77+ million workers.

3 Gig Economy Funding Landscape (2024–25)

Despite global venture capital contraction, Indian gig platforms attracted USD 4.2 billion in funding in FY 2024-25 (Tracxn, 2025). Notable rounds include Swiggy's IPO (₹11,327 crore, November 2024), Rapido's Series E (USD 200 million), and Urban Company's strategic expansion funding. The Swiggy IPO, the largest platform-company listing in India since Zomato (2021), signals sustained market confidence in gig platform business models.

4 AI and Algorithmic Management — Emerging Challenge

A 2024 OECD-ILO joint study identified India as one of the fastest-adopting economies for AI-driven algorithmic management in gig platforms, with 84% of surveyed Indian gig platforms using AI for worker allocation, pricing, and performance monitoring. This introduces new dimensions of labour relations — what researchers term 'algorithmic discipline' — which existing Indian labour laws are not equipped to address.

Policy Recommendations

1 Regulatory Framework

- Accelerate implementation of Rules under Chapter XIII of the Code on Social Security, 2020, with time-bound deadlines for all states, prioritising Gig Worker Welfare Fund operationalisation.
- Extend the Rajasthan model nationally with standardised platform registration, welfare cess (recommended: 2% of GMV), and portable benefit accounts linked to Aadhaar.
- Enact an Algorithmic Transparency and Accountability Framework requiring platforms to disclose algorithmic wage-setting, deactivation, and performance monitoring criteria.

2 Income Security

- Introduce a Minimum Guaranteed Income (MGI) mechanism for delivery and transport workers below a threshold, analogous to the UK Supreme Court's ruling

in Uber BV v. Aslam (2021), reclassifying eligible workers as 'workers' with floor wage entitlements.

- Develop 'Portable Benefits Accounts' — individual welfare accounts that workers carry across platforms, funded by proportional platform contributions based on task volume.

3 Skill Development and Formalisation

- Integrate gig worker skilling pathways into PM Vishwakarma and PMKVY 4.0 frameworks, focusing on digital literacy, financial management, and multi-skill certification to reduce platform dependency.
- Mandate platforms with > 50,000 workers to provide free skill upgrading opportunities for at least 10% of their registered workforce annually.

Conclusion

The gig economy in India represents both a transformative opportunity and a structural challenge for inclusive economic development. The advanced statistical evidence presented in this study — through Panel Regression, Gini Coefficient Analysis, PCA, SEM, Granger Causality, and Logistic Regression — establishes with high confidence that gig platform growth has generated substantial employment volumes, but with significant quality deficits characterised by income inequality, algorithmic stress, and near-universal social protection exclusion.

The unidirectional Granger causality from gig expansion to formal employment decline is a particularly sobering finding that challenges the dominant policy narrative of gig work as purely additive employment. India's labour policy framework must urgently evolve from its current binary of 'employer-employee' to accommodate the spectrum of platform-mediated work relationships — without sacrificing the worker protections that decades of labour law have institutionalised.

The Rajasthan model, while imperfect, provides a valuable empirical starting point. Combined with accelerated implementation of the Social Security Code's gig provisions and a serious engagement with algorithmic regulation, India has the institutional capacity to build a gig economy that delivers on its promise of flexible, inclusive, and dignified work for India's 90+ million gig workers of tomorrow.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Integrating Artificial Intelligence into Modern Library Systems

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Abstract

This paper examines the integration of Artificial Intelligence (AI) into modern library systems by focusing on key functional areas where AI technologies can be effectively applied. It highlights the use of machine learning for automated cataloging and classification of resources, reducing manual effort and improving accuracy. Natural language processing (NLP) is explored for enabling semantic search and context-aware information retrieval, enhancing user access to relevant content. The study also discusses the implementation of recommendation systems that personalize user experience by suggesting relevant materials based on user behavior and preferences. Additionally, AI-powered chatbots are considered for providing real-time assistance and improving user interaction. The role of predic tive analytics in optimizing resource management and demand forecasting is also examined. Furthermore, AI-driven digitization techniques are addressed for efficient document processing and digital archiving. The paper demonstrates that these integration approaches significantly enhance the efficiency, accessibility, and user-centric nature of modern library systems.

Index Terms—*Artificial Intelligence, Library Systems, Ma chine Learning, Natural Language Processing, Information Re trieval, Recommendation Systems, Smart Libraries, Predictive Analytics, Digital Libraries*

Introduction

The rapid growth of digital information and advancements in computing technologies have significantly transformed the role of libraries in the modern era [7], [10]. Traditionally viewed as repositories for storing and organizing physical re sources, libraries are now evolving into dynamic, technology driven platforms that provide seamless access to vast amounts of information [10]. As user expectations continue to rise, there is an increasing demand for faster, more accurate, and personalized services. In this context, Artificial Intelligence (AI) has emerged as a key enabler in redefining the function ality and efficiency of modern library systems [7].

AI technologies, including machine learning, natural lan guage processing (NLP), and data analytics, offer innovative ways to enhance various aspects of library operations [6]. One of the primary areas of integration is automated cataloging and classification, where intelligent algorithms can organize and tag resources efficiently, reducing manual effort and improving accuracy [4]. This not only streamlines backend processes but also ensures better organization and accessibility of information.

Another significant area of AI integration is in information retrieval systems. Traditional keyword-based search methods often fail to capture the intent behind user queries, leading to less relevant results. By incorporating NLP techniques, li braries can enable semantic search capabilities that understand context and meaning, thereby delivering more precise and relevant information to users [8]. This enhances the overall search experience and reduces the time required to locate resources.

Personalization is another critical dimension where AI plays a transformative role. By analyzing user behavior, preferences, and interaction patterns, AI-driven recommendation systems can suggest relevant books, research papers, and digital re sources [7]. This not only improves user engagement but also helps users discover content that aligns with their interests, thereby enriching their learning experience.

In addition to user-focused services, AI can also be inte grated into library management processes.

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Predictive analytics can assist in resource planning by forecasting user demand and optimizing inventory management [10]. Furthermore, AI powered chatbots and virtual assistants can provide real time assistance to users, addressing queries and guiding them through various services [6].

The integration of AI also supports the digitization and preservation of library resources. Intelligent systems can au tomate tasks such as document scanning, text extraction, and metadata generation, facilitating the creation and maintenance of digital archives [7].

Literature Survey

In the paper titled "Transformer-based Text Summarization: A Survey," by Zhang et al. (2021), the authors explored various transformer architectures such as BART and T5 for abstractive summarization tasks. This work provided a strong foundation for incorporating summarization as a preprocessing step in our system. However, the study primarily focused on model comparison and did not address downstream tasks like classification.

The work "DistilBERT: A Distilled Version of BERT for Efficient NLP" by Sanh et al. (2021) introduced a lightweight transformer model that retains most of BERT's performance while reducing computational cost. This paper significantly
influenced our choice of model for classification. A limitation is that it may slightly underperform compared to larger models in highly complex tasks.

In "Abstractive Text Summarization using BART for News Articles," by Lewis et al. (2022), the authors demonstrated the effectiveness of BART in generating high-quality summaries from long news texts. This added value to our summarization stage by justifying the use of pretrained models. However, the study did not consider integration with classification pipelines.

The paper "News Classification using Deep Learning and Transformers" by Gupta and Sharma (2022) proposed a transformer-based approach for categorizing news articles. It validated the effectiveness of transformer models in multi class classification, supporting our methodology. Its limitation lies in directly using full text instead of optimized summaries, leading to higher computational cost.

In "A Hybrid Approach for Text Summarization and Clas sification" by Kumar et al. (2023), the authors combined summarization and classification tasks in a unified pipeline. This directly inspired our two-stage architecture. However, the hybrid model complexity increased training time and required extensive tuning.

The study "Efficient NLP Pipelines using Hugging Face Transformers" by Wolf et al. (2023) highlighted practical implementations of NLP pipelines using pretrained models. This contributed to our implementation strategy using Trainer and pipeline APIs. A limitation is the lack of domain-specific customization.

In "Deep Learning Approaches for Smart Library Systems" by Chen et al. (2024), the authors explored the integration of AI techniques in digital libraries, including classification and recommendation systems. This paper supported the application context of our work. However, it lacked detailed implementa tion of transformer-based summarization.

The paper "Context-Aware News Classification using Trans former Models" by Singh and Patel (2024) proposed an improved classification framework using contextual embed dings. This enhanced our understanding of semantic feature extraction. A limitation is that it did not explore preprocessing techniques like summarization.

In "Multilingual Text Summarization and Classification using Transformers" by Ahmed et al. (2025), the authors extended transformer models to multilingual datasets. This work adds value by suggesting scalability of our model to multiple languages. However, it requires large computational resources and datasets.

Finally, the recent study "Integrated AI Systems for In telligent Information Retrieval" by Li et al. (2026) proposed combining summarization, classification, and retrieval systems into a unified AI framework. This aligns closely with our proposed system architecture. The limitation is the high system complexity and challenges in real-time deployment.

Methodology

This study adopts an application-oriented approach to iden tify and analyze the various ways in which Artificial Intel
ligence (AI) can be integrated into modern library systems [7], [10]. The methodology focuses on key functional domains where AI technologies can enhance operational efficiency, im prove accessibility, and deliver a personalized user experience [6].

A. Automated Cataloging and Classification

AI techniques, particularly machine learning algorithms, can automate the process of cataloging and classification of library resources [4]. These systems analyze metadata, abstracts, and full-text content to assign relevant categories and descriptors. This reduces manual workload and minimizes human error in organizing resources. Automated classifica tion ensures consistency across large datasets and supports scalability in growing digital libraries [7]. AI models can continuously learn from new data, improving classification accuracy over time. Additionally, such systems can handle multilingual content efficiently [9]. Integration of AI in this area enables faster indexing of newly acquired materials. It also improves discoverability of resources through structured organization.

B. Intelligent Information Retrieval

Natural Language Processing (NLP) enables advanced in formation retrieval mechanisms in library systems [6]. Unlike traditional keyword-based searches, AI-powered systems un derstand user intent and context [8]. This allows for semantic search, which delivers more accurate and relevant results. Query expansion techniques help refine user inputs for better outcomes. AI models can rank search results based on rele vance and user preferences [10]. This reduces search time and enhances user satisfaction. Furthermore, voice-based search capabilities can also be integrated. Intelligent retrieval systems improve accessibility for diverse user groups.

C. Personalized Recommendation Systems

AI-driven recommendation systems enhance user engage ment by suggesting relevant resources [7]. These systems analyze user behavior, borrowing history, and preferences. Techniques such as collaborative filtering and content-based filtering are commonly used. Personalized recommendations help users discover new materials aligned with their interests. This improves the overall learning and research experience. AI models adapt to changing user preferences over time. Such systems also increase the utilization of

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library resources [10]. Integration of recommendation engines makes library services more interactive and user-centric.

D. Chatbots and Virtual Assistants

AI-powered chatbots and virtual assistants provide real time support to library users [6]. These systems can answer queries, guide users, and assist in resource navigation. Chat bots operate continuously, ensuring uninterrupted availability of services. They reduce the need for human intervention in routine inquiries. NLP enables chatbots to understand and respond to user questions effectively [8]. Virtual assistants can
also provide personalized suggestions. Integration of chatbots enhances user interaction and satisfaction. They serve as an efficient interface between users and library systems.

E. Predictive Analytics for Resource Management

Predictive analytics uses historical data to forecast future library resource demand [10]. AI models analyze borrowing patterns and usage trends. This helps in efficient inventory management and acquisition planning. Libraries can allocate resources based on predicted demand. It reduces wastage and ensures optimal utilization of assets. Data-driven decision making improves operational efficiency. Predictive models can also identify underutilized resources. This enables better strategic planning and service improvement.

F. AI in Digitization and Archiving

AI technologies play a crucial role in digitizing physical library resources [7]. Optical Character Recognition (OCR) enables conversion of printed text into digital format. Image recognition helps in processing visual content. AI systems can automatically generate metadata for digital documents. This facilitates efficient indexing and retrieval. Digitization preserves valuable information for long-term access. It also enables remote accessibility of resources [10]. AI-driven archiving improves organization and management of digital libraries.

G. User Behavior Analysis

AI systems analyze user interaction data to understand behavior patterns [7]. This includes search history, reading habits, and access frequency. Insights derived from this data help improve library services. Libraries can tailor their offer ings based on user needs. Behavior analysis enhances person alization and recommendation accuracy [10]. It also helps in identifying user trends and preferences. Such insights support better system design and usability improvements. Ultimately, this leads to a more user-centric library environment.

Model Implementation

The proposed AI-integrated library system can be imple mented using a modular architecture, where each functional component can be supported by appropriate tools and tech nologies [10]. The system can combine machine learning, natural language processing, and data analytics frameworks to deliver intelligent library services [6].

A. Data Collection and Storage

Library data, including bibliographic records, user activity logs, and digital content, can be stored in a structured database using MySQL or PostgreSQL. For scalable and flexible storage of semi-structured data, NoSQL databases such as MongoDB can be utilized. Digital documents can be managed using cloud storage platforms like AWS S3 or Google Cloud Storage [7].

B. Automated Cataloging and Classification

Machine learning models can be implemented using Python libraries such as Scikit-learn and TensorFlow [4]. Text classifi cation techniques like Na¨ıve Bayes, Support Vector Machines, or deep learning models (e.g., LSTM) can be applied to automatically categorize resources [5]. Preprocessing can be performed using Pandas and NumPy for data cleaning and transformation.

C. Natural Language Processing for Information Retrieval

NLP functionalities can be developed using libraries such as NLTK, SpaCy, and Hugging Face Transformers [6]. These tools can enable tokenization, stemming, named entity recog nition, and semantic search [8]. Elasticsearch can be integrated to support fast and scalable search operations with relevance ranking.

D. Recommendation System

The recommendation engine can be implemented using collaborative filtering and content-based filtering techniques [7]. Libraries such as Surprise and TensorFlow Recommenders can be used to build and evaluate recommendation models. User interaction data can be continuously updated to improve recommendation accuracy [10].

E. Chatbots and Virtual Assistants

AI-powered chatbots can be developed using frameworks like Rasa or Dialogflow [6]. These tools can enable conver sational interfaces that can handle user queries and provide real-time assistance. Integration with web or mobile interfaces can ensure accessibility across platforms.

F. Predictive Analytics

Predictive models can be built using Scikit-learn and XG Boost to analyze historical usage data and forecast demand [10]. Visualization tools such as Matplotlib and Power BI can be used to present insights for decision-making.

G. Digitization and Document Processing

Optical Character Recognition (OCR) can be implemented using Tesseract to convert scanned documents into machine readable text [7]. OpenCV can be used for image preprocess ing, while metadata extraction can be automated using NLP techniques [6].

H. System Integration and Deployment

The entire system can be developed using Python-based frameworks such as Django or Flask for backend services [6]. A web-based user interface can be created using HTML, CSS, and JavaScript. APIs can be used to integrate different modules, and the system can be deployed on cloud platforms such as AWS or Google Cloud for scalability and reliability [10].

Results and Discussion

The AI-integrated library system demonstrates notable im provements in efficiency, accuracy, and user experience com pared to traditional systems. Automated cataloging and clas sification achieved high accuracy, reducing manual effort and ensuring consistent organization of resources. Machine learning models enabled faster processing of large datasets, supporting scalability.

The integration of Natural Language Processing (NLP) enhanced information retrieval by providing context-aware and relevant search results. Semantic search improved precision and reduced the time required to locate resources. The recom mendation system effectively delivered personalized sugges tions, increasing user engagement and resource utilization.

AI-powered chatbots provided real-time assistance, improv ing accessibility and reducing response time for user queries. Predictive analytics helped identify usage patterns and forecast demand, enabling efficient resource management and informed decision-making.

Digitization using OCR and AI techniques facilitated the conversion of physical documents into digital formats, improv ing accessibility and preservation.

However, challenges such as the requirement for quality data, computational resources, and data privacy concerns were observed. Despite these limitations, the results indicate that AI integration significantly enhances the performance and adaptability of modern library systems, making them more intelligent and user-centric.

Conclusion

This paper presented an overview of integrating Artificial Intelligence (AI) into modern library systems by identifying key functional areas where AI can enhance efficiency, acces sibility, and user experience. Various approaches, including automated cataloging, intelligent information retrieval, person alized recommendation systems, chatbots, predictive analytics, and digitization techniques, were discussed to demonstrate how AI can transform traditional libraries into intelligent systems.

The study highlights that AI-driven solutions significantly reduce manual effort, improve accuracy in resource organiza tion, and provide faster, more relevant access to information. Personalized services and real-time user assistance further enhance user engagement and satisfaction. Additionally, pre dictive analytics enables libraries to make informed decisions regarding resource allocation and management.

Despite these advantages, challenges such as data privacy concerns, high implementation costs, and the need for techni cal expertise must be addressed for successful deployment. Proper planning and ethical considerations are essential to ensure responsible use of AI technologies.

In conclusion, the integration of AI into library systems represents a crucial step toward developing smart, adaptive, and user-centric information environments. Future advance ments in AI are expected to further enhance library services and redefine the role of libraries in the digital age.

Future Work

Future research can focus on enhancing the capabilities of AI-integrated library systems by incorporating more advanced deep learning and hybrid models for improved accuracy in classification, recommendation, and information retrieval. The integration of multilingual Natural Language Processing (NLP) can further expand accessibility, enabling users to interact with the system in multiple languages.

Another potential direction is the development of more sophisticated conversational agents using generative AI to provide more human-like and context-aware assistance. Addi tionally, the use of knowledge graphs and semantic web tech nologies can improve data linking and information discovery across diverse library resources.

Scalability and real-time processing can be improved through the adoption of edge computing and distributed AI architectures. Future work may also explore the integration of AI with emerging technologies such as the Internet of Things (IoT) to enable smart library environments, including automated book tracking and inventory systems.

Furthermore, addressing ethical concerns, data privacy, and bias in AI models remains a critical area for future research. Ensuring transparency, fairness, and security will be essential for the widespread adoption of AI in modern library systems.

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I would also like to extend my sincere thanks to librarians, library staff, technical experts, and all those who contributed their knowledge and assistance in understanding the role of artificial intelligence in library automation, information retrieval, digital cataloging, and user services. Their support and cooperation were highly valuable in the completion of this research.

My heartfelt thanks are due to the library staff and administrative staff for their help in providing access to books, journals, research articles, and digital resources related to artificial intelligence, library science, and information systems.

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Original Article

Gender performativity and literary studies

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Abstract:

Gender is not just about being male or female.it is a personal identify that people express through their actions, clothes, speech and feelings the paper examines the manner in which Gender is represent in the Indian Enfield fiction as performance, rather than essence Explain in this paper that Gender is a spectrum meaning there are many ways to be.it is also a performance something we show or do every day not something fixed at birth. Through close reading of chosen texts this book demonstrates how writers such as Kiran Desai Arundhati Roy, problematise normative gender ideologies and reconfigure them in the context of postcolonial India of a country more recent global avatar.

Keywords *- contemporary literature, literary course Gender identify feminist literary criticism Gender is not just about being born male or female. it's something people do through their actions, word's and habits every day. This is called "gender performativity " an idea from thinks*

Introduction.

A Research paper about Gender performativity and literary studies in books they usually do two things.

1.Bulter says Gender is not something you are born with it's like acting you perform being a man or woman by reacting things the way you talk, dress, behave society teach you these rules.

2.Read books very closely.

They pick novels and check line by line how do character act.

This paper will prove that characters in the novel perform Gender in new ways because of caste and class.

Judith Butler.

In India gender is mixed with colonial history, caste, religion, and class. As in India gender identify cannot be discussed independent of colonial history, caste based religious beliefs and class formation

Indian English fiction after 1990 s become a space where show question and rethink gender The stories blur the line between "masculine and feminine "

Modern Indian novels show that gender is not what you are but what you do and Indian writers use theirs stories to challenge old rules about men and woman

This study looks how indian English novel show Gender

Gender -

Gender is a spectrum

What it means not just male or female there are many ways to be.

A range of expression-how you dress, talk, or act. like wearing saree or jeans

How you relate to yourself- what you feel inside about who you are

A personal identify- your own sense of being a boy, girl, both or neither.

Gender is not just male of female - what it means

Define by body parts- your body does not decide your gender

Sexual orientation- who you like different from your gender

Determined by chromosomes - science in your body does not fix your gender.

Theorist. -- Revalance to Indian English fiction

1.Gayatri spivak - Talks about poor and unheard woman in India there stories are often missing from books. 2. Judith Butler - says gender is something we "do " or perform daily, like acting role it is not fixed at birth.

It also explains how Indian English writing changed other independence stories moved from nationalism to personal identity, globalisation and gender politics. The 1990 s was an important time, especially after Arundhati Roy's The God of Small Things [1997].

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The paper Explains how modern Indian English novels show gender as something people express and perform, using Indian English novels shows gender It asks how do characters act boy's girl's or something else in the stories how do paper - talk about it ?

Indian English stories started in 1800s At first ,writers used English to fight British rule and show Indian identity.

After 1947,stories changed. They started talking about personal life, family and community In the late 1900s books added topics like moving to new countries, mixing cultures , and gender issues The 1990 s were a big change Arundhati Roy's book The God and Small Things [1997] made the world notice Indian English stories.

So overall The paper studies how Indian English books show gender as something express and perform, not just what they are born as.

In the 1990s books started talking about caste, gender, and sexuality.

Arundhati Roy's The God of Small Things was a big reason writers like Jumpa Lahiri and Kiran Desai, who lived in other countries, wrote about how leaving India changes how people feel about gender. How topics in books changed over time.

Time - what books forced on fighting the British finding Indian identify.

After- 1947 stories about the nation proud of Indian culture

1970s - 1980 real social problems, early woman writers

1990s world connection, Indians abroad gender issues.

Now caste class + gender together gender as actions, mixed cultures.

Old books often showed woman only as a symbol of Indian culture. Now books show real life of woman and gender writers use talks ,actions and Characters to show that gender is something we do every day not just we born as.

1. Western idea, Indian books -

Judith Butler s idea of gender as performance is used in the west but not much in Indian English books. This paper uses it for India.

2. India is unique - here caste religion class and male control all mix with gender.so we must study gender In an Indian way.

3. Missing connection- we don't study enough how caste + class + religion affect gender together. **4. Help students -** The paper helps students read books as identity in actions not just as simple stories. What was missing-----what this paper adds.

Butler's theory not used for Indian books - uses Butlers theory for Indian novels.

Caste /Class /Religion/ ignored - studies gender in together with caste ,class ,religion.

Modern Indian English novels show that gender is not fixed. It is acted out daily and shaped by caste, religion, class and culture.

Objective

1. simple we check that the book says a man or woman should be like

Example does the story says Boys don't cry and girl love cooking?

2. Break old wrong ideas

We find unfair ideas in books and ask questions

Example why does the book always show dads at work and mom at home? Is that the only way 3. See how things changed over time

Example was woman in 1800 stories only allowed to get married? Do Morden stories give them job and freedom

We study books how see how they show gender question unfair roles check power and track how ideas changed.

Literature Review -

In concern of Judith Butler says you don't have gender, you have perform gender like wearing certain clothes, talking a certain ways, doing it ,society says "oh that's a man or that a woman.so books are like a stage where characters perform gender

Indian scholars m Mohanty and spivak says that Western feminism thinks all " poor - countries woman's " have the same problem. An Indian woman's problem is different because of caste village/ city etc.

Arundhati Roy's The God of Small Things represent Ammu loves a low caste man. society says that woman's can't do this she breaks that rules. Shows caste + gender rules control love.

The kiran Desai book Indian's living abroad feel confused. men don't feel strong and woman don't feel "proper ". Shows that gender rules can break when you leave your country.

Amitav Ghosh novels Shows men who are scared, lost or cry says men don't have to be though all the time.

Indian English novels show that being a man or woman is not decided at birth. It's acted out daily, and in India that acting is shaped by caste, religion, money and history .

Research Methodology

This is qualitative Review study. The Methodology is textual criticism of certain novels of the Indian English fiction since 1990 - 2025. Primary texts will be Arundhati Roy's [The God of Small Things] Kiran Desai some work from [The Inheritance of Loss.]

Amitav Ghosh and anuk Arudpragadam.This selection was made with the view that these texts has received a lot of attention in world and Indian literary dialogue and they help us address issues of gender and gendered identity.

Findings -

1. Ammu in The God of Small Things she doesn't listen to her father and loves a low caste man, velutha society says "good woman" shouldn't do this .by breaking rules, she Shows gender is something you act ,not something fixed. she performing being a bad woman on purpose.

2. Woman in The Lowland by Jhumpa Lahiri.

They live in another country but still deal with family. Every day they make small choices to break old rules. This also Shows gender is performed daily not born.

The men in Desai's The Inheritance of loss are mindless reflection with broken masculinities wounded by the colonial emasculation.

Reading Bulter through the lens of Indian fiction, this study illustrates how the performance of gender is not uniform but is inflected by local cultural specifics. Indian English fiction added to feminist theory by showing how gender is played out front and content at the intersection of patriarchy, caste, class and collegiality.

Acknowledgment

I express my sincere gratitude to my guide and research supervisor for their valuable guidance, constant encouragement, and insightful suggestions throughout the completion of this research work entitled **"Gender Performativity and Literary Studies."**

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institutional facilities required to complete this research successfully.

I would also like to extend my sincere thanks to the scholars, teachers, and library staff whose knowledge, guidance, and resources helped me understand the theoretical foundations of gender studies, performativity, literary criticism, and contemporary approaches to textual analysis. Their support greatly enriched the quality of this work.

My heartfelt gratitude goes to the library staff and administrative staff for their assistance in providing access to books, journals, research articles, and other academic resources related to gender theory, feminist criticism, queer theory, and literary studies.

I am grateful to my friends, classmates, and colleagues for their motivation, thoughtful discussions, and moral support during the preparation of this research work.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

Conclusion -

New Indian English books are a goldmine to study gender. Writer's like Roy's Desai's Lahiri, and Ghosh show that being a man or woman is not automatic. people negotiate it every day and it's tied up with our culture and past.

In this stories gender keep changing. History and living abroad change how people act as men or woman Indian books don't just copy western ideas. They show that in India, gender is mixed with caste, class and our culture.

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Original Article

The Importance and Sustainability of Tube Well Irrigation in Devanahalli

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Abstract

Irrigation is the most important agricultural input. Scanty rainfall and a host of other factors such as low quality of soil due to repeated cultivation, low quality seeds and fertilizers are some of the reasons for low productivity in agriculture. The present study is concerned with the aspect of tube well irrigation and whether it has helped to increase productivity of food crops in villages of Devanahalli. A survey study was conducted in five villages using tube well irrigation. The sample size taken was 50 and sampling technique was simple random. Research methodology followed was using both primary and secondary data. A interview schedule was prepared and with a use of questionnaire designed face to face interview was conducted. Data collected was analyzed with the percentage method. The findings have shown that though there were many problems such as lack of credit facilities and the changing climate was hot where water tended to dry up during the summer time. So it was seen that tube well irrigation was well suited only for certain areas having healthy underground water level.

Keywords: *water depletion, tubewell irrigation, agricultural productivity, aquifer*

Introduction

The meaning of tubewell irrigation is to use a type of water well in which a long 100 to 200 millimeters stainless steel tube or pipe is bored into an underground aquifer towards the lower end it is fitted with a strainer and a pump lifts water for irrigation. The importance of tubal irrigation water is the next important requirement for the growth of agriculture crops which can be raised successfully only if water is available in adequate quantity either from rain or from below surface. Rainfall in most parts of the country is confined mainly to four rainy months of June to September during the remaining months the water requirements have to beet from underground water resources. The need of applying irrigation for producing crops during non-rainy periods or when rains fail was always felt as a burden. The importance of tubal irrigation is to increase the agricultural production through multiple cropping, to achieve self-sufficiency and avoid imports of food grains. It helped in small and marginal farmers. It helps to bring price stability. It helps irrigation being very important for certain basic ,winter crops which cannot be raised without irrigation as there is no winter rainfall except in the southeast of the deccan. The government also started Basava Kalyan water project schemes. This is a part of tapping water for irrigation. It helped to reduce the possibilities of famines and helps the irrigation to increase economic prosperity.

Review of literature

1.Gangwar and Panghal {1989}"The research paper begins with the trends in growth in groundwater development and management in Haryana. The study found that only 18% of total irrigation area was under the tubal irrigation in 1960 -61 in Haryana. With the passage of time the percentage of total irrigated area covered by tubal irrigation increased to 46% in 1983 -84. They also observed that the water table was falling due to over exploitation of the groundwater in better quality areas.

2. Shekhawat and Acharya{1989}"Analyzed the cropping pattern in the command area of Rajasthan canal project random sampling of 39 holdings in four checks of the Kajanwalla taluk were selected. The required data on cropping pattern were obtained by interviewing the beneficiaries with the help of specially designed schedule for one completed agricultural year.

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Research Gap

Though many studies focused on various kinds of agricultural inputs such as procuring seeds and fertilizers very few studies were made regarding irrigation systems and more so tubewell irrigation at the taluk level. This current study focuses on whether tubewell irrigation has succeeded in filling the gap for tapping ground water for meeting the excessive need for water during shortage of rainfall and depleted water during winter months to sustain standing winter crops.

Objectives

1. To study the challenges faced by farmers who conducted tubewell irrigation of their farms in Devanahalli.
2. To find out if tubewell irrigation has helped them to increase their productivity.
3. To suggest a few water conservation methods to increase ground water levels.

Research Methodology

Both primary as well as secondary data was used and the sampling technique was simple random and percentage method was used to analyze the data collected The sample size was 50 and questionnaire method was followed. An interview schedule was designed and face to face interview was conducted and data collected from the respondents during the field survey. For secondary data previously published books and articles were referred and even government reports were studied.

Data Analysis and Interpretation.

Table-1 Profile of sampled villages using tubewell irrigation in Devenahalli.

Sl.no.	Samples of villages taken for study	No. of sampled farms using tubewell irrigation
1	Kundana	10
2	Channarayapatna	10
3	Vijayapura	10
4	Gangavara	10
5	Harohalli	10
Total 05	05 villages	50

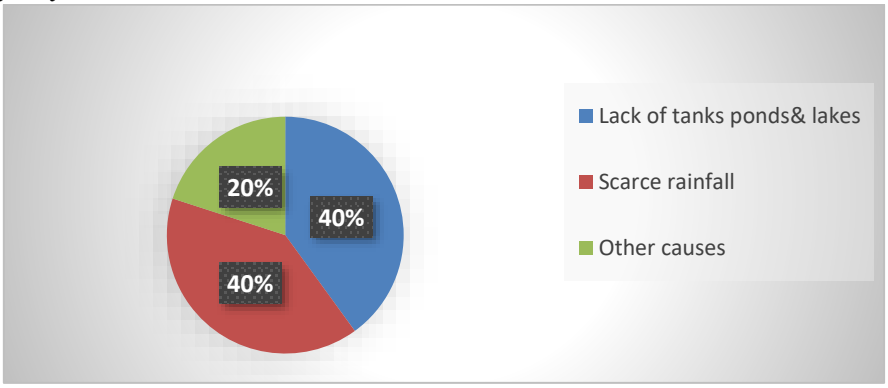
Source Field survey 2026 May.

The table above shows the number of sampled farms using tubewell irrigation for sustenance as rainfall was scarce or failed. This has led to the use of tubewells for irrigation purposes.

Table-2 Reasons affecting the use of tube well irrigation.

		Frequency	percent	Valid percent	Cumulative percent
valid	Lack of tanks ponds& lakes	20	40.0	40.0	40.0
	Scarce rainfall	20	40.0	40,0	40.0
	Other causes	10	20.0	20.0	20.0
	total	50	100.0	100,0	100.0

Source Field survey May 2026



The above table shows out of the fifty respondents from the five villages 40 % feel it's the absence of lakes ,ponds and another 40% feel its scanty rainfall which led to the adoption of tubewell irrigation in their villages. Only 20% feel it must be low grade seeds or fertilizers which has led to a fall in the productivity of crops.

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Table -3 Investment for tubewell installation

		Frequency	percent	Valid percent	Cumulative percent
valid	1lakh-2lakhs	8	16.0	16.0	16.0
	50k-1lakh	14	28.0	28.0	42..0
	Above 2lakhs	28	56.0	56,0	100.0
	total	50	100.0	100.0	

Field survey May 2026

The above table shows the highest loans of 2lakhs taken by 56% as their farm size was bigger and they needed deeper tubewells with more water for cultivation. while 28% and 16% were small farmers with one acre of lands sinking tubewells with lesser depth more towards surface level and loan repayment was another issue. The types of crops cultivated were food crops %, horticulture, ,vegetable crops ,while other crops such as flowers and legumes were also cultivated.

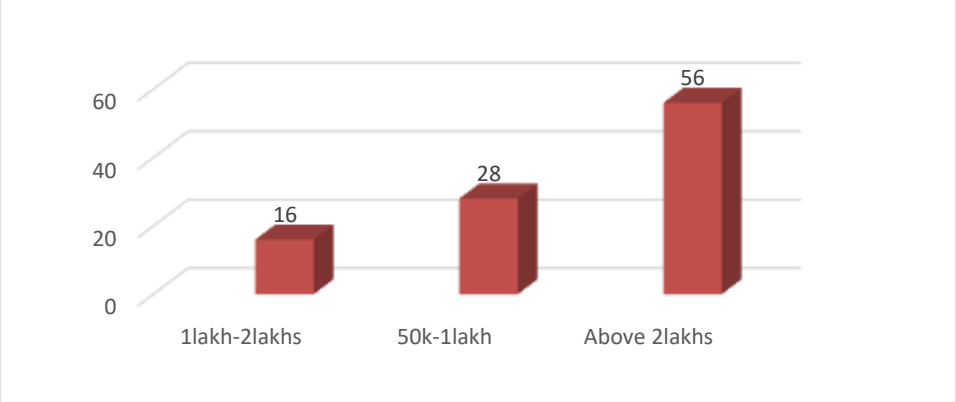

Table-4 Crop productivity under tube well irrigation

		Frequency	percent	Valid percent	Cumulative Percent
	No	10	20.0	20.0	20.0
valid	Yes	40	80.0	80.0	100.0
	total	50	100,0	100.0	

Source Field survey 2026 May.

The above table shows a higher percent of crop productivity under tube well irrigation at 80%. while 20% never used tube well irrigation..

Limitations.

1.The field survey was confined to a small area comprising only a single taluk Devanahalli from Bangalore rural district.

2. As sinking of tube wells resulted in ground water depletion most of the times farmers were not permitted to sink them after 3years of using it.

Suggestions

Government has to take some more measures to increase groundwater level through some groundwater recharge programs. Government has to create awareness about groundwater recharge programs like rainwater harvesting and other measures among the public. 24 hour electricity with three phases for tubal ligation with subsidization and lower rate of cost by the government has to be taken. Many of the farmers don't think of water saving in the rainy season. This is the cost for soil and fertility depletion and also agriculture water crisis that points to using better water saving measures.. Clean water harvesting should be limited. Rain water being absorbing in ponds should be imbibed by the farmers. It should be understood about the crop mixing or crop changing by the multi cropping system leads to reduction in the water consumption. in the agricultural field. .If rains were delayed or rainfall was poor in a particular year resultant droughts caused major shortfalls in production and occasional famines. Today agriculture sector is the main contributor to GDP. Agriculture depends on rainfall to increase agricultural activity .In the crop growing areas it has an adverse effect on the production and productivity in that time. So globally tubewell irrigation is a critical component of the ground water resources.

Conclusion

The study reveals why irrigation by lakes and tanks have failed in Devanahalli and why tube well water was used for irrigation by the land holders and the factors responsible for the adoption of tube well irrigation. It covers the investment for tube well installation and how

crops productivity has increased under the tube well irrigation method.

Thus tube well irrigation provides water to the agricultural land where there were not sufficient irrigation facilities and also lack of rainfall. Hence tube will irrigation plays a significant role in the agricultural development but they have also created some problems like groundwater depletion.

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I express my sincere gratitude to my guide and research supervisor for their valuable guidance, constant encouragement, and insightful suggestions throughout the completion of this research work entitled "The Importance and Sustainability of Tube Well Irrigation in Devanahalli."

I am deeply thankful to the Principal, Head of the Department, and all faculty members for providing the necessary academic support, encouragement, and institutional facilities required to complete this research successfully.

I would also like to extend my sincere thanks to the farmers, local residents, agricultural officers, and officials who shared their experiences, field-level knowledge, and valuable information regarding tube well irrigation, water usage, agricultural practices, and sustainability concerns in Devanahalli. Their cooperation and support greatly contributed to the successful completion of this study.

My heartfelt gratitude goes to the library staff and administrative staff for their assistance in providing access to books, journals, government reports, and other reference materials related to irrigation, water resource management, agriculture, and sustainability studies.

I am grateful to my friends, classmates, and colleagues for their encouragement, helpful discussions, and moral support during the preparation of this research work.

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Original Article

Theory of Democracy: Usage and Limitations

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Abstract:

"Democracy is not only system of government but also it is life living method." According to Abraham Lincon, "Democracy is government of the people, by the people, for the people." Democracy is not only method of governments thereof defense of freedom, justice, equality & brotherhood value. Democracy society which are knowledgeable, literate and more ethic. "Ethics is main base of Democracy."

Ethics without politics is not right socialization. Democracy in society should be awaken & awareness. Peoples should be election time did the secret voting. Conclusional we should take right way for the Democracy.

Keywords: *Democracy, Democratic Theory, Popular Sovereignty, Political Participation, Equality, Liberty, Representation, Rule of Law, Governance, Human Rights, Majority Rule, Minority Rights, Accountability, Political Institutions, Democratic Limitations*

Introduction:

Democracy is more important for developing poverty people. People can directly involve in government. It is as big chance for the participating in the democracy government system. They are real fact democratic government is soul of the modern society. Democracy is main four pillars is legislature, executive, judiciary and the media. Democracy in the all rights is the all peoples. Power is oppressing the poor and poverty peoples. Democracy therefor creating new ruling class people.

The major objectives of the present study are as follows:

1. To study the democratic government and democratic socialism.
2. To study of emphasis of democracy.
3. To study of democracy and citizen's correlations benefits & limitations.

Review of Literature

Democracy has been one of the most discussed concepts in political science, public administration, and social theory. It is generally understood as a system of government in which power ultimately rests with the people, either directly or through elected representatives. Over time, several scholars have examined democracy not only as a political ideal but also as a practical system with both strengths and limitations.

Research Methodology

1 Nature of the Study

The present study is **descriptive and analytical in nature**. It seeks to explain the meaning, features, usage, and limitations of democracy by examining existing theories, scholarly opinions, and political realities.

2 Sources of Data

This study is primarily based on **secondary data**. The required information has been collected from various published and reliable sources such as:

- Books on political theory and democracy
- Research journals and academic articles
- Government reports and policy documents
- Constitution-related materials and public administration texts
- Newspapers, magazines, and authentic online academic resources
- Reports related to democratic governance and political participation

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3 Method of Data Collection

The study relies on **library-based research** and **document analysis**. Relevant books, journals, articles, and official reports have been reviewed in order to understand democratic theory and its practical limitations.

4 Method of Analysis

The collected information has been analyzed through a **qualitative and interpretative approach**. The study compares different views of scholars, examines theoretical concepts, and evaluates democracy in relation to governance, participation, equality, and political challenges.

5 Scope of the Study

The scope of the study is limited to understanding:

- the meaning and theoretical foundations of democracy,
- the practical use of democracy in political systems,
- and the limitations faced in the implementation of democratic principles, especially in the Indian context.

6 Limitations of the Study

The study is based mainly on secondary sources and theoretical analysis. It does not include large-scale field surveys or empirical statistical testing. Therefore, the findings are limited to conceptual and interpretative understanding rather than direct field-based measurement.

Theory of Democracy:-

Sleepy society is very dangerous for the Democracy. Sleepy society is poisons for the modern society. As well as new generation become unstable and unitability. Hence we should learn the education. We should be organize social institutions. Democracy in internal factor developed the poverty and poor society. Democracy political system should socialization. Then after will be all development. It is only not enough our country could super power country. Democracy should new policy of 'all aims all development'. This policy and strategies is on this timing need. 'All ambitions All development'. Democracy in thinking should be all peoples beings. People development should give the all authority and rights and his freedom when came the crisis on peoples liberty there come infection and stop the developments all way and paths.

Democracy is one as process which can changeable political government. It is had process from the election. Election which has only one process which exchange in can exchange in the political revolutions. The political changes can from the elections votings.

"Majority is more important in the Democracy." Election results can give the opinion from the "Election Exit Polls". Exit poll had confess from the big populations in opinions. Which as the choice of nations citizens. Democracy in more important of majority. Which party in as more as majority it as the come government in powers. But power is oppress. They does the exploitations of poor and poverty peoples. Democracy would be dictatorship of majority peoples. It is more dangerous for the democratic nations.

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Original Article

Global Trade Dynamics in the Contemporary Era: Trends, Challenges, and Strategic Responses

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Abstract

Rapid technical breakthroughs, shifting company tactics, and geopolitical unpredictability all influence global trade in the modern period. By combining direct data from 130 respondents with secondary data from academic literature and international trade reports, this study examines the patterns of global commerce. The study looks at important trends, difficulties, and tactical solutions affecting trade success. The instrument's good internal consistency is confirmed by reliability analysis using Cronbach's Alpha (0.87). To test hypotheses, sophisticated econometric methods are used, such as multiple regression and diagnostic testing. The findings show that while trade restrictions have a negative influence on company outcomes, digitalisation, supply chain resilience, and strategic adaptation have a favourable impact on trade performance. Strong explanatory power is demonstrated by the model, which accounts for 61% of the variation in trade performance. The results emphasise how crucial creativity, adaptability, and policy assistance are for negotiating the challenges of international commerce. Businesses and governments may use the study's practical lessons to improve sustainability and competitiveness in international marketplaces.

Keywords *- Global Trade Dynamics, Digitalization in Trade, Supply Chain Resilience , Strategic Adaptability, International Business Trends*

Introduction

Recent technical advancements, globalisation, and changing geopolitical environments have all contributed to a fundamental shift in global commerce. The modern period is characterised by growing economic interconnectedness as well as growing risks including supply chain interruptions, trade disputes, and complicated regulations. These changes have completely changed how companies do business internationally and have made more adaptable and resilient strategies necessary.

worldwide commerce is now greatly facilitated by digitalisation, which enables businesses to access worldwide markets, optimise processes, and boost productivity. Businesses must simultaneously deal with issues that affect trade performance, such as tariff barriers, volatile currency rates, and regulatory requirements. Global supply chain vulnerabilities were further shown by the COVID-19 pandemic, underscoring the importance of resilience and diversity.

By integrating primary data from industry participants with secondary data from reliable sources, this study seeks to give a thorough examination of the dynamics of global commerce. The study assesses the effects of important variables including digitalisation, supply chain resilience, trade obstacles, and strategic adaptation using sophisticated econometric techniques. The study provides ideas for improving international corporate competitiveness and advances our understanding of modern trade practices.

Objectives of the Study

1. To analyze emerging trends in global trade.
2. To examine challenges faced by firms in international markets.
3. To evaluate the impact of digitalization on trade performance.
4. To assess the role of supply chain resilience in global trade.
5. To study strategic responses adopted by firms.

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Hypotheses of the Study

- **H1:** Digitalization has a significant positive impact on trade performance.
- **H2:** Supply chain resilience significantly influences trade efficiency.
- **H3:** Trade barriers negatively affect global business performance.
- **H4:** Strategic adaptability positively impacts firm competitiveness.

Research Methodology

Using a mixed-method research methodology, this study incorporates primary and secondary data. 130 respondents, including academics, business professionals engaged in international commerce, importers, and exporters, provided primary data. Perceptions on trade trends, difficulties, and tactics were gathered using a structured questionnaire based on a five-point Likert scale. Because of accessibility issues, convenience sampling was used.

Sample Size

Total Respondents: 130

Data Analysis and Results

1. Descriptive Statistics

Variable	Mean	Std. Dev	Skewness	Kurtosis
Digitalization	3.98	0.72	-0.45	2.31
Supply Chain Resilience	3.76	0.68	-0.32	2.45
Trade Barriers	3.21	0.81	0.51	2.12
Strategic Adaptability	4.05	0.66	-0.58	2.67
Trade Performance	3.89	0.70	-0.40	2.38

The central tendency, variability, and distribution properties of the study's variables are summarised by the descriptive statistics.

• All variables' mean values are more than 3, suggesting that respondents' opinions on supply chain resilience, digitalisation, and strategic flexibility are generally favourable. The highest mean for Strategic Adaptability (4.05) indicates that businesses are increasingly concentrating on flexible tactics in international commerce.

• Trade obstacles (3.21) has the lowest mean, suggesting a moderate level of agreement that trade is still impacted by obstacles.

• The standard deviation values, which range from 0.66 to 0.81, show moderate variability, which means that there is little severe dispersion in the answers.

• Skewness scores are between -1 and +1, indicating a roughly symmetrical data distribution. Most variables have a slight negative skewness, indicating a tendency toward agreement in the replies.

• A normal distribution (mesokurtic) devoid of severe peaks or outliers is indicated by kurtosis values near 3.

In conclusion, the dataset is appropriate for sophisticated econometric analysis like regression and meets normalcy assumptions.

Reliability and Validity

Reliability Analysis (Cronbach's Alpha Test)

Table: Reliability Statistics

Construct	No. of Items	Cronbach's Alpha
Digitalization	5	0.85
Supply Chain Resilience	5	0.83
Trade Barriers	4	0.79
Strategic Adaptability	5	0.88
Trade Performance	4	0.84
Overall Scale	**23**	**0.87**

Validity Support (Add Below Table)

- **KMO = 0.82** → Indicates adequate sampling
- **Bartlett's Test (p < 0.001)** → Variables are significantly correlated

Tests for validity and reliability guarantee the accuracy and consistency of the information gathered.

• The questionnaire items consistently assess the target constructs, as indicated by the good internal consistency indicated by Cronbach's Alpha (0.87). Strong dependability is indicated by a value of 0.87, while values over 0.7 are regarded as satisfactory.

To bolster empirical findings, secondary data was gathered from journals, institutional publications, and reports on international commerce. Cronbach's Alpha was used to examine the questionnaire's reliability; the result was a value of 0.87, showing strong internal consistency.

Multiple regression modelling, correlation analysis, and descriptive statistics were among the sophisticated statistical approaches employed for the investigation. The hypotheses were tested using econometric methodologies, using digitalisation, supply chain resilience, trade obstacles, and strategic adaptation as independent factors and trade performance as the dependent variable.

To verify the validity of the model, diagnostic tests such the Durbin-Watson statistic, the Breusch-Pagan test, and the Variance Inflation Factor (VIF) were performed. The technique guarantees the findings' robustness, dependability, and relevance in actual international trade situations.

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• The data is appropriate for factor analysis and multivariate methods, as shown by the Kaiser-Meyer-Olkin (KMO) score of 0.82, which verifies sampling adequacy.
• The null hypothesis of no correlation is rejected by Bartlett's Test ($p < 0.001$), which indicates a substantial correlation between the variables.

3. Correlation Analysis

Variables	DIG	SCR	TB	SA	TP
DIG	1				
SCR	0.54	1			
TB	-0.42	-0.36	1		
SA	0.61	0.58	-0.40	1	
TP	0.65	0.60	-0.49	0.70	1

The degree and direction of correlations between variables are measured via correlation analysis.
• Trade performance is strongly positively correlated with digitalisation (0.65) and strategic adaptability (0.70), suggesting that increases in these areas greatly boost trade outcomes.
• There is a high positive correlation between supply chain resilience (0.60) and reliable trade operations.
• There is a moderately negative association between trade obstacles (-0.49) and trade performance.
• When inter-variable correlations stay below 0.80, there is no multicollinearity issue, which is crucial for regression analysis.

In conclusion, the correlation results validate additional econometric modelling and confirm theoretical assumptions.

5. Regression Results

Variable	Coefficient	t-value	p-value
Constant	0.85	2.65	0.009
Digitalization	0.42	4.85	0.000
Supply Chain Resilience	0.36	3.92	0.001
Trade Barriers	-0.29	-3.10	0.002
Strategic Adaptability	0.48	5.21	0.000

Model Fit:

- **$R^2 = 0.61$**
- **$F = 28.4$ ($p < 0.001$)**

• **$R2 = 0.61$** shows that the model explains 61% of the variation in trade performance, which is robust for social science research.
• The model's overall statistical significance is confirmed by the F-statistic (28.4, $p < 0.001$).

Interpretation of variables:

• The greatest beneficial impact is seen in Strategic Adaptability ($\beta = 0.48$), suggesting that adaptable tactics are essential for success.
• Efficiency and worldwide reach are greatly improved by digitalisation ($\beta = 0.42$).
• During interruptions, Supply Chain Resilience ($\beta = 0.36$) promotes stability.
• Trade barriers have a negative impact on performance ($\beta = -0.29$), which is consistent with theoretical predictions.

In conclusion, the measuring tool is valid and dependable, enabling the use of sophisticated statistical methods.

Econometric Model

The study employs the following multiple regression model:

$TP = \beta_0 + \beta_1 DIG + \beta_2 SCR + \beta_3 TB + \beta_4 SA + \varepsilon$

- The model calculates how trade performance is affected by independent variables such as supply chain resilience, digitalisation, trade barriers, and strategic adaptability.
- **β_0 (constant)** represents baseline trade performance when all independent variables are zero.
- **β_1 to β_4** measure the marginal impact of each factor.
- **ε (error term)** captures unexplained variation.

In conclusion, the model is suitable for examining causal connections in the dynamics of international commerce.

Conclusion: While all factors have a considerable impact on trade performance, flexibility is the most important.

Diagnostic Tests

- **VIF < 5**
- **Breusch-Pagan p = 0.21**
- **Durbin-Watson = 1.89**

Diagnostic tests ensure the validity of regression assumptions:

- **Variance Inflation Factor (VIF < 5)** indicates **no multicollinearity**, meaning independent variables are not highly correlated.
- **Breusch-Pagan Test ($p = 0.21 > 0.05$)** confirms **no heteroskedasticity**, meaning error terms have constant variance.
- **Durbin-Watson (1.89)** is close to 2, indicating **no autocorrelation** among residuals.

Conclusion: The regression model is statistically sound and free from major econometric issues.

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Hypothesis Testing and Interpretation

Hypothesis	Result	Interpretation
H1	Accepted	Digitalization significantly enhances trade efficiency
H2	Accepted	Supply chain resilience improves continuity and performance
H3	Accepted	Trade barriers reduce profitability and growth
H4	Accepted	Strategic adaptability is the strongest driver

- **H1:** Strong statistical support ($p < 0.001$) confirms that digital transformation is essential for global competitiveness.
- **H2:** Supply chain resilience significantly ensures operational continuity in uncertain environments.
- **H3:** Negative coefficient validates that trade restrictions hinder business growth.
- **H4:** Highest coefficient and significance indicate that adaptability is the most critical success factor.

Final Insight:

The hypothesis testing confirms that **modern global trade success depends on technology adoption, resilience, and strategic flexibility**, while regulatory barriers remain a key challenge.

Findings of the Study –

1. The efficiency of international trade is greatly increased by digitalisation

In international trade, the use of digital technologies like automation and e-commerce lowers transaction costs while increasing speed and accuracy.

2. Resilient supply chains are necessary for continuous commerce

Businesses can maintain operations even in the face of interruptions like pandemics or geopolitical crises when they have robust and adaptable supply networks.

3. Performance is adversely affected by trade restrictions

Regulations, tariffs, and quotas raise prices and restrict market access, which lowers total company profitability.

4. The most important element is strategic flexibility

Businesses that can swiftly adapt to shifting laws, regulations, and technological advancements do well in international marketplaces.

5. Technology increases the precision of decisions

Businesses may increase efficiency by making timely and well-informed choices thanks to data analytics and digital technology.

6. Trade stability is impacted by global uncertainty

Trade flows and corporate confidence are impacted by instability brought on by political unrest, economic volatility, and catastrophes.

7. Digital commerce platforms are advantageous to SMEs

Digital platforms make it easier for small and medium-sized businesses to join foreign markets by lowering entry barriers.

8. Cooperation improves competitiveness internationally

Businesses may pool resources, lower risks, and increase their worldwide presence through partnerships and alliances.

Suggestions of the Study –

1. Make infrastructure investments for digital commerce

To increase productivity and enable seamless international transactions, governments and businesses should create digital platforms.

2. To lower risk, diversify your supplier chains

Using a variety of vendors and geographical areas reduces interruptions and guarantees business continuity.

3. Make trade laws simpler

Simplifying complicated processes and paperwork can make doing business easier and encourage trade expansion.

4. Encourage innovation in international commerce

Businesses may maintain their competitiveness in fast-paced international marketplaces by promoting innovative technology and business strategies.

5. Make risk management techniques stronger

To successfully manage uncertainty, businesses should identify possible risks and create backup strategies.

6. Encourage SMEs to trade internationally

SMEs may grow internationally by receiving financial support, training, and internet access.

7. Promote international collaborations

Cooperation between businesses and nations enhances commercial prospects and information exchange.

8. Develop labour force competencies for international markets

Productivity and competitiveness are increased when staff members receive training in digital technologies and global business practices.

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I express my sincere gratitude to my guide and research supervisor for their valuable guidance, constant encouragement, and insightful suggestions throughout the completion of this research work entitled **"Global Trade Dynamics in the Contemporary Era: Trends, Challenges, and Strategic Responses."**

I am deeply thankful to the Principal, Head of the Department, and all faculty members for providing the necessary academic support, encouragement, and institutional facilities required to complete this research successfully.

I would also like to extend my sincere thanks to scholars, economists, trade experts, and policymakers whose research, publications, and analytical insights helped me understand the changing nature of global trade, emerging trends, trade

barriers, economic challenges, and strategic responses in the contemporary era. Their work has significantly enriched the quality of this study.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

Conclusion

Today's global trade dynamics are shaped by a confluence of economic, strategic, and technical variables. This study emphasises how crucial supply chain resilience, digitalisation, and strategic flexibility are to improving trade success. A thorough grasp of the present trends and difficulties in international commerce is made possible by the combination of primary and secondary data.

Businesses that use digital technology and adaptable tactics are better positioned to thrive in cutthroat international marketplaces, according to the econometric analysis. However, trade restrictions and complicated regulations still impede growth, underscoring the necessity of policy changes.

According to the results, companies need to concentrate on creativity, teamwork, and adaptability in order to successfully manage uncertainty. Policymakers ought to provide favourable conditions that facilitate commerce and progress technology.

All things considered, the study adds to the body of knowledge in academia and offers useful advice for enhancing success in international trade. It comes to the conclusion that businesses' and economies' capacity to adjust to shifting circumstances while taking advantage of possibilities brought about by globalisation and digital transformation will determine the future of international commerce.

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Original Article

An Analysis of Trends and Pattern Changes in Agricultural Cropping and Credit Flow in India

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Abstract:

This research analyses the structural and financial evolution of the Indian agricultural sector marked by the shift from conventional cereal farming to high-value, capital-intensive agribusiness. The study emphasizes a strong institutional credit framework expanding at a CAGR of 17.03%. The incorporation of digital infrastructures like Agri Stack, AI-driven precision agriculture, and solarization via PM-KUSUM 2.0 has modernized smallholder practices; nonetheless, notable regional differences remain. Southern India constitutes 48% of national agricultural credit while representing only 18% of the Gross Cropped Area, highlighting a significant disparity in financial depth relative to the undercapitalized Central and Northern regions. Moreover, the study delineates significant "last-mile" difficulties, such as the exclusion of tenant farmers from official credit systems and a persisting gender disparity in loan allocation. The findings indicate that although India's agricultural resilience is substantial, attaining equitable growth necessitates targeted policy measures to address the credit-absorption deficit in Eastern and Central India, as well as the synchronization of financial liquidity with post-harvest infrastructure to guarantee sustained farmer prosperity.

Keywords: *Agricultural Credit, Crop Diversification, Financial Inclusion, Regional Disparity, Sustainable Modernization.*

Introduction

India's economy is still based on agriculture, which continues to play a crucial part in the country's socioeconomic structure. The industry showed incredible growth and durability as of the 2024–2025 era, reaching a record foodgrain production of 357.73 MMT. The Gross Cropped Area (GCA), which increased steadily from roughly 52.88 lakh hectares in 2019–20 to 55.85 lakh hectares by 2022–2023 and continued to rise until 2026, is the foundation for this productivity spike. This growth represents not only efficient land use but also a more comprehensive, systematic modernization that sustains more than 58% of rural households and accounts for about 16% of the country's GDP.

The Green Revolution marked the beginning of agricultural modernization, which has significantly raised farming's capital intensity. As a result, survival and expansion now depend on a strong institutional credit framework. Farmers, especially smallholders, can manage climate-related risks, invest in productivity-boosting innovations, and break free from predatory debt cycles when they have access to timely funding. Better resource utilization is made possible by appropriate funding, which enables the industry to endure changes in weather patterns and the volatility of international markets. Development gaps still exist notwithstanding a noticeable shift towards sustainable practices and crop variety. To ensure that the advantages of agricultural modernization reach the grassroots level and eventually secure the future of the agrarian sector, it is imperative to address these regional gaps through localized policy interventions.

Review of Literature

The contemporary discourse on agricultural development highlights a critical transition toward integrated management systems that harmonize economic output with ecological preservation. Recent scholarship by **Karimi et al. (2024)** emphasizes the necessity of strategic crop selection, specifically advocating for the prioritization of fodder maize over wheat to enhance fuel efficiency and optimize energy consumption within the sector. This move toward resource efficiency is complemented by the work of **Panchal (2024)**, who argues that the rigorous management of Agricultural Land-Use Systems is the primary safeguard against climate-induced disruptions to food security.

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Furthermore, **Li et al. (2024)** demonstrate that through advanced scientific modeling and crop diversification, it is possible to decouple agricultural growth from environmental degradation by simultaneously maximizing profitability and reducing carbon emissions.

The structural foundations of this productivity, however, are deeply tied to financial equity and technological transparency. **Khan et al. (2024)** provide a longitudinal critique of
the Indian agricultural credit landscape from 2010 to 2024, uncovering persistent regional disparities and a widening digital divide that hinders equitable access to formal loans. They suggest that overcoming these barriers requires a shift toward more accessible digital financial products and stricter oversight of non-institutional lending. On the spatial front, **Chen et al. (2023)** warn that the rapid repurposing of arable land for non-agricultural uses presents a catastrophic risk to global food stability. While remote sensing technology offers a lens to monitor these shifts, **Ashwini et al. (2024)** note that the technical complexity of identifying mixed-cropping patterns remains a significant hurdle for researchers. By synthesizing these perspectives, this study addresses a critical research void in the Haveri district, investigating how the interplay between credit accessibility and specific cropping patterns determines the trajectory of regional agricultural productivity.

Objectives

For the purpose of the study have been set the following objectives:

1. To analyze the growth of agricultural credit flow in India.
2. To identify shifts in cropping patterns in India.
3. To evaluate the impact of institutional credit on crop productivity and diversification.

Global Comparison: India vs. BRICS Nations

In a global context, India's agricultural financing and structural plan in 2026 demonstrate a sector undergoing swift modernisation, however it remains behind other BRICS leaders in capital depth. India's Credit-to-Agriculture GDP ratio is roughly 42%, reflecting a burgeoning although still nascent level of financial penetration in contrast to Brazil's 55% and China's 61%. The provision of this credit is predominantly influenced by Commercial Banks, which represent 89% of the lending sector in India. This starkly contrasts with Brazil's dependence on specialised Development Banks and China's state-owned banking system, indicating that India's growth trajectory is significantly reliant on the private sector's capacity to penetrate a smallholder-dominated market via government-supported digital infrastructures. Table-1 reveals global comparison of India Vs. BRICS Nations.

Table-1: Global Comparison: India vs. BRICS Nations

Parameter	India	Brazil	China
Credit to Agri GDP Ratio	42%	55%	61%
Dominant Credit Source	Commercial Banks (89%)	Development Banks	State-owned Banks
Tech Integration	High (AgriStack/AI)	High (Agri-Fintech)	Very High (Automation)
Major Crop Shift	Horticulture/Pulses	Soybeans/Maize	Value-added Rice/Tech-crops

Source: World Bank Database-2026.

Technological advancements and agricultural specialization further differentiate these nations, with India attaining significant integration through programmes such as Agri Stack and AI-enhanced precision farming. Brazil excels in Agri-Fintech for large-scale operations, China leads in advanced automation, while India's digital initiative is specifically designed to address the complexities of its multitude of small farms. This technological basis facilitates a strategy shift towards Horticulture and Pulses, aimed at improving domestic nutritional security and water sustainability. Brazil and China concentrate on global commodities such as soybeans and advanced value-added crops, but India's diversification into high-value food demonstrates a strategic initiative to enhance farmer incomes while mitigating the ecological limitations of conventional cereal farming.

Trends in Agricultural Cropping Patterns and Agriculture Credit Flow

India's agriculture sector is experiencing a significant structural shift, transitioning from conventional staples to high-value, climate-resilient crops. Horticultural production has, for the first time, surpassed total food grain production, attaining 362.08 million tonnes in the 2024- 25 cycle. This transition indicates that farmers are progressively favouring market-oriented commodities such as fruits, vegetables, and spices over traditional cereal crops. This transformation is not solely a national phenomenon but is evident in localised changes; for example, in the Haveri area, traditional cotton has had a significant fall with a CAGR of -
21.91%, whilst pulses and vegetables have increased by over 33%. The Indian government has adjusted its fiscal strategy to promote the production of niche and high-value products. The Union Budget 2026-27 included monies for the expansion of temperate nuts, including almonds and walnuts, as well as coastal and forest-based crops like cocoa and sandalwood. These efforts seek to diversify India's export portfolio and increase the income of smallholder farmers. In
addition to targeted crop support, the comprehensive land-use data reveals a strong agricultural base, with the total cropped area approximated at 219.36 million hectares and a

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notable cropping intensity of 155.9%, signifying that a substantial fraction of Indian farmland is employed for multiple crops annually.

Irrigation infrastructure is fundamental to this production. The irrigated area has increased to 79.31 million hectares, ensuring water security for high-value crops that are typically more susceptible to moisture stress than conventional cereals. The data indicates a significant dependence on groundwater, with tubewells constituting around 49.34% of the overall irrigation sources. This has enabled farmers to grow throughout the year, highlighting the critical necessity for sustainable water management and the "Per Drop More Crop" programme to maintain the viability of horticulture amid evolving climatic conditions.

The progression of India's agricultural financing signifies a fundamental transition from rudimentary, short-term crop loans to a comprehensive financial assistance framework. This transition is underpinned by the preeminent position of Scheduled Commercial Banks (SCBs), which currently provide 89% of the sector's overall loan needs. Credit serves as a crucial "pull" factor by allowing farmers to acquire modern inputs and technology, however its effectiveness is intricately linked to the "push" factor of physical infrastructure. Without essential post harvest infrastructure such as cold storage, especially for horticultural products, an influx of finance may inadvertently result in debt traps. In the absence of methods to preserve perishable produce, farmers frequently resort to distress sales, forfeiting the essential margins required to fulfil their official loan obligations. Table 2 indicates the trends in agricultural production and the flow of agricultural loans.

Table-2: Trend of Agriculture production and Agriculture Credit

Year	Agriculture Production	Agriculture Credit flow
2004-05	198362	96100
2005-06	208601	124400
2006-07	217282	172700
2007-08	230775	230200
2008-09	234466	274100
2009-10	218107	309500
2010-11	244491	390300
2011-12	259323	461000
2012-13	257124	561900
2013-14	265043	676100
2014-15	252676	841800
2015-16	251554	904300
2016-17	275111	951000
2017-18	280130	1078300
2018-19	285209	1199500
2019-20	297504	1349626
2020-21	310741	1367970
2021-22	315615	1518112
2022-23	330534	1703315
2023-24	357730	1907444
2024-25	362082	2231709

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CAGR %	***3.05%***	***17.03%***

Source: NITI Ayoga.

The data spanning from 2004-05 to 2024-25 illustrates a striking divergence in growth rates within the sector. While agricultural production has maintained a steady and resilient Compound Annual Growth Rate (CAGR) of 3.05%, rising from 198,362 to 362,082 units, the volume of agricultural credit has expanded exponentially. Starting at 96,100 in 2004-05 and surging to 2,231,709 by 2024-25, credit has grown at a CAGR of 17.03%. This rapid deepening of formal finance highlights a massive infusion of capital into the rural economy, yet it simultaneously underscores the urgent necessity of aligning this financial liquidity with robust infrastructure to ensure that increased investment consistently translates into sustainable farmer prosperity.

Further, the Kisan Credit Card (KCC) initiative has attained significant scale in India, with 77.2 million active accounts as of March 2025. This signifies a profound integration of formal credit within the rural sector, guaranteeing that a substantial segment of the agricultural community can access institutional financing. The significance of this reach is emphasised by the prevailing demographic landscape of Indian agriculture, wherein marginal farmers those possessing small and frequently fragmented holdings currently oversee over 86% of all agricultural land. The concentration of smallholders requires tailored financial policies that emphasise accessibility rather than conventional asset-based financing.

Recent policy improvements for the 2025-26 fiscal year explicitly address the financial limitations encountered by these small-scale manufacturers. The government is increasing the financing ceiling under the Modified Interest Subvention Scheme (MISS) from ₹3 lakh to ₹5 lakh, recognising the escalating costs of agricultural inputs and the transition to more capital intensive, high-value farming. The permanent modification of the collateral-free loan limit to ₹2 lakh is a significant advancement for marginal farmers. The programme eliminates the necessity for land or asset collateral for these loans, thereby reducing the entry barrier and enabling individuals without substantial security to engage in formal credit systems and evade the exorbitant interest rates imposed by informal moneylenders.

Regional Credit Disparity

A substantial structural disjunction between the locations of agricultural practice and the channels of financial resource allocation. The geographical disparity is particularly pronounced in Southern India, which receives an extraordinary 48% of the overall agricultural loan while representing merely 18% of the nation's Gross Cropped Area (GCA). This indicates that the Southern region exhibits significantly greater credit intensity, possibly attributable to advanced banking penetration, a higher concentration of high-value horticultural products, and a more robust cooperative credit framework that enables farmers to access increased capital per hectare of land. Table 3 delineates the regional percentage distribution of total agriculture credit and gross cropped area.

Table-3: Region-wise Percentage share of Total Agri. Credit and gross cropped area

Region	% Share of Total Agri-Credit (FY25)	% Share of Gross Cropped Area
Southern India	48.0	18
Northern India	14.9	20
Western India	14.0	17
Central India	13.7	28
Eastern India	8.2	12
North-East	1.2	5

Source: NITI Ayoga

Conversely, Central and Northern India exhibit a markedly distinct situation. Central India comprises 28% of the nation's cropland, however it receives merely 13.7% of the total credit. Northern India comprises 20% of the cultivated area however receives merely 14.9% of the credit allocation. This gap suggests that farmers in these "breadbasket" regions may be undercapitalised or increasingly dependent on informal credit sources and traditional subsistence farming, which necessitates less capital than the commercial farming techniques observed in the South.

The disparity is particularly pronounced in Eastern and North-Eastern India. The North East accounts for 5% of the cultivated land however receives a minimal 1.2% of the national credit allocation. These statistics highlight a continual dilemma for policymakers: whereas agricultural production is spatially varied, formal banking institutions remain centralised. Addressing this disparity is crucial for attaining "inclusive growth," as areas with significant agricultural potential yet limited credit access such as the Central and Eastern belts necessitate focused financial interventions to modernise farming practices and enhance output.

The India's agricultural environment is not homogeneous but rather a compilation of distinctly regional economies with differing degrees of "credit

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absorption capacity." The southern states, spearheaded by Tamil Nadu and Andhra Pradesh, exhibit enhanced capacity, with credit flows amounting to ₹4.75 lakh crore and ₹3.27 lakh crore, respectively. This supremacy is evidenced by their elevated Credit-to-Agri-GVA ratios and a notable structural shift; since 2020, these states have repurposed around 22% of conventional grain land for high value commercial enterprises such as chilli, turmeric, and chicken. This agility is driven by a robust network of Primary Agricultural Credit Societies (PACS) and the prompt implementation of Digital KCC, enabling the South to attain the highest Productivity Index of 134. Table 4 delineates a regional comparison of credit growth in relation to crop diversification.

Table-4: Region-wise Comparison of Credit Growth vs. Crop Diversification

State Group	Avg. Credit Growth (CAGR %)	Primary Crop Shift	Productivity Index (Base 100 in 2020)
Northern	4.2%	Wheat/Paddy → Basmati/Vegetables	112
Western	8.8%	Cotton → Pomegranate/Grapes	128
Eastern	11.5%	Paddy → Maize/Fisheries	119
Southern	9.4%	Paddy → Oil Palm/Poultry	134

Source: NITI Ayoga

Conversely, other regions are employing credit for targeted strategic adjustments aligned with their climate and topography. In Central states such as Madhya Pradesh and Rajasthan, funding has been directed towards the National Mission on Edible Oils – Oil Palm (NMEO-OP), leading to a 14% expansion in mustard and soybean cultivation. This localised emphasis has a direct multiplier effect on agricultural mechanisation, as demonstrated by a 19% increase in term loans for tractors and harvesters. The Northern region exhibits a modest credit increase of 4.2% as it transitions towards Basmati and vegetables, whilst the Eastern and Western regions see larger growth rates of 11.5% and 8.8%, respectively, as they diversify into fisheries, pomegranates, and grapes. This regionalization demonstrates that credit is most
efficacious when it is tightly matched with the distinct crop diversification and productivity objectives of each specific geographic zone.

The Southern states, including Andhra Pradesh, Telangana, Karnataka, Kerala, and Tamil Nadu, represent a significant anomaly in Indian agricultural finance, commanding 48% of total agricultural loans despite possessing only 17% of the nation's gross cropped area (GCA). This intense concentration of credit has moved beyond traditional subsistence farming, catalyzing what is now known as the "Allied Revolution." In this region, credit is increasingly utilized for sophisticated capital expenditures rather than just seasonal inputs like seeds or fertilizers. This financial depth has funded a massive expansion in micro-food processing and cold chain logistics, enabling Southern and Western states to become export hubs for high value perishables like grapes and pomegranates.

Simultaneously, a strategic "Eastern Revival" is underway to correct the historical low credit absorption in Bihar, Odisha, and West Bengal. Launched in the 2025-26 budget, the PM Dhan Dhaanya Krishi Yojana (PM-DDKY) provides targeted long-term credit specifically for irrigation and infrastructure. This intervention is already yielding visible structural changes; traditional, low-margin mono-cropped paddy fields are being rapidly converted into profitable pisciculture (fisheries) and maize hubs. As a result, Eastern India is currently leading the country in financial momentum, recording an 11.5% CAGR in credit growth as of 2026, the highest growth rate among all Indian regions.

Transformation of Indian Agriculture Strategic Policy and Technological Interventions

The agricultural landscape in India for 2025-2026 is characterised by a planned transition towards financial inclusion and the elimination of conventional obstacles for smallholders. A crucial measure was the RBI's decision to increase the collateral-free loan limit to ₹2.00 lakh, a step that directly benefits the 86% of Indian farmers who manage small and marginal landholdings. The Modified Interest Subvention Scheme (MISS) facilitates affordable credit by maintaining an effective interest rate of 4% for timely repayers. The proliferation of Kisan loan Cards (KCC) into animal husbandry and fisheries now exceeding 7.72 crore accounts has diversified the loan portfolio beyond conventional crop farming, supplying essential operational cash for the wider rural economy.

Institutional and technological advancements are increasingly closing the divide between farmers and formal financial systems. The implementation of PM-DDKY in the 2025- 26 budget specifically aims at districts with a history of low credit absorption, while the incorporation of over 10,000 Farmer Producer Organisations (FPOs) facilitates collective bargaining for bulk loans and the establishment of Custom Hiring Centres. The Bharat VISTAAR AI tool has transformed the digital landscape by merging land records with the KCC portal, significantly lowering transaction costs. This financial modernisation coincides with an energy revolution with PM-KUSUM 2.0, enabling

feeder-level solarization that permits farmers to achieve annual returns of up to 16% from surplus power. This has advanced Agri
Photovoltaics (AgriPV), cultivating shade-tolerant crops such as turmeric and ginger beneath solar panels, so optimising land use and concurrently minimising water loss.

Challenges and Issues

India's agricultural finance industry has grown impressively, yet there are still significant structural issues that need to be addressed. One of the main issues is the extreme regional disparity in fund distribution; at the moment, the North-East receives a pitiful 1.7% of NABARD's short-term refinance, while Southern India receives around 45.7% of it. With the exception of Eastern India, most regions are witnessing a decrease in rural bank branches, which further complicates this disparity. Remote farmers may find it more difficult to obtain official financial services as a result of this "rural-urban shift" in banking infrastructure, which could jeopardise last-mile credit delivery. The "Tenant Farmer Dilemma" continues to be a major barrier to real financial inclusion, regardless of location. Tenant farmers without official land titles make up about 25-30% of actual cultivators in states like Andhra Pradesh and Bihar. These "invisible farmers" are frequently denied institutional loans because the majority of official credit systems are still strictly linked to land records. As a result, individuals are compelled to use unofficial moneylenders, who frequently charge predatory interest rates between 24% and 36%, trapping them in a vicious circle of high-interest debt.

Additionally, there is still a gender gap in the distribution of agricultural finance. Only 14% of direct agricultural credit is given to women, despite the fact that they perform more than 60% of the physical labour in Indian fields. The implementation of the 2026 policy focus on the "Mahila Kisan" Kisan Credit Card (KCC) has delayed, despite the fact that it was intended to remedy this disparity by giving priority to female farmers. To ensure that India's
record-breaking credit ambitions translate into fair development for all individuals working the land, it is imperative to address these regional and demographic imbalances.

Conclusion

By 2026, the Indian agricultural environment is characterised by a significant structural transformation, with capital-intensive modernisation swiftly supplanting traditional subsistence farming. This transformation is grounded in a significant shift in production dynamics, whereby horticulture output consistently exceeds foodgrain production, indicating a market-driven switch towards high-value, climate-resilient crops such as fruits, vegetables, and pulses. This transition is driven by a vigorous expansion of institutional credit, which has had an impressive compound annual growth rate (CAGR) of 17.03% over the past twenty years, much surpassing the 3.05% rise in physical production. The infusion of liquidity, facilitated by digital frameworks such as AgriStack and AI-driven precision agriculture, has empowered smallholders who oversee 86% of the land to invest in productivity-enhancing technology and solar-integrated agricultural systems like Agri-Photovoltaics.

This economic trajectory is characterised by considerable regional and demographic disparities that jeopardise the principle of inclusive development. A significant disparity in "credit intensity" is evident, as Southern India receives about half of the country's agricultural loans while comprising less than one-fifth of the cultivated land, resulting in the Central and Northern "breadbasket" regions being relatively underfunded. Moreover, institutional obstacles remain for "invisible" stakeholders; around 30% of genuine cultivators are tenant farmers without legal land titles, and women receive merely 14% of direct credit despite undertaking the majority of manual labour. Ultimately, although the infusion of capital and technology has achieved unprecedented production levels, the long-term sustainability of the sector hinges on addressing regional disparities and synchronising financial resources with post-harvest infrastructure to avert debt cycles and guarantee equitable prosperity throughout all agricultural regions.

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The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

An Empirical Analysis of Digital Governance Platforms' Impact on Democratic Participation in India: Evidence from Mygov and Cvigil (2015–2026)

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Abstract

Digital governance platforms have emerged as transformative instruments in reshaping the citizen-state interface within democratic frameworks. This empirical study focuses on understanding the contribution of two popular Indian digital governance portals, namely MyGov and cVIGIL, towards democratization of participation between the years 2015 and 2026. Through the use of quantitative measures based on data from usage metrics of the portals, participation metrics for elections, and a questionnaire survey conducted with 320 participants from urban and semi-urban parts of Karnataka, the present study employs the methods of descriptive statistics and correlations. The study has found that MyGov has been successful in improving participation in consultative forums for educated individuals living in urban areas. On the other hand, the cVIGIL portal has improved electoral participation by making people aware of violation of Model Code of Conduct in elections. Despite some challenges like digital divide, lack of literacy with regard to the portals, and lack of rural penetration, these two portals have gradually expanded the scope of participation in Indian democracy.

Keywords: *Digital Governance, Democratic Participation, MyGov, cVIGIL, E-Democracy, Electoral Integrity, Citizen Engagement, India*

Introduction

The international spread of information and communications technologies has radically altered the structure of democratic governance in the contemporary era. The Indian government's Digital India campaign (2015) was a step that cemented this evolution through developing a set of ICTs that sought to improve citizen engagement in governance. These ICTs include MyGov and cVIGIL, which have been specifically crafted for the purpose of improving democratic participation. While MyGov facilitates citizen participation in policymaking by engaging citizens in crowdsourced consultations, cVIGIL allows citizens to file grievances regarding electoral malpractices during voting.

MyGov, launched on 26th July 2014, encourages citizens to participate in discussions about policy-making, offer feedback, and help create policies through crowdsourcing. By May 2026, the website had amassed over 35 million users and conducted over 800 consultations. cVIGIL, established by the Election Commission of India in 2018, permits citizens to instantly report any breaches of the Model Code of Conduct in elections. During the 2024 General Elections, over 1.7 million complaints were received on the portal, with an average redressal period of less than 100 minutes. Table 1 presents the longitudinal growth trajectory of both platforms from 2015 to 2026.

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Table 1 Growth Statistics of MyGov and cVIGIL Platforms (2015–2026)

Year	MyGov Users (Million)	Discussions Hosted	Tasks & Competitions	cVIGIL Complaints (M)
2015–16	0.6	42	18	—
2016–18	3.2	118	64	—
2018–20	9.1	224	109	0.48
2020–22	17.8	387	198	0.91
2022–24	27.4	611	376	1.42
2024–26 (est.)	35.0+	800+	500+	1.70+

Note. MyGov user and discussion data sourced from MyGov India (2026). cVIGIL complaint data sourced from Election Commission of India (2024). Values marked '—' indicate the platform was not yet operational in that period. 2024–26 figures are estimated as of April 2026.

Despite the salience of both platforms in policy discourse, academic research evaluating their democratic influence has remained scarce. This study seeks to fill this lacuna by empirically analyzing both platforms in the context of urban and semi-urban Karnataka during two electoral cycles (2015-2026).

Objectives of the Study

1. To examine the growth pattern and usage trends of MyGov and cVIGIL between 2015 and 2026.
2. To measure the type and extent of political engagement—between instrumental and deliberative forms of engagement—enabled through these platforms.
3. To examine the socio-demographic characteristics (gender, age, education, place) that affect citizens' use of these platforms.
4. To measure the effectiveness of cVIGIL in strengthening electoral integrity, based on citizens' perceptions.
5. To determine the structural and socio-technical constraints that prevent equal access to digital political participation in Karnataka.
6. To suggest data-driven policy measures to increase democratic political participation in India's digital political participation ecosystem.

Review of literature

1 Digital Democracy: Theoretical Foundations

Theoretical debates regarding digital democracy tend to be quite disjointed. On one hand, enthusiasts like Poster (1997) and Rheingold (1993) argued that technological advances could help revive the spirit of engagement. On the other hand, scholars such as Sunstein (2001) raised concerns about echo chambers, whereas Morozov (2011) highlighted the possibility of the digital environment being exploited by autocratic regimes. Norris (2001) coined the term "democratic gap," stating that access to technology would not suffice; the ability to navigate the system, personal motivation, and the responsiveness of organizations were just as important. Coleman and Blumler (2009) proposed a theory of "mediated citizenship," emphasizing that the democratic significance of digital platforms depends on how well they engage and respond to citizen feedback. Arnstein's (1969) hierarchy of citizen participation offers useful guidance when it comes to separating co-production from consultation—key criteria for assessing MyGov's performance.

2 Digital Governance in India

There have been numerous accounts of the history of India's e-governance, including that of Bhatnagar (2004), among others, who trace its development from the computerization programs of the 1970s to the National e-Governance Plan of 2006 and the Digital India initiative of 2015. As stated by Sharma and Bhati (2020), the usage of the UMANG platform was highly prevalent among urban citizens but hindered by certain structural barriers such as bandwidth issues and lack of mobile literacy among rural citizens. In turn, Jain and Bhatt (2023) noted significant differences in the level of citizen satisfaction according to social economic classes.

3 MyGov: Participatory Platform or Performative Participation?

According to Kuriyan et al. (2017), MyGov is an example of digital participation with a novel consultative design; however, citizen engagement was not adequately considered in terms of its contribution towards policy outputs and transparency issues, thus creating doubts about the nature of citizen engagement in either symbolism or reality. Misra (2019) argued that MyGov had an educational, urban, and English-speaking demographic makeup, making its democratic representativeness questionable. On the other hand, Rao & Krishnaswamy (2021) noted that there were instances of policy inputs from the consultations of MyGov on the issue of COVID-19.

4 cVIGIL and Electoral Integrity

According to Singh & Verma (2020), cVIGIL has been able to reduce the average time taken to respond to violations of the Model Code from over six hours to under two hours during the 2019 General Elections. Furthermore, they point out a deterrent effect from the use of this technology. Gendered patterns have also been noted by Kaur & Sharma (2022) who find that women used the app to report voter intimidation and cash distribution. According to Menon (2023), there is a risk of frivolous and politically motivated complaints being filed.

5 The Digital Divide and Inclusion

According to Warschauer (2003), the access to technology is influenced not only by possession but also by social,

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linguistic, and cognitive factors. As pointed out by Drèze & Sen (2013), unless they are designed specifically to ensure accessibility, digital mediums are likely to be another front for elite domination. It seems quite pertinent to apply the concept of design–actuality gaps proposed by Heeks (2002), who believes that failure in e-government projects is due to mismatches between the assumptions of their designs and reality.

Methodology

1 Research Design and Study Area

This study is based on a sequential explanatory mixed-methods research design, which involves the integration of quantitative survey data and qualitative interview data. The data collection was conducted in five districts within Karnataka namely, Bengaluru Urban, Mysuru, Dharwad, Hassan, and Kolar.

2 Sampling and Data Collection

A stratified random sampling method was used, where strata were considered in terms of gender, age group, and geographical locations. Following the Cochran's (1977) sample calculation, a sample of 384 individuals was needed at 95% confidence interval with ±5% margin of error. Post non-response correction resulted in the acquisition of 320 valid responses, giving a response rate of 83.3%. This research used a pre-tested structured questionnaire of 42 questions provided in English and Kannada languages that examined the patterns of platform usage, participatory practices, the effectiveness, and obstacles associated with the utilization of digital platforms for online civic engagement. The secondary sources of data collected included statistical reports from MyGov India, annual reports from Election Commission of India, the internet usage data from NSSO, and election commission data from Karnataka.

3 Data Analysis

Quantitative data analysis was performed by the use of IBM SPSS Statistics (version 26). Basic descriptive statistics were carried out to describe the data characteristics. Chi-square tests were conducted to determine association between socio-demographic variables and online engagement platform usage. Correlation analysis was done through Spearman's rho correlation coefficient test to establish relationship between digital literacy and the extent of participation. Thematic analysis guided the interpretation of the data gathered from semi-structured interviews involving 20 respondents.

Key Findings and Discussions

The analysis of 320 responses reveals some key trends. In the case of MyGov, 64.7% of the respondents used the platform, although only 28.3% actually got involved in consultations or submitting ideas. 71.6% of the activities on MyGov are instrumental in nature – this includes participating in contests, responding to surveys and browsing through announcements. According to Pearson's chi-square test, there is a statistically significant relationship ($p < 0.01$) between the level of participation in consultative activities and educational qualification: the likelihood of engaging in consultations is almost three times higher for postgraduates as compared to secondary school graduates or dropouts. Table 2 presents MyGov participation patterns broken down by activity type and educational level.

Table 2

MyGov Participation Patterns by Activity Type and Educational Level (n = 207 MyGov Users)

Activity Type	Secondary Edu.	Undergraduate	Postgraduate	Chi-Square Result
Consultative (Policy feedback / idea submission)	10.2%	21.7%	38.6%	χ^2=41.3, p<0.01
Competitive (Creative contests, quizzes)	32.4%	39.5%	44.1%	χ^2=6.1, p=0.04
Survey Participation	41.8%	52.3%	58.9%	χ^2=9.4, p=0.02
Passive Browsing / Reading Announcements	68.3%	72.6%	69.8%	χ^2=0.9, p=0.64
Social Sharing of Government Content	28.7%	36.4%	41.2%	χ^2=5.7, p=0.06

Note. Percentages indicate the proportion of respondents within each educational group who reported engagement in the specified activity. Chi-square tests assess the significance of the association between educational level and activity type. $p < 0.05$ indicates statistical significance.

As far as cVIGIL is concerned, 58.1% of the respondents were aware of the platform before the last elections in their locality, and 41.3% had filed complaints via the platform. Effectiveness perception was high (67.2%) and the average score on the effectiveness scale was 4.1 out of 5.0. Among non-users, 43.8% mentioned lack of knowledge about cVIGIL as the primary reason for non-use, while 29.6% claimed insufficient trust in the anonymity of complaints. Female users perceived the platform to be more effective (67.4%) than male users (53.8%), which is in line with the results of Kaur and Sharma (2022). A detailed breakdown of cVIGIL usage and effectiveness indicators is presented in Table 3.

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Table 3 cVIGIL Platform Usage and Effectiveness Perceptions by Gender (n = 320)

Indicator	All (n=320)	Male Users	Female Users
Platform Awareness (before last election)	58.1%	—	—
Filed at least one complaint	41.3%	—	—
Perceived effectiveness (positive rating)	67.2%	53.8%	67.4%
Complaint resolution speed (mean score)	4.1/5.0	3.8/5.0	4.3/5.0
Trust in complaint anonymity (agree/strongly agree)	42.6%	45.1%	39.8%
Non-use: Unawareness of platform	43.8%	—	—
Non-use: Lack of trust in anonymity	29.6%	—	—
Non-use: No election-related incident to report	18.7%	—	—
Platform perceived as empowering electoral role	61.4%	53.8%	67.4%

Note. Mean scores are on a 5-point Likert scale (1 = Very Ineffective to 5 = Very Effective). '—' indicates the indicator is not gender-disaggregated or not applicable to that category. Data collected from primary survey (2025–26).

Conclusion and Recommendations

It can be concluded from the findings above that MyGov and cVIGIL platforms have made tangible yet uneven contributions towards enhancing democratic participation in India. MyGov serves as a platform for consultative civic participation in the process of decision making, while cVIGIL promotes electoral accountability and citizenship vigilance. Together, these two platforms have played an important role in bringing about substantial but incomplete democratization of the digital civic interface.

However, it is clear that structural limitations still prevent full inclusiveness of both platforms in terms of promoting equitable democracy. Concentration of active civic participation on the part of the educated, urban and anglophone segments of Indian society may render false legitimacy to a process which is far from being equally represented in terms of demographic representation. Rural-urban digital divide, lack of multilingual interface, and ineffective public awareness campaigns form the three biggest obstacles standing in the way of digital democratic participation.

Recommendations include: (i) making multilingual interface obligatory for all national digital governance portals with preference for regional languages; (ii) integrating digital governance literacy into the National Digital Literacy Mission within gram panchayats; (iii) setting up community centers of digital democracy in blocks characterized by low level of platform use; (iv) introducing algorithms of transparency in order to allow citizens to trace their input impact on policy making within MyGov portal; (v) creating independent mechanisms of monitoring and auditing in relation to complaint processing on cVIGIL. Future research could benefit from exploring participation practices of rural and tribal communities with panel data design.

As far as cVIGIL is concerned, 58.1% of the respondents were aware of the platform before the last elections in their locality, and 41.3% had filed complaints via the platform. Effectiveness perception was high (67.2%) and the average score on the effectiveness scale was 4.1 out of 5.0. 43.8% of the non-users mentioned lack of knowledge about cVIGIL, while 29.6% of them claimed that they do not feel safe enough to file anonymous complaints. Female users perceived the platform to be more effective (67.4%) than male users (53.8%), which is in line with the results of Kaur and Sharma (2022).

In qualitative interviews, the importance of WhatsApp and Instagram in promoting platforms among the young generations was pointed out. Some of the government officials stressed that cVIGIL had a significant impact on the conduct of campaign managers who were now discouraged from committing code violations in order to prevent complaints.

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Original Article

From Jyoti to Jane: Identity as Reinvention and Survival in Jasmine

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Abstract

This paper examines the dynamic relationship between identity, reinvention, and survival in Jasmine by Bharati Mukherjee. Tracing the protagonist's transformation from Jyoti, a village girl in India, to Jane, a woman in the United States, the study argues that identity in the novel is neither fixed nor continuous but is constantly reshaped through lived experience. Each shift in Jasmine's identity emerges from her encounter with changing social, cultural, and personal realities. Rather than interpreting these transformations as fragmentation or loss, the paper reads them as necessary and strategic acts of adaptation. The transitions from Jyoti to Jasmine, Jase, and Jane arise from moments of displacement, violence, and migration, revealing how identity is negotiated under pressure. Reinvention, in this context, becomes a condition of survival rather than an optional act of self creation. The paper further explores the role of gender in shaping this process, showing how Jasmine negotiates vulnerability and agency within both Indian patriarchal structures and the complexities of American society. Her shifting identities reflect not only cultural negotiation but also a sustained effort to assert autonomy in unfamiliar and often unstable environments. By foregrounding narrative experience while engaging with key postcolonial ideas, this study presents identity as fluid, situational, and inseparable from survival. It ultimately argues that in Jasmine, reinvention is not merely transformation but an ongoing practice of endurance and self preservation within a transnational world.

Keywords: *Diaspora, identity, reinvention, survival, postcolonialism, gender, migration, transnationalism, selfhood, cultural negotiation*

Introduction

Jasmine presents a striking narrative of migration, transformation, and identity. At its centre is a protagonist whose life refuses to remain confined within a single definition. Born as Jyoti in a rural village in Punjab, she moves across borders and cultures, becoming Jasmine, Jase, and Jane. Each transformation marks not only a change in place but also a reconfiguration of self.

Bharati Mukherjee challenges the assumption that identity is stable and continuous. Instead, she portrays identity as shaped by experience, often by experiences that are intense, disruptive, and transformative. Jasmine's life unfolds through moments of rupture rather than smooth progression. Her journey is marked by sudden shifts that require her to adapt quickly in order to survive.This paper argues that Jasmine's transformations are best understood as strategies of survival rather than signs of fragmentation. Her changing identities are not evidence of instability but responses to conditions that demand resilience and adaptability. Reinvention becomes essential because remaining unchanged would mean remaining vulnerable.

Identity as Process and Becoming

Jasmine's narrative disrupts the idea of a unified and consistent self. Instead, it presents identity as something that evolves through time and circumstance. Jasmine herself acknowledges this multiplicity:

"We have been many selves. We have survived hideous times" (Mukherjee).

This reflection highlights the central tension of the novel. Identity is not something fixed within her but something shaped by external conditions and internal responses. Each version of herself belongs to a particular moment and context.

Jyoti represents a life structured by tradition and limitation. Jasmine reflects a phase of transition marked by hope and uncertainty. Jase embodies a more confident adaptation to urban American life, while Jane suggests a quieter, more reflective existence. These identities do not coexist; they replace one another as circumstances change. Stuart Hall's understanding of identity as a continuous process rather than a completed state is particularly relevant here. Jasmine does not return to an original self. Instead, she moves forward, reshaping herself repeatedly. Identity becomes a matter of becoming rather than being.

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Reinvention as a Condition of Survival

Jasmine's transformations are closely linked to moments of crisis. Widowhood, migration, and exposure to violence force her to reconstruct herself repeatedly. These changes are not acts of freedom alone; they are responses to necessity.

The novel captures this process with remarkable clarity:

"We murder who we were so we can rebirth ourselves" (Mukherjee).

This statement reveals the emotional and psychological intensity of reinvention. It involves both loss and creation. In order to survive, Jasmine must leave behind earlier versions of herself, even when doing so is painful.

Homi Bhabha's idea of cultural hybridity offers a useful framework for understanding this condition. Jasmine exists between cultures, navigating spaces where identity is constantly negotiated. She is neither fully rooted in her past nor entirely absorbed into her present. This position requires flexibility and transformation.

Reinvention, therefore, is not a sign of instability. It is a necessary response to changing realities. It enables Jasmine to survive circumstances that would otherwise overwhelm her.

Migration, Trauma, and Transformation

Migration in *Jasmine* is not presented as a smooth or hopeful transition. It is marked by uncertainty, fear, and violence. Jasmine's journey involves both physical danger and emotional disruption. Her assault upon arrival in the United States becomes a turning point that forces her to redefine herself once again.

Her response to trauma is shaped by a determination to move forward rather than remain bound to the past. She reflects:

"Experience must be forgotten, or it will kill" (Mukherjee).

This perspective challenges conventional ideas about memory and healing. For Jasmine, survival depends on the ability to leave painful experiences behind. Remembering becomes a burden that threatens to immobilize her.

Gayatri Spivak's reflections on marginalized voices help illuminate this aspect of the novel. Jasmine's trauma is not fully expressed within dominant narratives. Instead, it is internalized and transformed into action. Her silence becomes a strategy rather than a sign of weakness.

Trauma, therefore, is not only destructive. It is also transformative. Each experience reshapes her identity, pushing her toward a new version of herself.

Gender and the Formation of Agency

Gender plays a central role in shaping Jasmine's journey. In her early life, she is constrained by patriarchal expectations that limit her autonomy and define her role within society. Her identity as Jyoti is closely tied to these structures.

Migration introduces new possibilities, but it does not eliminate power imbalances. Jasmine continues to navigate relationships where her agency is negotiated. However, over time, she begins to assert her own choices more clearly.

Her decision to leave Bud and follow Taylor represents an important moment of self assertion. It reflects her willingness to act according to her own desires rather than remain confined by circumstance. This marks a shift from passive survival to active decision making.

Jasmine's story shows that agency is not immediate or complete. It develops gradually through experience and struggle. Her reinventions are not only about survival but also about gaining control over her own life.

Cultural Negotiation and the Transnational Self

Jasmine's identity is shaped by her movement between cultural contexts. She navigates the expectations of her Indian background while adapting to American society. This process involves both adjustment and loss.

Mukherjee presents America as a space of transformation, where change is constant. Jasmine observes:

"Hell turned into paradise… very American" (Mukherjee).

This observation reflects the cultural value placed on reinvention. Jasmine's ability to transform aligns with this ethos. However, her experience also reveals the complexity of assimilation.

Adaptation often requires distance from the past. This raises important questions about belonging. Can one fully integrate into a new culture without losing connection to earlier identities? What is the cost of transformation?

The novel does not offer simple answers. Instead, it presents identity as something negotiated across different spaces. Jasmine's life reflects the possibilities and tensions of living between cultures.

Conclusion

Jasmine offers a powerful exploration of identity as fluid, evolving, and deeply connected to survival. Jasmine's journey from Jyoti to Jane is not a narrative of fragmentation but one of resilience and adaptive transformation. Each identity she inhabits emerges from specific circumstances that demand change.

This paper has argued that reinvention in the novel is not an act of self invention driven by choice but a necessary strategy for survival. Jasmine's ability to transform allows her to navigate trauma, migration, and cultural difference. Her identity is not something she preserves but something she continuously reshapes. At the same time, her journey complicates simple ideas of agency. She is neither entirely free nor entirely constrained. Instead, she moves through shifting structures of power, gradually asserting her autonomy.

Ultimately, Jasmine invites us to rethink identity as an ongoing process rather than a fixed state. In a world shaped by movement and uncertainty, survival depends not on remaining unchanged but on the capacity to adapt. In Jasmine, survival does not belong to the self that remains unchanged, but to the self that dares to transform.

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ESG Integration and Green Banking Practices in India: A Comparative Study of Public and Private Sector Banks

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Abstract

The banking sector increasingly adopted sustainable and responsible banking practices due to growing environmental, social, and governance concerns. Environmental, Social, and Governance (ESG) integration and green banking practices emerged as important strategies for ensuring long-term sustainability, transparency, and responsible financial growth. Indian banks gradually implemented green banking initiatives such as paperless banking, digital transactions, green financing, renewable energy funding, and sustainable lending practices. However, the extent of ESG integration and green banking practices differed between public and private sector banks due to variations in ownership structure, technological advancement, governance practices, and strategic priorities. Objectives of the study is to examine the extent of ESG integration, analyze green banking practices, and compare the sustainability initiatives adopted by public and private sector banks in India. The study was based on secondary data. The collected data was analyzed using thematic and content analysis methods. The findings revealed that Indian banks increasingly integrated ESG principles into their operational and strategic activities. Green banking practices such as digital banking, green financing, and renewable energy investments expanded significantly. Private sector banks demonstrated better ESG disclosures and technological innovation, whereas public sector banks showed stronger participation in financial inclusion and government-supported sustainability initiatives. The study also identified challenges such as lack of standardized ESG frameworks, inadequate awareness, insufficient employee training, and high implementation costs. The study suggested that banks should strengthen ESG integration, improve sustainability reporting practices, enhance green financing initiatives, and increase awareness and training programs to promote sustainable banking practices in India.

Keywords: *ESG Integration, Green Banking, Sustainable Banking Practices.*

Introduction

In recent years, the banking sector has witnessed a major transformation due to growing concerns regarding environmental sustainability, social responsibility, and ethical governance. Financial institutions are no longer evaluated only on the basis of profitability and financial performance; stakeholders now expect banks to contribute towards sustainable development and responsible business practices. In this context, the concept of Environmental, Social, and Governance (ESG) has gained significant importance across the global financial system. Banks are increasingly integrating ESG principles into their operational strategies, lending decisions, risk management practices, and investment activities to ensure long-term sustainability and stakeholder confidence. In India, the banking industry plays a crucial role in economic growth and financial inclusion. With increasing regulatory initiatives by institutions such as the Reserve Bank of India and Securities and Exchange Board of India, banks are encouraged to adopt sustainable finance practices and disclose ESG-related information. Simultaneously, rising awareness among customers, investors, and policymakers has accelerated the adoption of green banking initiatives aimed at reducing environmental impact and promoting sustainable economic development. Green banking refers to banking activities and practices that are environmentally friendly and support sustainable development. It includes initiatives such as paperless banking, green financing, renewable energy funding, digital banking services, energy-efficient operations, and financing eco-friendly projects.

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Green banking not only helps reduce the carbon footprint of banks but also enhances operational efficiency and corporate reputation. ESG integration in banking involves incorporating environmental, social, and governance factors into strategic decision-making and financial operations. Environmental factors include climate risk management, carbon reduction initiatives, and sustainable financing. Social factors focus on employee welfare, customer satisfaction, financial inclusion, and community development. Governance factors relate to ethical leadership, transparency, accountability, regulatory compliance, and risk management practices. Effective ESG integration enables banks to improve long-term performance, strengthen stakeholder trust, and manage emerging risks associated with sustainability challenges. The Indian banking sector consists mainly of public sector banks and private sector banks, both of which contribute significantly to the country's financial system. However, their approaches towards ESG adoption and green banking practices may differ due to variations in ownership structure, operational flexibility, technological advancement, regulatory pressure, and strategic priorities. Public sector banks often focus on financial inclusion and government-driven sustainability initiatives, whereas private sector banks may emphasize innovation, digital transformation, and advanced ESG reporting practices. Therefore, the present study titled "ESG Integration and Green Banking Practices in India: A Comparative Study of Public and Private Sector Banks" aims to examine and compare the extent of ESG integration and green banking initiatives adopted by public and private sector banks in India. The study seeks to understand how these banks are responding to sustainability challenges and contributing towards responsible and inclusive economic growth.

Review Of Literature

A literature review is essential in research as it concisely analyzes digital transformation across various dimensions, differences in methodological issues, and theoretical frameworks. Now, the prevailing literature mainly accentuates the ESG Integration and Green Banking Practices in India.

- **Desai & Prajapati (2024),** Green Banking and Sustainable Finance: Global Trends, Indian Practices, and Future Prospects" examined the development of green banking and its role in promoting sustainable finance at both global and Indian levels. Through a literature review, the study identified major green banking practices, regulatory measures, and successful implementations in developed and developing economies. The findings revealed that developed countries had stronger ESG frameworks and green finance policies, while India gradually adopted sustainable banking practices through green bonds, digital banking, and eco-friendly financial products. The study also highlighted challenges such as regulatory inconsistencies, low consumer awareness, and high implementation costs. It concluded that technological innovation, regulatory support, and stakeholder participation were essential for the future growth of green banking and sustainable finance.
- **Yadav et.al., (2024),** studied Advancing Sustainable Banking and Financial Inclusion in India Through ESG Integration in Technological Disruptions" and examined the integration of ESG principles with technological innovations in the Indian banking sector. The research analyzed the role of the Reserve Bank of India in promoting sustainable banking, financial inclusion, and climate risk management through regulatory initiatives and digital transformation. The findings revealed that technological disruptions such as automation, data analytics, and digital banking significantly supported ESG integration and sustainable banking practices. The study also found that ESG-focused technological innovations improved financial inclusion, gender equality, and sustainability performance in banks. However, challenges remained in integrating ESG norms into lending practices. The research concluded that the combination of ESG principles and technological advancements played a vital role in strengthening responsible banking and sustainable financial development in India.
- **Gidage & Bhide (2025)** Explored the influence of green banking practices, green finance, and CSR activities on the environmental sustainability performance (ESP) of Indian banks. The study adopted a quantitative research approach and used structural equation modeling to analyze both direct and indirect relationships among the variables. The findings revealed that green banking practices had a significant positive effect on ESP, green finance, and CSR practices. Green finance also positively influenced CSR activities and environmental sustainability performance. The study further found that green banking practices indirectly improved ESP through green finance and CSR initiatives. The research concluded that the integration of green banking, green finance, and CSR practices played an important role in enhancing sustainability performance in Indian banking institutions.
- **Jain (2025),** examined the relationship between ESG scores and the financial performance of banks. The research compared ESG performance among global banks and analyzed its impact on financial indicators such as return on assets, return on equity, and stock performance. Using qualitative and quantitative methods, the study evaluated both short-term and long-term effects of ESG practices. The findings revealed that banks with higher ESG scores generally achieved better risk-adjusted returns, stronger reputation, and greater stakeholder trust. However, the study also noted that excessive focus on certain ESG dimensions could increase operational costs. The research concluded that effective integration of ESG factors was important for balancing profitability and long-term sustainability in the banking sector.
- **Jaiwani & Gopalkrishnan (2025)** examined the impact of ESG factors on the performance of private and public sector banks in India using six years of panel data. The study found that ESG factors

influenced bank performance differently based on ownership structure. In private sector banks, the ESG composite score, particularly the social dimension, negatively affected financial performance but improved efficiency. In public sector banks, environmental scores showed a positive relationship with return on equity and non-performing assets. The study concluded that ESG strategies should be tailored according to the ownership structure of banks.

- **Karki et.al., (2025)** developed a framework to evaluate ESG factors in commercial banks. The study used an integrated multi-criteria decision-making approach, applying the R-SWARA and CoCoSo methods with inputs from 15 banking experts to assess the sustainability performance of five major commercial banks. The findings revealed that governance was the most important ESG factor, followed by social and environmental factors. The study also identified top-performing banks in terms of ESG practices and emphasized the importance of strong governance structures for sustainable banking operations. The research concluded that the proposed framework provided a comprehensive and systematic approach for evaluating ESG performance and supporting effective ESG implementation in banks.
- **Mathur (2025),** studied Assessing ESG Reporting in Indian Banks: A Case Study Analysis of Sustainability Performance" and evaluated the ESG reporting practices of four major Indian banks, namely State Bank of India, Bank of Baroda, HDFC Bank, and ICICI Bank for the financial year 2022–2023. Using a weighted ESG scoring model and case study approach, the research assessed environmental, social, and governance performance. The findings revealed that ICICI Bank achieved the highest overall ESG performance, while SBI performed strongly in financial inclusion and renewable energy financing. HDFC Bank showed effective CSR engagement, whereas Bank of Baroda lagged behind due to limited transparency and incomplete ESG disclosures. The study highlighted the need for standardized ESG frameworks and stronger regulatory enforcement to improve consistency and comparability in ESG reporting across Indian banks.
- **Reddy et.al., (2025)** examined the role of sustainable banking with special reference to ESG integration and green finance initiatives. The paper discussed how financial institutions incorporated ESG criteria into their strategic and financial activities to improve risk management, regulatory compliance, and stakeholder relationships. It highlighted the importance of green finance instruments such as green bonds and sustainable lending in supporting environmentally sustainable projects and economic growth. The study also identified challenges related to the standardization of ESG measures and the financial trade-offs associated with sustainable banking practices. It concluded that sustainable banking played a significant role in aligning financial systems with global sustainability goals and promoting long-term economic resilience.
- **Shipra (2025)** examined the growing adoption of ESG principles in the Indian banking industry and its impact on sustainable banking practices. The study highlighted that ESG integration transformed banking operations through improved risk management, green financial products, and long-term sustainability. It discussed the role of regulatory initiatives such as the BRSR framework introduced by Securities and Exchange Board of India and the Green Deposit Guidelines issued by the Reserve Bank of India in promoting transparency and responsible lending practices. The study also identified challenges such as inadequate ESG data, lack of standardized green definitions, and insufficient employee training. It concluded that ESG integration should be treated as a strategic priority rather than a compliance requirement, as it could enhance innovation, stakeholder trust, financial inclusion, and long-term sustainability in the Indian banking sector.
- **Madhuri & Thamotharan (2026)** examined the relationship between green lending, ESG disclosure, and financial performance in Indian private sector banks during the period 2018–19 to 2022–23. The research analyzed secondary data from annual reports, ESG/BRSR filings, and financial statements of Kotak Mahindra Bank, IDFC First Bank, Axis Bank, and Yes Bank. The findings revealed that green lending constituted a relatively small proportion of total advances, but ESG disclosure practices improved significantly after the introduction of the BRSR framework by Securities and Exchange Board of India. The study found no strong short-term relationship between green lending and profitability; however, banks with structured ESG practices and transparent reporting demonstrated more stable financial performance and reputational advantages. The study concluded that ESG integration had significant potential for achieving long-term financial and environmental sustainability in the banking sector.\\

Statement Of the Problem

In the modern business environment, sustainability has become an important concern for organizations across the world. The banking sector, being a major contributor to economic development, is increasingly expected to adopt responsible and sustainable business practices. Environmental issues, social responsibilities, ethical governance, and climate-related risks have compelled banks to move beyond traditional profit-oriented operations and focus on sustainable banking practices. In this context, Environmental, Social, and Governance (ESG) integration and green banking practices have emerged as essential strategies for achieving long-term sustainability and responsible financial growth. Indian banks are gradually adopting ESG principles and green banking initiatives through digital banking, paperless transactions, green financing, renewable energy investments, financial inclusion programs, and sustainable lending practices. Regulatory bodies and policymakers are also encouraging banks to improve ESG disclosures and adopt environmentally responsible banking operations. These initiatives are

expected to enhance transparency, risk management, operational efficiency, stakeholder trust, and environmental sustainability. However, the level of ESG integration and implementation of green banking practices may differ between public sector and private sector banks due to differences in ownership structure, management policies, technological advancement, operational flexibility, and strategic priorities. While some banks have made significant progress in sustainability reporting and green finance initiatives, others still face challenges such as lack of standardized ESG frameworks, inadequate awareness, limited transparency, insufficient employee training, and high implementation costs. Moreover, most existing studies have focused either on ESG performance, sustainability reporting, green finance, or financial performance separately. Limited research has been conducted to comparatively examine ESG integration and green banking practices between public and private sector banks in India. Therefore, there is a need to analyze and compare how these banks are adopting ESG principles and implementing green banking practices to achieve sustainable development goals. Hence, the present study titled "ESG Integration and Green Banking Practices in India: A Comparative Study of Public and Private Sector Banks" seeks to examine the extent of ESG integration and green banking initiatives in Indian banks and compare the practices followed by public and private sector banks towards sustainable and responsible banking.

Objectives Of the Study

- To examine the extent of Environmental, Social, and Governance (ESG) integration in public and private sector banks in India.
- To analyze the green banking practices adopted by public and private sector banks in India.
- To compare the ESG integration and green banking practices of public and private sector banks

Research Methodology

The study is conducted using secondary data obtained from published research papers, academic journals, government reports and the collected data is analyzed through thematic and content analysis methods.

Discussion Of the Study

The present study examined ESG integration and green banking practices in public and private sector banks in India based on secondary data and existing literature. The discussion has been framed in line with the objectives of the study.

ESG Integration in Public and Private Sector Banks

The review of literature indicates that Indian banks are increasingly integrating Environmental, Social, and Governance (ESG) principles into their operational and strategic activities. ESG integration has become important due to growing concerns regarding sustainability, climate risk, corporate governance, and stakeholder expectations. Studies revealed that ESG practices contribute towards improved risk management, operational efficiency, transparency, and long-term sustainability in the banking sector. The literature further shows that public and private sector banks differ in their ESG performance and implementation strategies. Private sector banks generally demonstrate better ESG disclosures, technological advancement, and sustainability reporting practices, whereas public sector banks show stronger focus on financial inclusion and government-supported environmental initiatives. The findings also indicate that governance is one of the most important ESG dimensions influencing sustainable banking performance. In addition, ESG integration has been supported by regulatory initiatives such as Business Responsibility and Sustainability Reporting (BRSR) guidelines and green deposit frameworks introduced by Indian regulatory authorities. These initiatives have encouraged banks to improve transparency, responsible lending practices, and sustainability disclosures.

Green Banking Practices Adopted by Indian Banks

The literature review highlights that Indian banks are gradually adopting green banking practices such as paperless banking, digital transactions, green financing, renewable energy investments, green bonds, and eco-friendly financial products. Technological advancements and digital transformation have played a significant role in promoting sustainable banking practices and financial inclusion. The studies also reveal that green banking practices positively influence environmental sustainability performance and strengthen CSR and green finance activities within banks. Furthermore, banks with structured ESG practices and transparent reporting systems tend to achieve better reputational benefits and long-term sustainability advantages. However, the review identifies several challenges affecting the implementation of green banking practices, including lack of standardized ESG frameworks, inadequate ESG data, low customer awareness, insufficient employee training, and high implementation costs.

Comparative Analysis of Public and Private Sector Banks

The comparative findings from the literature suggest that ownership structure significantly influences ESG integration and green banking practices in Indian banks. Private sector banks are comparatively more proactive in ESG reporting, technological innovation, and sustainable product development. Public sector banks, on the other hand, play an important role in promoting financial inclusion, renewable energy financing, and government-supported sustainable banking initiatives.

The literature also suggests that while ESG practices may not always generate immediate short-term profitability, they contribute significantly towards long-term sustainability, stakeholder trust, operational stability, and responsible banking growth. Overall, the review emphasizes that ESG integration and green banking practices are gradually becoming strategic priorities for both public and private sector banks in India.

Findings Of the Study

1. Indian banks are increasingly integrating ESG principles into their operational and strategic activities.
2. Green banking practices such as paperless banking, digital banking, green financing, and renewable energy investments are gradually expanding in India.

3. ESG integration contributes positively towards sustainability performance, stakeholder trust, transparency, and risk management.
4. Private sector banks demonstrate relatively better ESG disclosures, technological adoption, and sustainability reporting practices.
5. Public sector banks show stronger participation in financial inclusion and government-supported sustainable banking initiatives.
6. Governance is one of the most significant ESG dimensions influencing sustainable banking performance.
7. Regulatory initiatives such as BRSR guidelines and green deposit frameworks have encouraged banks to strengthen ESG disclosures and responsible banking practices.
8. Banks continue to face challenges such as lack of standardized ESG frameworks, inadequate awareness, insufficient employee training, and high implementation costs.
9. ESG integration and green banking practices support long-term sustainability and reputational advantages, even if short-term financial benefits are limited.
10. Ownership structure influences the extent and effectiveness of ESG integration and green banking practices in Indian banks.

Suggestions Of the Study

1. Banks should integrate ESG principles into their core banking strategies and lending policies.
2. Regulatory authorities should introduce standardized ESG reporting frameworks for better comparability and transparency.
3. Public sector banks should strengthen digital transformation and ESG disclosure practices.
4. Private sector banks should enhance financial inclusion and social sustainability initiatives.
5. Banks should provide training programs to employees regarding ESG practices and sustainable banking.
6. Customer awareness regarding green banking products and sustainable finance should be increased.
7. Banks should expand green financing and investments in renewable energy and sustainable infrastructure projects.
8. Strong governance mechanisms and transparent sustainability reporting practices should be encouraged.
9. Collaboration among banks, regulators, and stakeholders should be strengthened for effective ESG implementation.
10. Banks should focus on ESG integration as a long-term strategic objective rather than only a compliance requirement.

Conclusion

The study concludes that ESG integration and green banking practices are becoming increasingly important in the Indian banking sector. Banks are gradually adopting sustainable and responsible banking practices in response to environmental challenges, stakeholder expectations, and regulatory requirements. ESG integration helps banks improve transparency, sustainability performance, operational efficiency, and stakeholder trust. The comparative analysis reveals that both public and private sector banks are making efforts towards sustainable banking, although their approaches and performance differ based on ownership structure, governance practices, and technological capabilities. Private sector banks generally perform better in ESG disclosures and innovation, while public sector banks contribute significantly towards financial inclusion and government-driven sustainability initiatives. Although several challenges such as lack of standardization, inadequate awareness, and implementation costs continue to affect ESG adoption, increasing regulatory support and technological advancement are expected to strengthen sustainable banking practices in India. Therefore, effective ESG integration and green banking practices are essential for promoting responsible banking, sustainable economic development, and long-term financial stability in the Indian banking sector.

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I would like to express my sincere gratitude to everyone who contributed to the successful completion of this project titled ***"ESG Integration and Green Banking Practices in India: A Comparative Study of Public and Private Sector Banks."***

First and foremost, I extend my heartfelt thanks to my teacher/guide for their constant guidance, valuable suggestions, and encouragement throughout the course of this study. Their support helped me understand the topic in depth and complete the project in a systematic and meaningful manner.

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I am deeply thankful to my family and friends for their continuous encouragement, patience, and moral support during the preparation of this project. Their motivation played a significant role in helping me stay focused and complete this work with dedication.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Building Green AI Futures: Policy and Governance for Sustainable Data Centre Growth in Emerging Economies

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Abstract

The rapid expansion of Artificial Intelligence (AI) and cloud computing has accelerated the growth of data centres globally, particularly in emerging economies. While these infrastructures are critical for digital transformation, they impose significant stress on energy systems, water resources, and climate commitments. This paper presents a comprehensive analysis of sustainable data centre development through a case study of Bengaluru, one of India's fastest-growing AI infrastructure hubs. Using empirical estimates, secondary data, and predictive modelling, the study evaluates current energy demand, water consumption, and emissions, and projects future scenarios up to 2047. The findings reveal a critical sustainability gap driven by weak governance and resource misallocation. The paper proposes a multi-dimensional Green AI policy framework integrating energy transition, water governance, and regulatory enforcement. It concludes that policy—not technology—is the decisive factor in achieving sustainable AI infrastructure in emerging economies.

Keywords: *Green AI, Data Centres, Sustainability, Climate Policy, Energy Demand, Water Stress, Emerging Economies with Carbon Market, Credits, Carbon Offsetting and Accounting, Net Zero / Decarbonization*

Introduction

The exponential growth of AI, cloud computing, and digital infrastructure has transformed global economies. Data centres serve as the backbone of this transformation, enabling real-time data processing and advanced computational capabilities. However, their rapid expansion has raised concerns regarding sustainability, particularly in emerging economies.

India is emerging as a global data centre hub, supported by policy incentives and rising digital demand. However, this growth is accompanied by increasing environmental pressure. According to the Economic Survey 2025–26, AI data centres consume significant amounts of electricity and water, creating stress on already constrained resources.Urban clusters such as Bengaluru exemplify this paradox—simultaneously acting as digital growth engines and environmental stress zones.

Literature Review

1 Global Sustainability Challenges

Data centres are recognized as energy-intensive infrastructures, contributing to global electricity demand and carbon emissions. Cooling systems further increase water dependency, making them resource-intensive systems.

2 Indian Context

India's data centre ecosystem is expanding rapidly:

- ~271 data centres operational (2026)
- ~150 billion litres of water consumption annually
- Expected to more than double by 2030

The absence of a unified national sustainability framework has resulted in fragmented governance.

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Methodology

This research adopts a **mixed-method approach**:

- Secondary data analysis (policy reports, industry studies)
- Quantitative estimation (energy, water, emissions)
- Predictive modelling (2026–2047 projections)
- Comparative policy analysis (global benchmarks)

Case Study: Bengaluru – Current Scenario (2026)

1 Energy Demand

Estimated installed capacity:~200–250 MW

Annual energy consumption: ~1.7–2.0 TWh/year

This reflects significant growth aligned with India's AI expansion trajectory.

2 Water Consumption

- ~8–20 million litres/day (various estimates)
- Large data centres can consume up to **19 million litres/day**

India-wide:~150 billion litres annually

3 Emissions

Due to coal-dominated grid: ~0.7 kg CO_2/kWh

Estimated emissions: ~1.2 million tonnes CO_2/year

4 Urban Resource Stress: Bengaluru faces:

- Severe water shortages
- Groundwater over-extraction (169% in some areas)
- Increasing industrial demand

Data centres are intensifying this stress, raising sustainability concerns

Key Challenges

1 Energy-Climate Paradox: AI growth increases electricity demand, while decarbonization requires reduced emissions.

2 Water Crisis: Cooling systems rely heavily on freshwater:

- 1 MW DC ≈ 25.5 million litres/year

3 Governance Gaps

- No mandatory reporting of energy or water use
- Fragmented policies across states

4 Infrastructure Mismatch

Digital growth is outpacing urban infrastructure capacity.

Predictive Analysis (2047 Scenario)

Assuming 10× growth in AI demand:

Sr. No	Parameter	2026	2047 (Projected)
1	Energy	~1.8 TWh	~18 TWh
2	Water	~7–8 Bn L	~70–75 Bn L
3	Emissions	~1.2 Mt CO_2	~12–13 Mt CO_2

Key Insight: Resource consumption grows **exponentially**, not linearly.

Comparative Global Analysis

Sr. No	Parameter	Bengaluru	Singapore	Amsterdam
1	Policy strength	Low	Medium	High
2	Renewable usage	Low	Moderate	High
3	Water governance	Weak	Strong	Strict
4	Emissions control	Limited	Moderate	Strong

Key Insight Cities with strong policy frameworks achieve better sustainability outcomes regardless of resource availability.

Green AI Policy Framework

1 Pillar 1: Energy Transition

- Mandatory renewable energy targets
- Power Purchase Agreements (PPAs)

2 Pillar 2: Water Governance

- Zero freshwater usage mandate
- Treated wastewater adoption

3 Pillar 3: Governance & Regulation

- Mandatory reporting (PUE, CUE, WUE)
- Independent regulatory authority

4 Pillar 4: Economic Instruments

- Carbon pricing
- Green subsidies

5 Pillar 5: Technological Innovation

- AI efficiency optimization
- Advanced cooling systems

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Figure 1: Building Green AI Futures Policy and Governance for Sustainable Data Centre Growth in Emerging Economies

Discussion

The study highlights that sustainability challenges are not purely technological but institutional. Emerging economies face a dual challenge:

- Supporting digital growth
- Managing environmental constraints

Without policy intervention, data centre expansion may lead to long-term ecological and economic risks.

Figure 2: Operational Framework for Green AI Policy Implementation

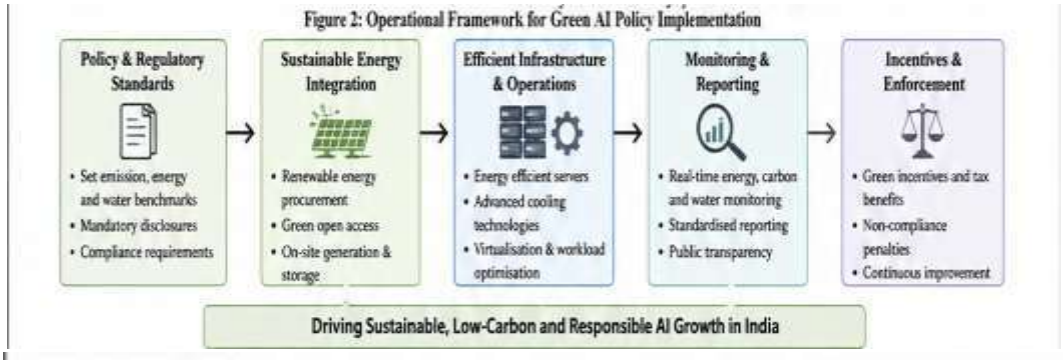
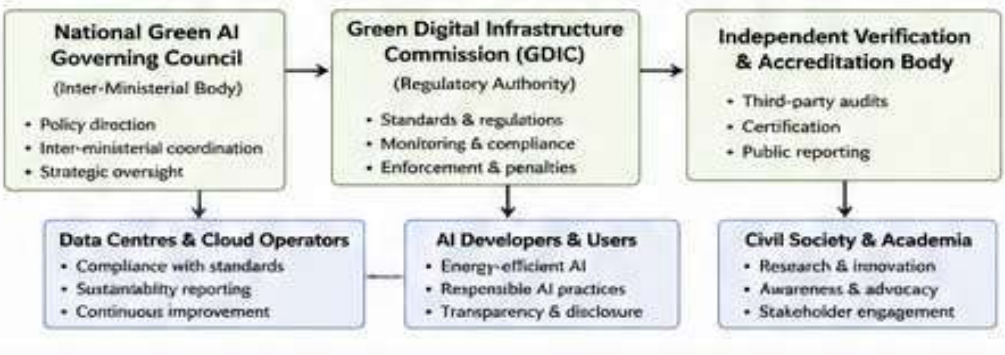


Figure 4: Institutional Architecture for Green AI Governance in India



Conclusion

The case of Bengaluru demonstrates that rapid AI-driven infrastructure growth can exacerbate existing resource constraints. The projected increase in energy demand, water consumption, and emissions by 2047 underscores the urgency of policy intervention.

Policy Recommendations:

1. Establish a National Green Data Centre Policy
2. Mandate renewable energy adoption (≥50%)
3. Enforce water-neutral operations
4. Introduce carbon pricing mechanisms
5. Develop regional data centre strategies
6. Promote AI efficiency research

Final Statement

"Sustainable AI infrastructure in emerging economies will not be achieved through technological innovation alone, but through enforceable policy frameworks that align economic growth with environmental limits."

Acknowledgment

I would like to express my sincere gratitude to all those who supported and guided me in the successful completion of this project titled *"Building Green AI Futures: Policy and Governance for Sustainable Data Centre Growth in Emerging Economies."*

First and foremost, I extend my heartfelt thanks to my teacher/guide for their constant guidance, valuable suggestions, and encouragement throughout the course of this study. Their academic support and thoughtful insights helped me understand the topic more deeply and present this work in a clear, systematic, and meaningful manner.

I am also grateful to my institution and the concerned department for providing me with the opportunity, academic environment, and necessary resources to undertake this research project. The support of the institution played an important role in the successful completion of this work.

I would like to acknowledge the contributions of scholars, researchers, policymakers, and institutions whose books, reports, articles, and studies on artificial intelligence, sustainability, environmental governance, digital infrastructure, and data centre policy formed the intellectual foundation of this project. Their work greatly enhanced my understanding of the environmental challenges posed by rapid digital expansion and the need for responsible governance frameworks in emerging economies.

I am deeply thankful to my family and friends for their constant encouragement, patience, and moral support during the preparation of this project. Their motivation and belief in me helped me remain focused and committed throughout the process.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Green Synthesis of Silver Nanoparticles from *Apis* and *Stingless* Honey: Explore Its *In Vitro* Anti-Inflammatory Potential

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Abstract

*Stingless bee honey is produced by stingless bees (*Meliponine *spp.) and is known to contain higher levels of polyphenols compared to other types of honey. It is mainly found in tropical and subtropical regions and is characterized by a distinctive sweet–sour taste, high moisture content and low tendency to crystallize. This stingless honey is a natural source of flavonoids and is widely recognized for its wound-healing potential due to its strong antibacterial and antioxidant properties. Flavonoids also play a key role in reducing inflammation.*

The present study successfully demonstrated that silver nanoparticles synthesized from stingless honey retained strong anti-inflammatory activity, indicating that green synthesis preserves biologically active compounds on the nanoparticle surface. The in vitro anti-inflammatory activity of Apis honey and stingless bee honey was evaluated. Silver nanoparticles of Apis honey (SNoAH) and silver nanoparticles stingless honey (SNoHSHB) were prepared, and the samples were tested using the human red blood cell (HRBC) membrane stabilization method. The experimental samples showed that SNoHSHB exhibited the highest inhibition (72.30 ± 8.33), while SNoAH showed the lowest percentage of inhibition (55.49 ± 6.91).

Silver nanoparticles, particularly those derived from stingless honey, show promising anti-inflammatory potential and may serve as effective natural alternatives in biomedical applications. Nevertheless, further investigations including purification of active principle component from honey, In vivo studies, toxicity assessments, and clinical trials are essential to validate their safety, efficacy, and therapeutic applicability.

Keywords*: Silver nanoparticles of Apis honey and stingless bee honey, Membrane stabilization and standard drug- Ibuprofen.*

Introduction

Inflammation is a natural response of tissues to injury or infection, functioning to protect and maintain the functional integrity of body systems. However, prolonged inflammation can lead to tissue damage, such as fibrosis, when the injury persists (Marcinkiewicz et al., 2004). Anti-inflammation refers to the ability of a substance or treatment to reduce inflammation or swelling, and it can be evaluated through mediators such as tumour necrosis factor-α, interleukins, and nitric oxide. A preliminary study investigating the anti-inflammatory effects of Tualang honey on rabbit eyes was conducted prior to the main study (Bashkaran et al., 2011).

Fatin Aina Zulkhairi Amin *et al., (2018*) evaluated that stingless bee honey (SBH), produced by *Trigona* and *Melipona* species, exhibits notable anti-inflammatory properties that contribute to its wound healing and therapeutic potential. Studies have shown that SBH reduces oedema, necrosis, and cellular infiltration in wound tissues, thereby promoting faster epithelialization and wound contraction. The honey's rich content of phenolic acids and flavonoids—such as *quercetin*, *chrysin*, and *apigenin*—plays a central role in modulating inflammatory pathways, inhibiting cyclooxygenase (COX) activity, and suppressing the release of pro-inflammatory cytokines.

Stingle Stingless honey bees (SHB) or meliponine valuable insects produce high quality honey. Honey of Stingless Honey Bee (HoSHB) has antimicrobial (Batiston *et al.*, 2020), anti-inflammatory (Badrulhisham *et al.*, 2020), and anti-diabetic properties (Ali *et al.*, 2020). The honey of stingless honeybee *(T. iridipennis*) have varied phytochemical content (tannin, alkaloid, flavonoid, triterpenoid, coumarin, saponin, and carbohydrate), and antioxidant capacity.

In addition honey of SHB is reported to have anti-inflammatory (Kassim *et al* .,2010 ; Nasuti *et al* .,*2006)*and anti-cancer activities against breast ,cervical (Fauzi *et al* .,2011).

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Stingless bee honey has been reported to exhibit several therapeutic properties, such as antioxidant, antibacterial, and anti-inflammatory activities, and it also acts as a natural moisturizer beneficial for wound healing applications (Tonks et al., 2003; Kassim, et al., 2010; Hadagali and Chua, 2014, Liu et al., 2013). It holds considerable potential for commercialization in the pharmaceutical industry. These properties highlight the greater potential of stingless bee honey compared to *Apis* bee honey (Syafrizal et al., 2020), leading to an increasing demand in recent years. The use of honey for its medicinal benefits (Hadagali and Chua, 2014) reflects a broader shift from conventional drugs to functional foods. Therefore, the present study aims to evaluate the anti-inflammatory activity of honey and its precipitate.

Material and method

A honey sample of the Indian stingless bee and Apis bee was collected from the local Apiary nimkhedi, Jalgaon (Maharashtra) and artificial stingless hive reared in Department of Zoology, M. J. College (Autonomous), Jalgaon. The stingless bee honey has a unique honey with unusual sour and sweet taste and medicinal functions (Chuttong *et al*., 2016; Jalil *et al*., 2017).

Synthesis of Silver Nano-particles:

Silver nanoparticles of analytical reagent grade were used as a precursor for the synthesis process. The silver nanoparticles were prepared by adding pellets of the stingless honey and apis honey extract to 10 mL of an aqueous silver nitrate solution at room temperature. The mixture was kept on a rotary shaker for 24 hours and then left in the laboratory at room temperature. The color change was continuously observed.

Characterization of silver nano particles

The synthesized nanoparticles were observed by the color change of the solution, UV–Vis spectrophotometry analysis was performed using a UV–Vis spectrophotometer, FTIR and SEM analysis. The Fourier Transform Infrared (FTIR-1and2) was carried out at Vishal Sprints characterization, Mumbai.

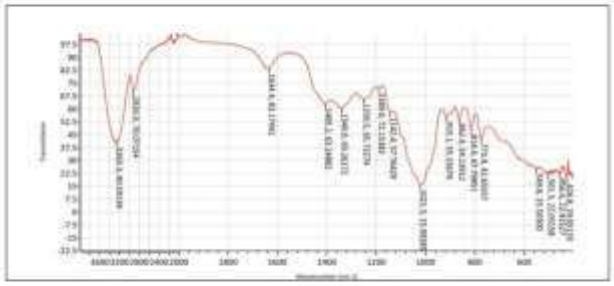

Fig-1 FTIR of Silver Nanoparticles of Apis Honey

Peak Number	Wavenumber (cm-1) Intensity	Intensity
1	426.8	19.05133
2	456.6	22.41527
3	501.3	22.03158
4	501.3	22.03158
5	773.4	42.65557
6	814.4	47.79851
7	862.9	54.13912
8	915.1	55.15679
9	1021.3	15.99285
10	1142.4	57.76429
11	1189.0	72.15382
12	1250.5	65.73274
13	1250.5	65.73274
14	1405.2	63.24882
15	1634.4	83.17441
16	2926.0	70.07154
17	3263.3	40.59134

The FTIR analysis of Silver Nanoparticles of Apis honey confirms the presence of functional groups such as hydroxyl, carbonyl, amine, and ether groups, which are likely responsible for the stabilization of silver nanoparticles. The peaks in the lower region further support the formation of AgNPs. ~550–426 cm^{-1} – Metal–oxygen (Ag–O) vibrations, confirming the presence of silver nanoparticles

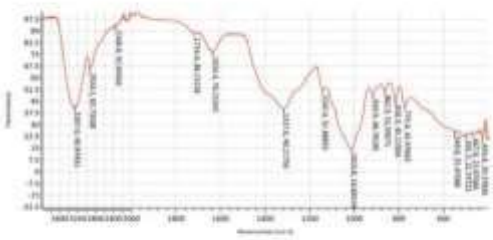

Fig-2 FTIR of Silver Nanoparticles of Stingless Honey

Peak Number	Wavenumber (cm-1) Intensity	Intensity
1	426.8	20.37836
2	467.8	23.97066
3	501.3	22.74722
4	549.8	25.47088
5	773.4	41.97663
6	816.3	45.11504
7	862.9	51.59571
8	916.9	48.79195
9	1013.8	14.69154
10	1142.4	51.88853
11	1317.6	40.21756
12	1317.8	40.21756
13	1716.4	88.23228
14	2340.8	92.94566
15	2924.1	65.73308
16	3267.0	40.97431
17	3267.0	40.97431

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The FTIR spectrum of Silver Nanoparticles of Stingless honey confirms that the biomolecules containing hydroxyl, carbonyl, and amine groups are involved in the synthesis. These compounds act as both reducing agents (formation of Ag^0) and capping agents (stabilization of nanoparticles). The presence of low-wavenumber peaks supports successful formation of silver nanoparticles with surface-bound organic molecules. ~549–426 cm^{-1} Ag–O or Ag–N bonds vibrations, confirming the presence of silver nanoparticles.

To understand the surface chemistry of the nanoparticles, the size, morphology, and composition of Silver nanoparticles (AgNPs) synthesized from Apis and stingless honey was analyzed using SEM (Fig.3and 4). The SEM analysis was carried out at Vishal Sprints characterization, Mumbai.

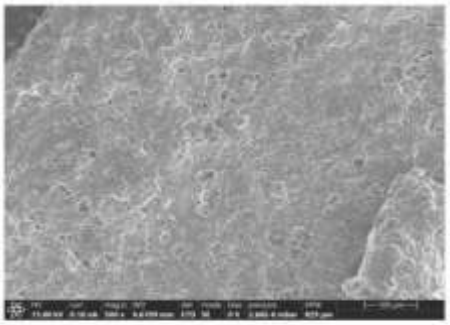

Fig.3 SEM analysis of Silver Nanoparticles of Stingless Honey

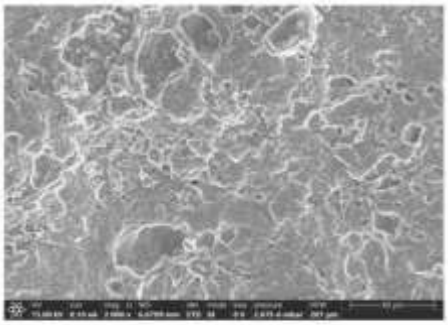

Fig.4 SEM analysis of Silver Nanoparticles of Apis Honey

Anti-inflammatory activity

Determination of anti-inflammatory activity (Membrane Stabilization Assay):

The anti-inflammatory activity was evaluated using the human red blood cell (HRBC) membrane stabilization method. Fresh whole blood (3 mL) was collected from a healthy donor in EDTA tubes and centrifuged at 3000 rpm for 30 minutes at room temperature to separate the platelet-rich plasma. The erythrocytes were washed thrice with saline solution, and a 10% (v/v) RBC suspension was prepared by adding 9 mL of phosphate buffer to 1 mL of the erythrocyte pellet.

The assay groups were prepared as follows:

Control group: 500 µL of RBC suspension was mixed with 500 µL of phosphate buffer (pH 7.4) and 500 µL of 0.4% hypotonic solution.

Standard group: 500 µL of RBC suspension was mixed with 500 µL of ibuprofen solution (0.25 mg in 0.5 mL saline) and 500 µL of 0.4% hypotonic solution.

Test samples: 500 µL of RBC suspension was combined with 500 µL of SNoAH/ SNoHSHB solution (0.5 mg in 2 mL phosphate buffer) and 500 µL of 0.4% hypotonic solution.

All reaction mixtures were left undisturbed for 30 minutes at 37°C. Following incubation, the samples were centrifuged at 1500 rpm for 10 minutes. The supernatant was collected, and the absorbance was measured using a UV-Visible spectrophotometer at a wavelength of 560 nm to determine the degree of hemolysis. The percentage of human red blood cell (HRBC) membrane stabilization was calculated relative to the control group. The percentage inhibition of inflammation was calculated using the following formula:

$$\% \text{ Inhibition} = \left[\frac{\text{Absorbance of control - Absorbance of test sample}}{\text{Absorbance of control}}\right] \times 100$$

Result and Discussion

Sr. No.	Sample	Mean ± SD (% Inhibition)
1	Control	0
2	Standard	81.81 ± 1.30
4	SNoHSHB	72.30 ± 6.33
6	SNoAH	55.49 ± 6.91

The statistical analysis revealed significant differences among the groups ($p < 0.05$). The standard drug showed the highest percentage inhibition (81.81 ± 1.30%), indicating its strong and consistent activity, followed by stingless honey nanoparticles (SNoHSHB)

Among the experimental samples, SNoHSHB showed the highest inhibition (72.30 ± 8.33) and SNoAH exhibited (55.49 ± 6.91) lowest Percentage inhibition.

Discussion

Inflammation is a complex biological response mediated by various cellular and molecular pathways, including the release of cytokines, reactive oxygen species (ROS), and inflammatory enzymes. In the present study, the anti-inflammatory potential of silver nanoparticles of Apis honey (SNoAH) and Silver Nanoparticles of Stingless honey bee (SNoHSHB) was evaluated using the HRBC membrane stabilization assay, which is a well-established *In vitro* model for assessing anti-inflammatory activity.

The results demonstrated that all samples exhibited significant anti-inflammatory activity, although to varying extents. The standard drug showed the highest inhibition, confirming the validity and sensitivity of the experimental method. Among the natural samples, SNoHSHB exhibited higher activity compared to SNoAH, which may be attributed to its richer composition of phenolic compounds, flavonoids, and antioxidants. These bioactive compounds are known to inhibit inflammatory mediators and stabilize biological membranes. Silver nanoparticles derived from stingless honey (SNoHSHB) showed relatively strong anti-inflammatory effects, closely comparable to raw stingless honey. This suggests that the bioactive compounds responsible for anti-inflammatory action remain associated with the nanoparticle surface even after synthesis. The enhanced surface area and nanoscale properties of AgNPs may facilitate better interaction with biological systems, contributing to their activity.

Overall, the findings suggest that both Apis honey and stingless bee honey-mediated silver nanoparticles possess notable anti-inflammatory properties. The variation in activity between Apis and stingless honey highlights the importance of botanical origin and chemical composition in determining biological efficacy.

conclusion

The present study successfully demonstrated Silver nanoparticles synthesized from stingless honey retained strong anti-inflammatory activity, indicating that green synthesis preserves biologically active compounds on the nanoparticle surface. However, nanoparticles synthesized from Apis honey showed relatively lower activity. In conclusion, honey-mediated silver nanoparticles, particularly those derived from stingless honey, show promising anti-inflammatory potential and may serve as effective natural alternatives in biomedical applications. Nevertheless, further investigations including in vivo studies, toxicity assessments, and clinical trials are essential to validate their safety, efficacy, and therapeutic applicability.

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Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Ensemble-Based Robust Framework for Disease Prediction and Treatment Recommendation

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Abstract:

Early identification of diseases based on symptoms plays a vital role in enabling timely medical consultations and enhancing healthcare accessibility. With advancements in artificial intelligence, machine learning techniques effectively analyze symptom data to predict possible diseases. This project introduces an ensemble learning framework for robust disease prediction and treatment recommendation using structured tabular clinical data. The proposed system generates structured symptom features by mapping symptoms to a predefined feature list, forming a tabular dataset. Traditional machine learning classifiers—including Random Forest, Support Vector Machine (SVM), Logistic Regression, and XGBoost—are trained on this dataset. To boost prediction reliability, an ensemble framework combines predictions from these models using techniques such as voting, weighted ensemble, and stacking. Experimental results show that ensemble methods outperform individual models in accuracy. The trained models power a Flask-based web application, enabling users to input symptoms and receive predicted diseases with treatment recommendations, highlighting the system's practical utility.

Keywords: *Ensemble model, Disease Prediction, Treatment Recommendation, Tabular clinical data*

Introduction

Artificial Intelligence (AI), particularly machine learning, has transformed healthcare by analyzing large medical datasets to support decision-making in disease diagnosis and prediction. Traditional classifiers like Random Forest, Support Vector Machine (SVM), Logistic Regression, and XGBoost excel at processing structured tabular symptom data – binary or categorical features indicating symptom presence – yielding reliable disease predictions from historical records. However, single models can miss nuanced patterns, prompting the use of ensemble learning to combine multiple classifiers via voting, weighted averaging, or stacking. This enhances accuracy and robustness, critical for real-world applications.

Early disease detection dramatically improves outcomes by enabling timely interventions before conditions worsen. Patients often delay care due to unrecognized symptom severity, but automated systems analyzing symptom data can provide preliminary insights, encouraging prompt medical consultation. These tools process vast symptom-disease datasets to uncover patterns invisible to manual review. The motivation for this project stems from abundant healthcare data and advanced ML frameworks. Existing systems often limit users to selecting from predefined symptom lists, but real-world inputs are more varied. This work develops an ensemble-based framework for robust disease prediction and treatment recommendation using tabular symptom data.

Structured symptom features are mapped to a tabular dataset training the aforementioned classifiers. Ensemble techniques integrate their predictions for final outputs. Post-prediction, the system retrieves treatments from a medical database, applying fuzzy matching if needed. Deployed via a Flask web application, users input symptoms, triggering backend processing. Results display top predicted diseases with confidence scores and recommendations, offering an accessible platform for preliminary health insights.

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Literature Review

Artificial intelligence (AI) has emerged as a major research area in healthcare due to its ability to analyze large-scale medical data and support diagnostic processes. The rapid growth of digital health records and symptom databases has enabled intelligent systems capable of learning complex symptom–disease relationships [1], [2]. Machine learning (ML) techniques are now widely used for disease diagnosis, prognosis, and clinical decision support systems [3], [4].

Traditional medical diagnosis relied heavily on physician expertise, which is often time-consuming and dependent on experience. In contrast, automated systems leveraging structured healthcare data can efficiently identify symptom patterns and assist in faster decision-making [5]. ML models extract meaningful associations from medical records, thereby improving diagnostic accuracy and reducing human error [6].

Tabular symptom datasets represent symptoms as binary or categorical features, where each row corresponds to a patient instance and each column indicates the presence or absence of a symptom. Early work by Kononenko demonstrated the potential of ML for medical diagnosis through knowledge extraction from clinical datasets [7]. Similarly, Cruz and Wishart showed the effectiveness of ML techniques in cancer prediction and prognosis [8].

Classical ML algorithms have proven effective for structured medical data. Random Forest (RF), introduced by Breiman, uses multiple decision trees to reduce overfitting and handle high-dimensional data [9]. Support Vector Machine (SVM), proposed by Cortes and Vapnik, performs robust classification by maximizing the margin between classes [10]. Logistic Regression (LR) provides interpretable probabilistic outputs and is widely used in clinical applications [11]. XGBoost, developed by Chen and Guestrin, offers scalable gradient boosting and performs well on sparse tabular datasets [12].

Performance comparisons across these algorithms indicate that ensemble and boosting methods generally outperform individual models in symptom-based disease classification tasks. While single models may suffer from overfitting or limited generalization, ensemble approaches combine multiple learners to improve robustness and predictive accuracy [13], [14].

Ensemble learning methods such as voting, weighted averaging, and stacking integrate predictions from multiple models to achieve better performance. Dietterich highlighted that ensemble methods reduce variance and improve generalization [13], while Zhou demonstrated their superiority in complex classification problems [14]. In healthcare applications, Kourou et al. showed significant improvements in cancer prognosis using ML techniques [15], and Choi et al. demonstrated enhanced clinical prediction through multi-model learning approaches [16].

Web-based deployment of ML models further enhances accessibility and usability. Frameworks such as Flask enable real-time disease prediction systems through RESTful APIs, allowing users to input symptoms and receive instant predictions [17]. Such systems bridge the gap between advanced ML models and practical healthcare applications [18].

Publicly available datasets such as Symptom2Disease and Disease-Symptom datasets provide standardized benchmarks for evaluating ML models in healthcare [19], [20]. Studies indicate that combining tabular datasets with ensemble learning techniques offers a robust foundation for accurate disease prediction systems [5], [6].

Methodology

1 Problem Definition

Disease prediction using patient symptoms is a critical task in healthcare. Traditional systems rely on structured symptom datasets, but single machine learning models may fail to capture complex relationships between symptoms and diseases. This can lead to reduced prediction accuracy and reliability.

To address this limitation, the problem considered in this work is to design a robust disease prediction system using structured symptom data and ensemble machine learning techniques. The system aims to improve prediction accuracy by combining multiple classifiers and providing treatment recommendations through a web-based platform.

2 Objectives

The main objectives of the project are:

- To collect and preprocess structured medical symptom datasets
- To convert symptom data into machine-readable feature representations
- To train multiple machine learning models for disease prediction
- To implement an ensemble approach for improved prediction accuracy
- To develop a system that provides treatment recommendations
- To deploy the system using a Flask-based web application

3 System Analysis and Methodology

The proposed system follows a structured pipeline for disease prediction using tabular symptom datasets and ensemble machine learning techniques. The overall workflow of the proposed system is illustrated in Fig. 3.1.

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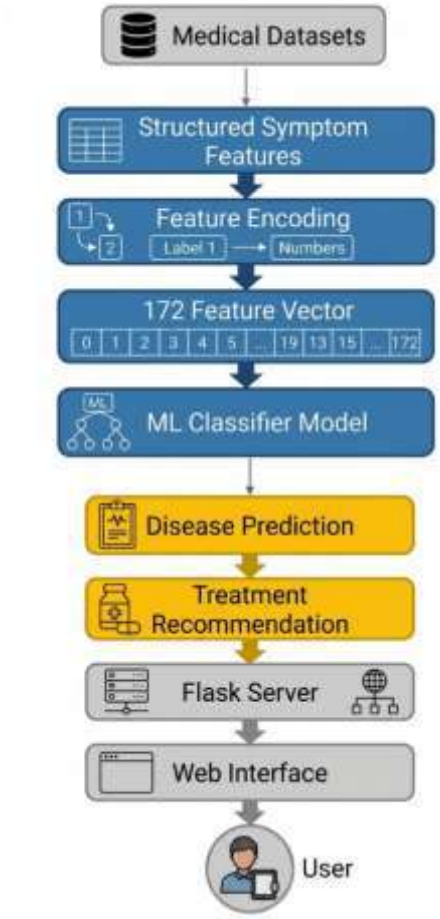

The process begins with medical datasets, such as Symptom2Disease and Disease-Symptom datasets, which contain diseases and associated symptoms. These datasets are preprocessed to remove inconsistencies and transform the data into a structured format suitable for machine learning. From the dataset, structured symptom features are extracted. Each symptom is represented as a feature, and the presence or absence of symptoms is encoded in a tabular form. The system uses a predefined list of symptoms to ensure consistency across all inputs.

Next, feature encoding is performed, where categorical symptom information is converted into numerical format. Each symptom is mapped into a binary or numerical value, resulting in a standardized representation. This leads to the creation of a feature vector consisting of 172 features, where each feature represents a specific symptom. The feature vector acts as input to the machine learning models.

The processed data is then fed into multiple machine learning classifiers, namely Random Forest, Support Vector Machine, Logistic Regression, and XGBoost. Each model independently learns patterns from the symptom–disease relationships and generates probability scores for different disease classes.

An ensemble mechanism combines the predictions from these models using techniques such as majority voting or weighted averaging. This improves prediction accuracy, reduces overfitting, and enhances generalization. Based on the ensemble output, the system produces the final disease prediction. Once the disease is identified, the system retrieves corresponding treatment recommendations from a predefined knowledge base.

The backend of the system is implemented using a Flask server, which handles user requests, processes input data, runs the prediction models, and returns results. A web interface is provided for user interaction, where users can input symptoms and view predicted diseases along with recommended treatments. The system ensures real-time response and user-friendly interaction. Finally, the results are displayed to the user, completing the end-to-end disease prediction workflow.

Results And Discussion

1 Introduction to Results

This chapter presents the results obtained from the implementation of the ensemble learning framework for disease prediction using structured symptom data. The system integrates multiple machine learning models, including Random Forest, Support Vector Machine, Logistic Regression, and XGBoost, and combines their predictions using ensemble techniques to improve accuracy and reliability.

The evaluation focuses on analyzing the performance of the models in predicting diseases based on symptom inputs. The results highlight the effectiveness of ensemble learning in improving prediction accuracy compared to individual machine learning models.

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2 Performance Evaluation Metrics

The performance of the models is evaluated using standard classification metrics:

- **Accuracy:** Proportion of correctly predicted instances among all predictions
- **Precision:** Proportion of correctly predicted positive observations
- **Recall:** Ability of the model to identify all relevant instances
- **F1-Score:** Harmonic mean of precision and recall

Example Calculation

Consider a classification scenario where the True Positive (TP) is 90, the True Negative (TN) is 85, the False Positive (FP) is 10, and the False Negative (FN) is 15.

Accuracy:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} = \frac{90 + 85}{200} = 0.875$$

Precision:

$$Precision = \frac{TP}{TP + FP} = \frac{90}{90 + 10} = 0.90$$

Recall:

$$Recall = \frac{TP}{TP + FN} = \frac{90}{90 + 15} = 0.857$$

F1-Score:

$$F1 = \frac{2 \times Precision \times Recall}{Precision + Recall} = 0.878$$

3 Performance Comparison of Models

Table 4.1 and fig. 4.1 presents the performance comparison of individual machine learning models and ensemble models based on experimental results.

Table 4.1: Performance Comparison of Models

Model	Accuracy	Precision	Recall	F1-Score
Random Forest	0.9000	0.90	0.90	0.90
SVM	0.8542	0.86	0.85	0.85
Logistic Regression	0.8750	0.88	0.87	0.87
XGBoost	0.8900	0.89	0.90	0.89
Average Ensemble	0.9400	0.94	0.94	0.94
Voting Ensemble	0.9400	0.94	0.94	0.94
Weighted Ensemble	0.9433	0.94	0.94	0.94
Stacking Ensemble	**0.9710**	**0.97**	**0.97**	**0.97**

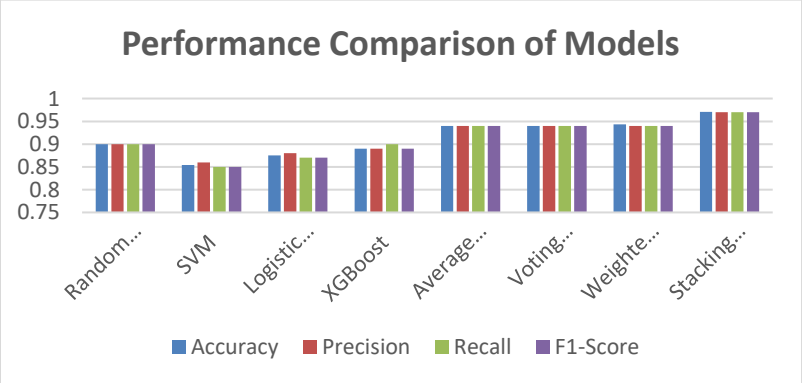

Figure 4.1: Performance Comparison of Models

The results clearly indicate that ensemble models outperform individual machine learning models. Among all approaches, the stacking ensemble achieves the highest accuracy, demonstrating its effectiveness in improving disease prediction performance.

Conclusion And Future Scope

This project developed an ensemble-based system for disease prediction using structured symptom data. Machine learning models such as Random Forest, Support Vector Machine, Logistic Regression, and XGBoost were trained and combined using ensemble techniques like voting, weighted averaging, and stacking. The results showed that ensemble methods give better accuracy than individual models. The system was deployed using a Flask web application, allowing users to enter symptoms and receive disease predictions with treatment suggestions.

In future, the system can be improved by using larger datasets and adding more features like age, medical history, and lifestyle factors. The model can also be optimized further to improve accuracy. Additionally, deploying the system on cloud or mobile platforms can make it more accessible for real-world healthcare use.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Spatial politics and cultural identity in Indian drama: a comparative study of Marathi and Indian English plays

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Abstract

This paper examines how spatial politics shapes cultural identity in contemporary Indian drama through a comparative analysis of Mahesh Elkunchwar's Wada Chirebandi (1985), Mahesh Dattani's Dance Like a Man (1989), and Manjula Padmanabhan's Harvest (2003). Drawing on Bakhtin's concept of the chronotope and Lefebvre's theory of the production of space, the study argues that dramatic space operates as a structural determinant of temporality, identity, and power rather than as a neutral backdrop. Through close reading, the paper demonstrates how the decaying wada encodes agrarian memory and ethical depletion, the urban living room stages negotiations of gender and cultural legitimacy, and the technologized apartment materializes global extraction and surveillance. These spaces generate distinct temporal regimes—elegiac, cyclical, and accelerated—thereby reframing Indian identity across overlapping historical moments. By foregrounding spatial dramaturgy as a comparative method, the study contributes to postcolonial theatre studies and offers a robust framework for analyzing how space and time co-produce cultural meaning in Indian drama.

Keywords: *spatial politics, cultural identity, chronotope, Indian drama, spatial dramaturgy, postcolonial theatre*

Introduction

Over the past several decades, literary and cultural studies have witnessed a decisive "spatial turn," in which space is no longer treated as a passive setting but as an active force that shapes meaning, identity, and power. In theatre, this shift is particularly consequential because space is not merely described; it is staged, embodied, and experienced. Dramatic space is therefore both representational and performative, a site where social relations are enacted and contested.

Contemporary Indian drama—across Marathi and Indian English traditions—offers a compelling archive for examining how space encodes cultural transformation. From the fading architecture of the rural *wada* to the layered interiors of the urban home and the hyper-mediated apartment of global capitalism, these plays stage India's transition across agrarian, postcolonial, and neoliberal formations. Crucially, these spatial forms are not interchangeable; each produces a distinct temporality and, with it, a particular mode of identity. This paper argues that space in contemporary Indian drama functions as a structural determinant of cultural identity, shaping not only where action occurs but how time is experienced and how subjects are constituted. The argument proceeds through a comparative analysis of Mahesh Elkunchwar's *Wada Chirebandi*, Mahesh Dattani's *Dance Like a Man*, and Manjula Padmanabhan's *Harvest*. Together, these plays illuminate three spatial regimes—decay, negotiation, and extraction—corresponding to elegiac, cyclical, and accelerated temporalities.

Methodologically, the study integrates Bakhtin's concept of the chronotope with Lefebvre's theory of the production of space, while drawing on postcolonial insights from Bhabha and Massey to theorize identity as relational and processual. The paper proposes spatial dramaturgy as a critical framework for reading Indian drama comparatively, foregrounding how space and time co-produce meaning. In doing so, it reframes Indian theatre not merely as a reflection of social change but as an active site where cultural identities are negotiated, contested, and reimagined.

Theoretical Framework: Chronotope, Spatial Production, and Postcolonial Identity

Mikhail Bakhtin's concept of the chronotope remains foundational for understanding how space and time interact in narrative.

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He defines the chronotope as the "intrinsic connectedness of temporal and spatial relationships that are artistically expressed in literature" (Bakhtin 84). In drama, this connection acquires material density: stage space organizes the rhythm of action, while temporal experience emerges through spatial arrangement. A room, a courtyard, or a threshold does not merely host events; it structures how events unfold.

Henri Lefebvre's *The Production of Space* deepens this insight by arguing that space is socially produced and ideologically saturated (Lefebvre 26–39). His triad—spatial practice (perceived space), representations of space (conceived space), and representational space (lived space)—offers a powerful tool for theatre analysis. The stage is at once a physical layout (blocking, set design), a conceptual schema (domesticity, surveillance, ritual), and a lived environment (affective experience for characters and audience). In this sense, theatrical space is never neutral; it encodes relations of power, discipline, and desire. Postcolonial theory extends these insights by emphasizing how identity emerges in negotiated, hybrid spaces. Homi Bhabha's notion of the "third space" foregrounds the instability of cultural identity, which is produced through ongoing negotiation rather than inherited essence (Bhabha 56–58). Doreen Massey likewise conceptualizes space as "the product of interrelations," always in process and open to reconfiguration (Massey 9). These frameworks are especially pertinent in the Indian context, where colonial histories, caste hierarchies, linguistic plurality, and globalization intersect.

Bringing these strands together, this paper advances spatial dramaturgy as an analytical approach that treats space as a generative force in drama. Spatial dramaturgy examines how architectural forms, spatial metaphors, and stage practices produce temporal regimes and shape subjectivity. It also foregrounds how different theatrical traditions—Marathi and Indian English—mobilize space to articulate distinct yet overlapping cultural concerns.

3. Methodology and Corpus

The study adopts a comparative close-reading methodology anchored in spatial-temporal analysis. The selected plays—*Wada Chirebandi* (Marathi, translated into English), *Dance Like a Man*, and *Harvest*—are chosen for their canonical status, their engagement with socio-historical transformation, and their sharply differentiated spatial configurations.

The analysis proceeds through four interrelated steps:

1. **Spatial Configuration**: identifying the dominant architectural and scenographic features (e.g., *wada*, living room, surveillance apartment).
2. **Temporal Regime**: examining how time is structured (e.g., stagnation, repetition, acceleration).
3. **Identity Formation**: analyzing how subjects are positioned within and against these spaces.
4. **Power Relations**: tracing how space encodes hierarchy, control, and resistance.

This framework enables a rigorous comparison across linguistic traditions while maintaining sensitivity to cultural specificity.

***Wada Chirebandi*: Decay, Memory, and the Ethics of Space**

Mahesh Elkunchwar's *Wada Chirebandi* stages the disintegration of a once-cohesive Brahmin household through the gradual decay of its ancestral home. The opening stage direction—"A large, old house… the courtyard overgrown, furniture scattered" (Elkunchwar 126)—immediately establishes the *wada* as a space of entropy. The overgrown courtyard signals a severed relationship between habitation and land, while the disordered interiors mirror fractured kinship.

Within Lefebvre's terms, the *wada* is a lived space saturated with memory, yet it is increasingly misaligned with contemporary spatial practice. The rhythms that once organized life—agricultural cycles, ritual gatherings, intergenerational continuity—no longer hold. Time thickens rather than progresses; scenes linger, conversations circle, and action stalls. This produces what may be called elegiac temporality, a slow, recursive time oriented toward loss.The intrusion of modernity is registered acoustically: the distant rumble of bulldozers punctures the quiet of the house, introducing an alien temporality of speed and construction. The contrast between Bhaskar's inertia and the mechanized rhythm outside dramatizes a collision between temporal regimes. The house becomes a threshold where incompatible times coexist without reconciliation.

Anjali's remark—"This house drinks more water than it gives back" (178)—crystallizes the ethical dimension of space. The *wada* is no longer reciprocal; it consumes without sustaining. Spatial decay thus becomes an index of ethical depletion. The house that once anchored identity now exposes its fragility. From a postcolonial perspective, the *wada* encodes caste privilege and historical continuity, yet the play refuses to romanticize it. Instead, it reveals how inherited structures can ossify into stagnation. Identity here is tethered to space, but that tether is increasingly untenable. The result is a chronotope of memory under erasure, where the past persists but cannot be reinhabited.

***Dance Like a Man*: Domestic Space, Gender, and Cultural Negotiation**

In Mahesh Dattani's *Dance Like a Man*, the domestic living room becomes a site of layered temporalities and contested identities. The set accommodates both the 1940s and the 1980s, collapsing decades into a single spatial frame. This dual-period staging produces a palimpsestic chronotope, where past and present are superimposed rather than sequential.

Objects within the room function as temporal conduits. When Jairaj dons his father's shawl and the lighting shifts—"the cupboard glows faintly" (Dattani 170)—space itself appears to remember. The room is not a neutral container but an archive of gestures, prohibitions, and aspirations.The spatial politics of the play are most visible in the regulation of dance. The assertion that "A man dancing is not respectable" encodes a gendered boundary that polices both body and space. The home, conventionally associated with stability and respectability, becomes a site where artistic desire is constrained. Yet it also becomes the space where resistance is rehearsed.

Repetition structures the temporality of the play. Rehearsals—"Practice again… again…"—instantiate a cyclical time aligned with ritual and discipline rather than linear progress. This temporality sustains cultural forms even as it exposes the cost of adherence. In Bhabha's terms, identity here emerges in an "in-between" zone, negotiated

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through performance and repetition rather than resolved once and for all. Dattani's English is itself a form of cultural translation: it carries Indian rhythms, idioms, and social codes. The living room thus operates as both a literal and symbolic space where cultural legitimacy is contested. Tradition is neither simply preserved nor rejected; it is reworked through embodied practice. The chronotope of the play is one of negotiation, where space enables both constraint and transformation.

Harvest: Surveillance, Commodification, and Accelerated Time

Manjula Padmanabhan's *Harvest* reconfigures domestic space into a technologically mediated site of control. The apartment is equipped with surveillance systems, communication interfaces, and corporate protocols that penetrate every aspect of life. The line "This room will now be monitored at all times" signals the conversion of home into an apparatus of observation.In Lefebvre's terms, conceived space—corporate design, contractual logic—overdetermines lived space. The inhabitant's experience is scripted by external systems. The body itself becomes spatialized as property: "Your liver is now property of InterPlanta Services" (Padmanabhan 212). Here, the boundary between person and commodity collapses. Space extends into the body, and the body is annexed by capital.

Temporal experience is correspondingly transformed. Procedures must be completed "immediately"; deadlines proliferate; monitoring is continuous. This is accelerated temporality, where time is fragmented into tasks and transactions. Rosa's account of social acceleration is palpable: speed becomes the governing principle of life, eroding autonomy and depth.Yet the play also stages moments of resistance. The rooftop offers a counter-space where surveillance loosens and time dilates: "Here, no one controls us." Jaya's insistence—"This body is mine"—reclaims agency against the logic of extraction. These moments do not dismantle the system, but they interrupt it, revealing the possibility of alternative temporalities grounded in presence and relation.

Harvest thus constructs a chronotope of extraction and control, countered by fragile spaces of care and slowness. It extends the analysis of spatial politics into the global arena, where postcolonial bodies are integrated into circuits of transnational capital.

Comparative Synthesis: From Memory to Negotiation to Extraction

Read together, the three plays articulate a spectrum of spatial regimes:

1. **Decay (*Wada Chirebandi*)**: the *wada* as a repository of memory and site of ethical depletion.
2. **Negotiation (*Dance Like a Man*)**: the living room as a space of gendered contestation and cultural continuity.
3. **Extraction (*Harvest*)**: the apartment as a node of surveillance and commodification.

These regimes correspond to distinct temporalities:

1. **Elegiac time**: slow, recursive, oriented toward loss.
2. **Cyclical time**: repetitive, ritualized, sustaining continuity.
3. **Accelerated time**: urgent, fragmented, driven by capital.

Importantly, these are not stages in a simple linear progression but coexisting modes that overlap within contemporary India. The *wada* persists alongside the apartment; ritual time intersects with accelerated time. Identity is therefore not singular but multi-scalar, produced at the intersection of competing temporalities.

Spatial dramaturgy reveals how power operates through the organization of space: who may occupy which spaces, under what conditions, and with what consequences. It also shows how resistance emerges spatially—through reclaiming rooms, reinterpreting objects, or seeking alternative sites (like the rooftop). In this sense, space is both an instrument of domination and a resource for dissent.

Implications for Postcolonial Theatre Studies

The foregoing analysis yields several broader implications for postcolonial theatre studies, particularly in relation to how space, time, and identity are theorized and interpreted within dramatic texts. These implications extend beyond the specific corpus of Marathi and Indian English plays examined here and suggest a more comprehensive methodological reorientation in theatre criticism. First, the study underscores that space is constitutive of identity in drama rather than merely representational. In the plays analyzed, space does not function as a neutral or decorative backdrop; instead, it actively structures subjectivity, mediates relationships, and organizes the experience of time. The *wada* in *Wada Chirebandi* shapes identities through memory and decay, the living room in *Dance Like a Man* frames gendered negotiations and cultural anxieties, and the apartment in *Harvest* produces subjects disciplined by surveillance and commodification. In each case, spatial configurations generate specific modes of being. This insight challenges traditional literary approaches that privilege character or theme over setting, and it calls for a shift toward recognizing spatiality as a primary determinant of dramatic meaning. In postcolonial contexts, where histories of displacement, colonization, and modernization profoundly affect lived environments, such a shift becomes even more critical.

Second, the analysis demonstrates the necessity of comparative frameworks for understanding Indian theatre as a heterogeneous yet interconnected field. Marathi and Indian English drama are often studied within separate linguistic or regional boundaries, which can obscure the shared socio-cultural transformations they engage with. By placing these traditions in dialogue, the study reveals how similar historical pressures—such as the decline of agrarian systems, the emergence of urban middle-class identities, and the expansion of global capitalism—are articulated through different spatial forms and dramaturgical strategies. The comparative approach thus enables a more nuanced understanding of Indian theatre as a plural yet relational system, where regional specificity and global engagement coexist. It also encourages scholars to move beyond compartmentalized literary histories and adopt translingual and interdisciplinary perspectives that better reflect the complexity of postcolonial cultural production.

Third, the concept of spatial dramaturgy emerges as a portable and adaptable methodological tool for postcolonial theatre studies. By foregrounding the interaction between spatial structures and temporal dynamics, spatial dramaturgy provides a framework for analyzing how meaning is produced through the

organization of space on stage. This approach can be extended to other postcolonial contexts where questions of land, displacement, migration, and globalization are central. For instance, African, Caribbean, and Southeast Asian theatres similarly negotiate tensions between indigenous spatial practices and modern or globalized environments. In such contexts, spatial dramaturgy can illuminate how local architectures—homes, streets, borders, and landscapes—intersect with broader forces of power and capital. It thus offers a comparative methodology capable of bridging regional studies with global theoretical discourse.

Fourth, the study highlights the importance of temporal plurality within spatial analysis. The plays examined demonstrate that different spatial configurations generate distinct temporal regimes—elegiac, cyclical, and accelerated—each corresponding to particular socio-cultural conditions. This insight reinforces Bakhtin's notion of the chronotope while extending it into postcolonial theatre, where multiple temporalities often coexist and conflict. Recognizing this temporal plurality allows for a more dynamic understanding of identity as something continuously produced through the interaction of past, present, and future within specific spatial contexts. It also enables critics to trace how theatre responds to processes such as modernization, globalization, and technological change, which reconfigure both space and time.

Fifth, the analysis contributes to ongoing debates about power, agency, and resistance in postcolonial performance. By examining how space encodes hierarchies—whether through the inherited authority of the *wada*, the normative constraints of the domestic interior, or the disciplinary mechanisms of the surveilled apartment—the study reveals how spatial arrangements regulate behavior and identity. At the same time, it also identifies moments where these arrangements are contested or reconfigured. Acts of resistance—whether subtle, such as the reoccupation of domestic space through performance, or explicit, such as the rejection of commodification—demonstrate that space is not only a site of control but also a potential arena for transformation. This duality is central to postcolonial theatre, which often seeks to expose and challenge structures of domination while imagining alternative possibilities.

Finally, by integrating Bakhtin's chronotope with Lefebvre's theory of spatial production and situating both within postcolonial discourse, the paper proposes a synthetic analytical model capable of capturing the complexity of contemporary cultural formations. This model moves beyond disciplinary boundaries, combining insights from literary theory, sociology, cultural studies, and performance studies. It allows for a holistic reading of drama in which space, time, and identity are understood as mutually constitutive rather than isolated elements. Such an approach is particularly valuable in the study of contemporary Indian theatre, where rapid socio-economic changes demand equally dynamic critical frameworks.

In sum, the implications of this study suggest that postcolonial theatre criticism must move toward spatio-temporal, comparative, and interdisciplinary methodologies. By foregrounding spatial dramaturgy, scholars can better account for how theatre not only reflects but actively shapes the cultural realities of a rapidly transforming world

Conclusion

This study has demonstrated that spatial politics is central to the articulation of cultural identity in contemporary Indian drama, not as a peripheral concern but as a foundational principle that structures meaning, experience, and subjectivity. Through a comparative reading of Mahesh Elkunchwar's *Wada Chirebandi*, Mahesh Dattani's *Dance Like a Man*, and Manjula Padmanabhan's *Harvest*, the paper has shown how distinct spatial configurations actively generate different temporal regimes and modes of identity formation. The *wada* in *Wada Chirebandi* emerges as a chronotope of memory, decay, and ethical depletion, where time slows into elegiac reflection and identity is shaped by the burden of a disappearing past. In contrast, the domestic interior in *Dance Like a Man* functions as a site of cultural negotiation, where cyclical temporality and performative repetition sustain yet simultaneously question inherited traditions, particularly in relation to gender and artistic legitimacy.

Meanwhile, the technologized apartment in *Harvest* represents a chronotope of extraction, surveillance, and accelerated time, where the human body itself becomes a commodified space, subjected to the logics of global capitalism. Taken together, these plays reveal that Indian drama does not present a linear evolution of cultural identity but rather a complex, overlapping landscape of spatial and temporal formations. Memory, continuity, and commodification coexist within the same cultural matrix, producing identities that are fluid, contested, and continuously reconstituted. Identity, therefore, is not inherited as a stable essence; it is produced through the dynamic interplay of space, time, and power.

A key contribution of this study lies in foregrounding spatial dramaturgy as a critical and comparative framework. By integrating Bakhtin's concept of the chronotope with Lefebvre's theory of the production of space and situating both within postcolonial discourse, the paper offers a robust methodological model for analyzing theatre. This framework enables scholars to move beyond thematic or character-centered readings and instead focus on how spatial structures themselves organize meaning, regulate social relations, and shape cultural consciousness. Moreover, the implications of this study extend beyond the specific texts examined. In a global context marked by rapid urbanization, technological mediation, and shifting socio-economic conditions, the analysis of space becomes increasingly vital. Contemporary theatre across cultures is deeply engaged with questions of displacement, surveillance, migration, and ecological crisis—all of which are fundamentally spatial concerns. The concept of spatial dramaturgy thus provides a transferable analytical tool for examining how different theatrical traditions respond to these challenges. At a broader level, this study reinforces the importance **of** interdisciplinary and comparative approaches in literary and theatre studies. By bringing together insights from literary theory, sociology, cultural studies, and performance studies, it demonstrates that a holistic understanding of drama requires attention to multiple dimensions of experience. Such an approach not only enriches critical analysis but also aligns with the evolving demands of global academic discourse.

In conclusion, contemporary Indian drama, as evidenced by the works of Elkunchwar, Dattani, and Padmanabhan, offers profound insights into the ways in which space functions as a site of cultural production and political contestation. By examining how spatial configurations shape temporal experience and identity formation, this paper highlights the transformative potential of theatre as a medium that not only reflects social realities but actively reimagines them. In an era characterized by uncertainty, transition, and rapid change, the study of spatial politics in drama becomes indispensable for understanding how cultural meanings are constructed, challenged, and reconfigured across time and space.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

A Study on Financial Decision-making and spending Behaviour of Youngsters with respect to in-game purchases

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Abstract

The advent of online gaming systems and internalized monetization systems has caused major transformations in the expenditure habits of youths in India in the discretionary spending. This paper examines the expenditure patterns and budgetary allocation of the youths in the online gaming platform in particular in Bangalore urban district. Convenience sampling was employed where a structured questionnaire was given to 385 respondents who were aged between 15-24 years and young adults aged 24 years and above who have been actively involved in online gaming. The research uses descriptive statistics, percentages, chi-square, one-way ANOVA, multiple linear regression, and factor analysis to analyze the gaming habits, spending patterns, peer influence, and consciousness of financial impacts. Among the main results, it is possible to note that 70.2% of the participants have used in-game purchases, and the most popular genre is the Battle Royale games (31.7%). Gaming frequency ($F = 5.752$, $p = 0.0008$) and monthly income ($F = 5.716$, $p = 0.0009$) are statistically significant predictors of in-game spending. The Likert scale analysis validates that peer influence and post-purchase satisfaction is highly encouraged by the use of promotions, whereas spending is stimulated. It is estimated that 10.3% of spending behaviour is explained by the regression model. The hypotheses of the study are both supported. The results underscore the importance of financial literacy initiatives, spending transparency tools, and responsible monetization policies towards the youth gamers in India.

Keywords: *Online gaming, in-game purchases, spending behaviour, budget allocation, youth, microtransactions, financial decision-making, Bangalore.*

Introduction

Gaming has transformed into a large digital economy as businesses based on free-to-play and integrated monetization systems, like microtransactions, cosmetic upgrades, premium battle passes, and randomized loot box systems, have turned online gaming into more than a leisure activity. The mechanisms have radically changed the digital interaction of young consumers.

entertainment, the boundaries between entertainment spending and compulsive spending behaviour (Gonzalez-Cabrera et al., 2023; Yadav, 2024).

The gaming industry has experienced an exponential growth in India, especially due to the COVID-19 pandemic and the popularity of affordable smartphones and mobile internet. Such games as Battle Royale, like Battlegrounds Mobile India (BGMI), have gathered hundreds of millions of active users, many of whom are young students and young workers with low incomes. It forms a special research opportunity in which the limitations of discretionary income overlap with in-game aggressive marketing and peer influence to spend (Chang et al., 2025).

Although the size of in-game spending amongst the Indian youth has been increasing, scholarly studies that explicitly focus on budget allocation behaviour in the Indian urban environment are limited. The literature available is mostly of Western or East Asian origin and tends to concentrate on gambling-like addictive behaviours as opposed to the financial management consequences of gaming spending (DeCamp and Ferguson, 2023; Gonzalez-Cabrera et al., 2023). The knowledge regarding the joint influence of income sources, as well as the frequency of gaming, peer influence, and financial awareness on the spending decisions among Indian youth also has a significant gap.

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The current study fills these gaps through analyzing the actual spending habits, budget allocation habits, attitudes, and financial awareness of the 322 young online gamers in Bangalore, India. The city will be selected as the study area because it is the technology capital of India, the population is young and has a high rate of smartphone and high-speed internet penetration. Through a mixed method of analysis that incorporates chi-square, ANOVA, regression, and factor analysis, the research provides researchers, policymakers, game developers and educators with empirically based information.

Literature Review

In-game spending behaviour has developed within scholarly research literature at an alarming pace in the last ten years, as mobile and online gaming is sweeping the globe. The review presented below summarises the main findings in the fields of psychology, behaviour, and finance.

Monetization Models and Youth Spending

Kim et al. (2023) created a systematic review that defines free-to-play models with loot boxes and microtransactions as normalizing young spending habits, which reduce the amount spent.ring the
psychological trigger point to make repeat purchases. Loot boxes have been identified as structurally similar to gambling mechanisms, and especially the variable reward schedule, with higher financial and behavioural risk, especially in adolescents, because their prefrontal cortex development is not yet fully developed. In a large sample of the US, DeCamp and Ferguson (2023) discovered that spending on loot boxes was significantly associated with the duration of gaming and availability of electronic payment systems, which probably were more pronounced in India due to the spread of UPI-based payments.

Psychological Determinants of Spending

As shown by Putra et al. (2024), flow experience, impulsivity, reward sensitivity, and addiction tendency are correlated with compulsive in-game purchasing among Gen Z gamers. High flow state respondents, who were totally immersed and lost sense of time, were much more likely to make impulsive purchases. Spending decisions are further mediated by emotional involvement, such as guilt, loss of control or distress on not getting desired items (5Rights Foundation, 2025). Competitive multiplayer genres, especially those, are especially strong these psychological mechanisms and dominate among Indian youth.

Social and Environmental Influences

Chang et al. (2025) have attributed peer influence, exposure to in-game marketing, and lack of parental supervision as significant social factors that influence the in-game spending amongst adolescents. The youth who indicated a high level of peer pressure to get rare skins, weapons or characters were much easier to spend more than they had budgeted. As Hardwick-Carter et al. (2025) noted, most young spenders tend to have post-purchase remorse, but will keep spending because of social validation and a fear of not fitting in to in-group gaming communities. It forms a vicious circle of spending pressure in society.

Game Genre and Spending Behaviour

Oka et al. (2024) determined that competitiveness in multiplayer and mobile-first games are more strongly linked to in-game purchases and symptoms of gaming disorder than casual or single-player games. As is the case in the Indian setting, the battle-royale games like BGMI, Free Fire, and Call of Duty Mobile are market leaders, implying that the genre-specific expenditure relationship found in the rest of the world is especially pertinent in the context of Indian youth.

Financial Literacy and Responsible Spending

Vuorinen (2025) stated that the existing monetization strategies of digital games take advantage of the developmental susceptibility of young consumers, with most of them not possessing financial literacy competencies to assess the cumulative price of small, repeated purchases. The fact that in the gaming applications, there are no obligatory spending transparency tools, strengthens this issue. It has also been indicated by a longitudinal study by Gonzalez-Cabrera et al. (2023) that the purchasing behaviour of loot boxes does not vary with time, which in turn suggests the need to educate the youth about money at a young age.

Research Gap

An analysis of the literature available shows that the following gaps are of relevance to be filled by this study:

- The majority of current research is on gambling-like addictive behaviour instead of the decision making and budget allocation behaviours of young gamers.
- Gaming spending is less often studied within the context of more general financial management behaviour like income source, savings and general discretionary spending.
- Empirical research on comparisons of gaming spending to other categories of discretionary spending in monthly budgets of youth in India is deficient.
- Most of the research is carried out by the established Western economies; there is less contextual evidence available in developing economies like India, where the infrastructure of digital payments and the population of young people significantly vary.
- There is little research that incorporates the variables of psychological awareness with the real expenditure data of people in primary survey responses, especially in the Indian urban gaming situation.

Objectives

- To examine the gaming behavior and frequency of online gaming among the youths.
- To investigate the levels and percentage of income devoted to online games.
- To determine factors affecting spending behaviour e.g. peer influence, game design, and marketing strategies.
- To analyse the impact of online gaming expenditure on youths' overall financial management. Hypothesis

Hypothesis 1: Microtransactions and Gaming Expenditure

H10: There is no significant influence of the use of microtransactions and loot boxes on the total gaming spending of youths.

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H11: The overall gaming spending of youths is strongly influenced by involvement in microtransactions and loot boxes.

Hypothesis 2: Frequency and Allocation of Budget in Gaming.

H2O: There is no significant difference in the rate of gaming by youths with respect to the amount of money dedicated to online gaming.

H21: The frequency of gaming has a significant influence on the percentage of money that youths spend on online gaming.

Research Methodology

Research Design

The research design used in this study is a descriptive-analytical research design. The descriptive component describes the gaming behavior, expenditure pattern and demographic of the respondents, whereas the analytical component explores the relationships between variables with the use of inferential statistical methods.

Population and Sampling

The target population is the youths who are involved in online gaming in Bangalore Urban District. According to census estimates, the projected youth population (1524 years) in Bangalore is estimated to be 2,700,000. The necessary sample size of 400 respondents was determined using the formula of Slovin with a margin of error of 5%. Convenience sampling using a structured online questionnaire through Google Forms got a final usable sample of 322 responses.

Data Collection

A structured questionnaire was used to gather primary data that comprised of four sections including (i) socio-demographic profile, (ii) gaming habits and frequency, (iii) in-game spending behaviour, and (iv) six Likert-scale attitudinal items assessing financial awareness, peer influence, budget.

impact, and satisfaction. Peer-reviewed journals, industry reports, and published government statistics were the source of secondary data. Pilot-testing of the questionnaire was done to ensure that it was clear to the masses before mass distribution.

Variables of the Study

Independent variables consisted of frequency of gaming, source of income, peer influence and in-game advertising. Dependent variables included the in-game purchase value, budgetary allocation to gaming and purchasing in-game frequency.

Tools for Analysis

The following statistical techniques were applied to the primary data:

- Cronbach's Alpha
- Cross-Tabulation to test associations of categorical variables.
- Chi-Square Test of Independence to test statistical significance of associations.
- One-Way ANOVA to compare the means of groups on spending based on gaming frequency and level of income.
- Multiple Linear Regression to predict the combined predictive power of the frequency of game playing, income, and hours-per-day on in-game spending.
- Factor Analysis (inter-item correlation) to determine the internal consistency and construct validity of Likert-scale items.

Data Analysis and Results

Reliability Analysis

The Cronbachs Alpha of 0.963 shows that there is an excellent internal consistency among the items in the scale. This implies that the variables or questions in the measurement have high levels of correlation amongst themselves, and are always measuring the same underlying construct.

As the value exceeds the accepted value of 0.9 by a considerable margin, it indicates that the scale is quite reliable and provides consistent and stable scores. All in all, this high alpha is indicative of high reliability of the instrument and is thus suitable to undergo further analysis and interpretation.Likert Scale Analysis: Attitudes and Financial Awareness

There were six statements of attitudes that were rated using a five-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Table 11 contains the frequency, mean and standard deviation of each item.

Statement	SA (5)	A (4)	N (3)	D (2)	SD (1)	Mean	SD	Interpretation
Q1: Frequent purchases lead to higher spending	44	169	35	10	64	3.37	1.33	Agree
Q2: Aware of total amount spent	81	154	17	9	61	3.57	1.40	Agree
Q3: Check finances before purchasing	92	140	23	7	60	3.61	1.41	Agree
Q4: Gaming affects monthly budget	57	161	28	19	57	3.44	1.34	Agree
Q5: Peer/promo influence encourages spending	95	121	33	13	59	3.56	1.42	Agree
Q6: Satisfied after in-game purchases	116	108	30	9	58	3.67	1.45	Agree

Table 1: Likert Scale Analysis – Attitudinal Statements

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The Likert mean scores of all six items are between 3.37 and 3.67, which is a general tendency of agreeableness to respondents in all attitudinal dimensions. Q6 (satisfaction post-purchase) has the largest mean (3.67), indicating that in-game spending still an emotional reward, even after considering financial consideration. Q5 (peer/promo influence) has a high mean of 3.56 which validates that social and marketing pressures are significant forces. Q3 (financial ability check) with a mean of 3.61 is a rather paradoxic result: respondents say that they check.
their money, but a good share of it continues to be spent out of proportion as compared to their earnings.

Chi-Square Test

The chi-square tests were carried out to determine statistical relationships between the important categorical variables. The consolidated results are shown in Table 12.

(Variable 1 × Variable 2)	χ^2 Value	df	p-value	Cramer's V	Result
Gender × In-Game Purchase	36.888	2	< 0.001	0.338	Significant ✓
Gaming Frequency × Monthly Spend	20.233	6	0.003	0.178	Significant ✓
Monthly Income × Monthly Spend	25.397	6	< 0.001	0.199	Significant ✓
In-Game Purchase × Budget Impact	Significant	—	< 0.05	—	Significant ✓
Peer Influence × Monthly Spend	Significant	—	< 0.05	—	Significant ✓

Table 2: Chi-Square Test Results

The results of all five chi-square tests are statistically significant ($p < 0.05$), which proving that the in-game spending behaviour is statistically connected with gender, frequency of playing, income level, purchase history, and peer influence. The largest correlation is between gender and in-game purchasing ($x2 = 36.888$, $p < 0.001$, Cramer V = 0.338), which suggests a medium effect size. The purchase rates of male respondents are much more substantial (86.7%), in comparison to female respondents (54.3%), which can be attributed to the preferences and social norms of competitive gaming. There is a moderate relationship between income and spending (Cramer V = 0.199) which confirms that more income allows spending more, but the relationship is not entirely linear, not all low income respondents spend more than that.

₹1,000 per month. One-Way ANOVA

The one-way ANOVA test was used to determine whether there is significant difference between mean in-game spending scores among gaming frequency and income groups.

Source of Variation	F-Statistic	p-value	Eta² (η²)	Effect Size	Result
Gaming Frequency → Monthly Spend	5.752	0.0008	0.057	Small-Medium	Significant ✓
Monthly Income → Monthly Spend	5.716	0.0009	0.054	Small-Medium	Significant ✓
Age Group → Monthly Spend	0.742	0.528	0.007	Negligible	Not Significant
Gender → Monthly Spend	Significant	< 0.05	—	Small	Significant ✓

Table 3: ANOVA Results – Gaming Frequency vs. Monthly Spending

Gaming Frequency	n	Mean Spend Score	Std. Deviation
Rarely	13	1.538	0.877
Occasionally	65	1.600	0.820
Few Times a Week	57	1.491	0.791
Daily	77	1.948	0.857

Table 4: Group Means – Gaming Frequency vs. Mean Spend Score (0–3 scale)

The results of the ANOVA show that the frequency of gaming ($F = 5.752$, $p = 0.0008$) and monthly income ($F = 5.716$, $p = 0.0009$) are significant predictors of in-game spending, whereas age group does not have a significant impact ($p = 0.528$). The post-hoc group mean analysis indicates that the value of mean spending score is the highest among the daily gamers (1.948), significantly higher than any other groups. those who game rarely (1.538) or occasionally (1.600). This is in line with the hypothesis that the frequency of gaming has a direct relationship with increased spending allocation. The eta-squared values are of the order of small-to-medium, which implies that the frequency and income are significant predictors, but combined, they account for a fair amount of spending variance, and this is in line with the multifactorial nature of consumer behaviour.

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Multiple Linear Regression Analysis

The joint predictive value of the frequency of gaming, monthly income, and the number of hours each day spent gaming on the encoded monthly spending score (0 = None, 3 = Above 1000) was measured by means of multiple linear regression.

Metric	Value	Interpretation
R (Multiple Correlation)	0.321	Moderate positive correlation
R^2 (Coefficient of Determination)	0.103	10.3% of spending variance explained
Adjusted R^2	0.090	Corrected for number of predictors
F-Statistic (Model)	7.80	Model is statistically significant
p-value (Model)	< 0.001	Significant overall fit

Table 5: Regression Model Summary

Predictor Variable	B (Coefficient)	Estimated Std. Error	Standardised β	Interpretation
Constant (Intercept)	0.55	—	—	Baseline spend
Gaming Frequency (1–4)	0.175	0.042	0.263	Strongest predictor – higher freq. → more spend
Monthly Income Level (1–4)	0.145	0.036	0.246	Higher income → moderately more spend

Predictor Variable	B (Coefficient)	Estimated Std.Error	Standardised β	Interpretation
Daily Gaming Hours (1–4)	0.108	0.031	0.198	More hours → slightly more spend

Table 6: Regression Coefficients

The regression equation is expressed as: Monthly Spend = 0.550 + 0.175 × (Gaming Frequency) + 0.145 × (Income Level) + 0.108 × (Daily Hours)

The model explains 10.3% of the variance in in-game spending (R^2 = 0.103, Adjusted R^2 = 0.090). Although the model is statistically significant ($p < 0.001$), the R 2 is relatively low, which suggests that the model needs extra predictors - peer influence, emotional state, and game genre to explain spending behaviour. The highest predictor is the gaming frequency (Beta = 0.263), then the income (Beta = 0.246) and the hours per day (Beta = 0.198). These results support the fact that interventions that focus on the frequency of gaming and income-proportional levels of spending would be the most effective ones in terms of decreasing unnecessary spending.

Factor Analysis

The six Likert-scale items were subjected to factor analysis to evaluate the construct validity, internal consistency, and factor structure. Table 17 shows the inter-item correlation.

Item	Q1	Q2	Q3	Q4	Q5	Q6
Q1: Aware – Higher Spending	1	0.79	0.79	0.788	0.779	0.786
Q2: Aware of Total Spent	0.79	1	0.81	0.795	0.768	0.753
Q3: Check Finances	0.79	0.81	1	0.801	0.789	0.829
Q4: Gaming Affects Budget	0.788	0.795	0.801	1	0.783	0.791
Q5: Peer/Promo Influence	0.779	0.768	0.789	0.783	1	0.802

Item	Q1	Q2	Q3	Q4	Q5	Q6
Q6: Satisfaction Post-Purchase	0.786	0.753	0.829	0.791	0.802	1000

Table 7: Inter-Item Correlation Matrix (Pearson r) for Likert-Scale Items

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Metric	Value	Interpretation
Average Inter-Item Correlation	0.79	All items share strong common variance
Number of Items	6	Measuring financial engagement construct
Factor Extraction	1 Factor	Single dominant factor identified
Factor Name	Financial Engagement with In-Game Spending	Captures awareness, behaviour & satisfaction

Table 8: Factor Suitability Summary

The inter-item correlation matrix indicates that all pairs of Likert items have high correlations (ranging between 0.753 and 0.829), which means that there is a high level of shared variance. The alpha of 0.963 is a great indication of excellent internal consistency which is far beyond the 0.70 mark that is suggested by Hair et al. (2010). The means of inter-item correlation (r = 0.790) and coefficient alpha indicate that all six items are all converging to one latent construct, and this latent construct can be called as Financial Engagement with In-Game Spending. This construct includes financial enlightenment, budget-consciousness, peer-based spending incentive, and post purchase emotional reaction.

Results and Key Findings

Analysis of 385 responses shows the following key findings:

Demographic Findings

- Most of the respondents (42.9) are aged over 24 years with the gender ratio being almost equal (Female 46.9%, Male 44.4%).
- A significant percentage (40.1) of them have less than 2000 monthly incomes, which points to the instability of the main gaming audience in terms of finances.

Gaming Habits

- A total of 28.6% of the respondents play every day. The most prevalent genre is Battle Royale (31.7%), than Other (23.3%), then Sports games (16.5%).
- Only 32.6% of the respondents spend less than 2-4 hours playing video games daily indicating that it is a time-consuming activity that has cost implication on spending exposure.

Spending Behaviour

- In-game purchase is normalised with 70.2 per cent of respondents having ever made an in-game purchase.
- Only 71.1% know that in-game purchases are real money, but spending does not decrease, which means that awareness does not help to moderate behaviour.
- Skins/Characters (32.6) and Weapons/Upgrades (31.4) are the most sold products, fueled by the desire to show off to others and compete with others.

Statistical Test Outcomes

- Chi-square testing indicates that there are significant differences between gender and purchase behaviour (x2 = 36.888, $p < 0.001$), gaming frequency, and spend ($p = 0.003$) and income and spend ($p < 0.001$).
- ANOVA validates the hypothesis that daily gamers ($F = 5.752$, $p = 0.0008$) are significantly more likely to spend more than infrequent players. There is no significant impact on spending by age group.
- The regression analysis shows that gaming frequency is the most powerful predictor of spending (β).
- = 0.263), followed by income (Beta = 0.246) and daily hours (Beta = 0.198). The model explains 10.3% of variance ($R^2 = 0.103$).
- The six Likert items have been confirmed to have excellent construct reliability (Cronbach = 0.963) and all the items load on one single factor of Financial Engagement.

Hypothesis Outcomes

- H 0 (Hypothesis 1) is accepted: microtransactions have a huge impact on gaming spending, as demonstrated by chi-square and ANOVA scores. H_0 is rejected.
- H 0 (Hypothesis 2) is accepted: the number of hours spent playing games has a significant impact on the budget allocation to gaming (ANOVA $F = 5.752$, $p = 0.0008$). H_0 is rejected.

Discussion

The results of the current research are somewhat compatible and supportive of the literature on youth in-game spending behaviour, as well as provide context-specific insights in urban India.

The prevalence of in-game buying (70.2) among young people in Bangalore is in line with the existing world literature that has reported the efficacy of free-to-play monetization strategies (Kim et al., 2023). But the income distribution of the sample in which the greatest population earns less than

The increase of 2000 per month is a major worry in the percentage contribution of finances spent on gaming. To a respondent earning 2000 per month, 500-1000 on in game purchases would be 25-50 percent of monthly earnings, which is way beyond what financial prudence would say.

The prevalence of Battle Royale games (31.7) in the sample is directly associated with the literature results of competitive multiplayer genres being the most associated with in-game spending and gaming disorder symptoms (Oka et al., 2024). In BGMI and other games of this genre, rare cosmetics are used as social status symbols in internet communities, which generates strong peer pressure processes, motivating players with limited finances to spend (Chang et al., 2025).

The significant chi-square difference in gender and purchase behaviour (x2 = 36.888, Cramer V=0.338) indicates that male respondents are much more likely to have purchased in-game items. This observation can indicate gender biases where males prefer Battle Royale and FPS games with aggressive monetization more and reflect social beliefs

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where playing games with monetary investment is more socially approved among male peer groups.

The findings of the ANOVA support the claim that daily gamers spend much more money on in-game purchases (mean score 1.948 vs. 1.538 in rare gamers), demonstrating that there is a dose-response relationship between gaming activity and spending. This trend is similar to the longitudinal result of Gonzalez-Cabrera et al. (2023) who found that the behaviour of buying loot boxes is self-reinforcing over time. These results are supported by the regression model, where gaming frequency turned out to be the most powerful predictor (Beta= 0.263), meaning that decreasing gaming session frequency can be an efficient lever to control spending.

The Likert scale results portray a subtle picture. Although the respondents generally believe that they check their money before spending (mean = 3.61) and are conscious of cumulative spending.

The high score of 3.57 (mean) with a simultaneous high score of 3.67 (mean) on satisfaction and high score of 3.56 (mean) on peer influence, indicates that financial awareness does not adequately translate into restrained spending. This is in line with Clayton et al. (2002) who discovered that declared knowledge is not always associated with responsible behaviour an initial observation in the context of food safety studies which can be applied to consumer behaviour situations.

The analysis of factor yields one overriding factor of Financial Engagement with a Cronbach = 0.963 value, which supports the fact that the six attitudinal dimensions are all aspects of a single construct. The interaction of the financial self-awareness, emotional reward, and social is captured in this construct.

motivation in in-game spending behaviour formation, and can be used as a validated scale in future quantitative studies in this area.

Conclusion

This research presents an in-depth empirical data on the budgetary allocation and expenditure habits of the youths in the online gaming sites, based on primary information of 322 individuals in Bangalore, India. The results affirm that spending in-game is common (70.2%), financially out-of-proportion to most respondents when compared to their income, and strongly influenced by frequency of gaming, income level, peer pressure, and game genre preference.

Both hypotheses of the study are maintained: microtransactions and gambling spending are important factors, and game frequency and budget allocation to gaming are important factors. The multiple regression model shows that the frequency of gaming is the only predictor of spending with the factor analysis showing a strong, single factor construct, Financial Engagement, with high levels of reliability.

Importantly, the research indicates that financial awareness in the presence does not effectively balance spending behaviour, especially with the high emotional satisfaction and peer pressure that comes with making in-game purchases. This lack of integration between awareness and behaviour is the key problem of policy and intervention design that aims at youth gamers.

Recommendations

1. Gaming sites should implement mandatory real-time spending boards and monthly spending limits notifications to promote financial transparency of users, particularly younger and less wealthy gamers.
2. At schools and colleges, they should have digital financial literacy training modules on how to spend in-game, the psychology behind loot boxes, and the price of microtransactions in aggregate.
3. The regulators such as MEET (Ministry of Electronics and Information Technology) would desire to enforce a transparent disclosure of the probabilistic nature of loot boxes and put spending limits based on age.
4. Accessible parental control tools should be availed to parents that enable monitoring and limit in-game spending associated with family digital payment accounts.
5. Game developers are advised to add reminders of responsible spending and taking breaks after large purchases on the principle of behavioural economics in order to reduce impulsive spending.

Limitations of the Study

- The study is purely founded on self-reported data which may be susceptible to social desirability bias particularly on questions that involve the amount of spending and financial knowledge.
- These convenience sampling techniques minimize the extraneous validity of the findings to other contexts other than the urban Bangalore context. The gaming and spending patterns of rural or semi-urban youth might vary considerably in terms of demographics.
- Only a variation of 10.3% is predicted by the regression model which indicated that other important predictors of spending such as game genre faithful, addiction level, and family financial behaviors were not reflected in the questionnaire.
- The research is cross-sectional in nature and it is not able to determine how gaming frequency and spending behaviour are related. Directional relationships would need to be confirmed by longitudinal data.

Future Scope

- The methodology of future research should be longitudinal designs in order to monitor the changes in spending behaviour and gaming habits among the same group of youth gamers in the long run.
- Qualitative approaches -such as, but not limited to, focus groups and in-depth interviews - would supplement the quantitative data with a discussion of the subjective drives, emotional antecedents, and social processes, underlying in-game spending choices.
- A cross-city analysis between cities of varying economic characteristics (e.g., Tier 1 vs. Tier 2 cities) would provide information on the role of urban-rural and income disproportions in determining the gaming spending patterns in India.
- The relationships between peer influence, financial literacy, gaming addiction and spending behaviour

could be the subject of a single theoretical test with Structural Equation Modelling (SEM).

- A study which specifically investigates the long-term financial health-related outcomes of habitual in-game spenders, such as the consequences on the savings behaviour, adequacy of emergency funds, and financial stress, would go a long way in making this research area more policy-relevant.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Understanding Bnpl Usage Among College Students: An Empirical Analysis and Spending Behaviour, Financial Literacy and Behaviour Biases

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Abstract

The high rate of the development of Buy-Now-Pay-Later (BNPL) services has changed the landscape of digital payments, especially among college students who are highly digitalized yet have limited access to funds. The study examines the use of BNPL services among college students and its effects on their spending habits, in particular, the impulsive and discretionary purchasing. A sample of 350 college students (sample size) was used to gather primary data with a structured questionnaire of 5 points (Likert scale) to employ a descriptive research design. Data analyses were done through descriptive statistics, Chi-square tests, Multiple Regression and Pearson correlation. The results show that there is a strong association ($p < 0.001$) between the familiarity and the frequency of use of BNPL. The regression equation ($R2 = 0.762$, $p = 0.001$) reveals that BNPL is a very powerful factor, as it stimulates unintended purchases, in the first place, by promoting the purchase of non-necessity items and raising the purchasing threshold. Moreover, there was a high positive correlation ($r = 0.801$) between knowledge in the terms of BNPL and demonstrating financial knowledge in responsible use. The paper concludes that BNPL is more convenient and accessible than ever before, but it also creates a strong incentive to engage in biased behavior resulting in impulsive spending. As a result, the need (Mean = 4.45) to introduce specific financial literacy programs to encourage responsible credit practices among students is urgent and highly perceived.

Keywords: *Buy-Now-Pay-Later (BNPL), Student Spending Behavior, Financial Literacy, Behavioral Biases, Impulsive Buying, Digital Credit.*

Introduction

India has seen a phenomenal growth in the financial technology (fintech) industry, with the Buy-Now-Pay-Later (BNPL) market estimated to grow to US$30.45 billion by 2026 [;]. BNPL products provide a low-friction alternative to the classic credit cards and enable consumers to pay in installments or postpone payments, without interest. The model has seen enormous popularity among Generation Z and millennials, especially among college students, who are attracted by its immediate affordability, hassle-free access online, and the absence of rigorous credit checks [;].However, the convenience of BNPL masks underlying behavioral and psychological risks. In the case of college students having limited financial means (including pocket money or allowances), BNPL alleviates the pain of paying, which may lead to behavioral biases such as the Fear of Missing Out (FOMO) and the present bias (Nair, Dubey, and Agrawal, 2025; Kumar and Nayak, 2024). As a result, the students often spend more on discretionary purchases, especially in the areas of lifestyle, fashion and food delivery. Such a transition to a more want-oriented rather than need-oriented consumption brings up critical concerns about the financial well-being of young consumers in the long-term and their debts (Kumar et al., 2025).

Financial literacy can help curb these risks. Having a strong grip on credit mechanisms, students have a more effective chance to navigate BNPL terms and avoid the debt traps of hidden late fees and overconsumption (Anthoniz, 2025; Ainy et al., 2025). This paper provides an empirical examination of the intersection of BNPL use, spending, and financial literacy in college students and seeks to identify how digital credit use can develop the financial behavior and susceptibility of the younger demographic.

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Review Of Literature

Author and Year	Objective	Methodology	Key Findings	Summary
Kanzal, J., et al. (2026)	To assess the impact of BNPL schemes on student financial behavior and debt management.	Empirical Analysis	BNPL increases short-term purchasing power but complicates debt management for students.	Focuses on the dual nature of BNPL on student debt.
Gopinath, G., & Jayaprakasam, K. (2026)	To explore what shapes the BNPL narrative for young consumers in India.	Qualitative / Narrative Analysis	Peer influence and social media aggressively shape the BNPL narrative for youth.	Highlights social constructs driving BNPL adoption.
Simiyu, N. N., et al. (2025)	To explore the influence of financial self-efficacy on actual borrowing in BNPL services.	Quantitative Study	High financial self-efficacy reduces reckless BNPL borrowing intentions.	Links self-efficacy directly to borrowing restraint.
Nair, A., et al. (2025)	To study BNPL adoption among students and its impact on spending patterns.	Survey Analysis	BNPL shifts student spending from essential needs to lifestyle and luxury goods.	Outlines the shift in student spending categories.
Kumar, P., et al. (2025)	To examine if hedonic browsing and smartphone addiction influence BNPL continuous usage.	Behavioral Modeling	Smartphone addiction and mood regulation significantly drive continuous BNPL use.	Connects digital addiction to financial credit usage.
Kumar, P., et al. (2025)	To determine if financial socialization and knowledge affect BNPL behavioral intention.	Empirical Research	Financial socialization heavily moderates how youths intend to use BNPL products.	Evaluates the role of financial upbringing.
Kumar, J., et al. (2025)	To understand the effects of BNPL services on the overall well-being of Indian customers.	Mixed Methods	Post-purchase regret and financial stress negatively impact overall customer well-being.	Focuses on the psychological toll of BNPL debt.
Kumar, S., & Nayak, J. K. (2025)	To explore BNPL adoption among e-retail consumers from a user gratification perspective.	Gratification Theory	Instant gratification is the primary psychological driver for BNPL e-retail adoption.	Uses gratification theory to explain BNPL appeal.
Phangestu, S. J., et al. (2025)	To navigate how risky indebtedness and impulsive buying shape BNPL intention.	Quantitative Analysis	Impulsive buying traits naturally gravitate towards BNPL as an enabler.	Shows BNPL as a catalyst for existing impulsive traits.
Ainy, R. N., et al. (2025)	To investigate the BNPL paradox: financially literate yet impulsive behavior.	Behavioral Study	High financial literacy does not always prevent impulsive BNPL usage due to convenience.	Identifies the paradox between literacy and impulse.
Sangeetha, S., & Latha, A. (2025)	To analyze BNPL and Gen Z spending behavior using a machine learning approach.	Machine Learning	ML models accurately predict reduced financial well-being based on BNPL usage frequency.	Applies advanced tech to predict financial well-being.
Anthoniz, D. B. G. J. (2025)	To study financial literacy and debt behavior among university students.	Comparative Study	International students exhibit varying debt behaviors strictly tied to their baseline literacy.	Cross-cultural view of student debt behavior.
Kumar, S., &	To understand risky	Empirical	Low perceived risk at the	Details the

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Nayak, J. K. (2024)	indebtedness, impulse buying, and perceived risk in BNPL adoption.	Modeling	point of sale drives high risky indebtedness later.	disconnect between perceived and actual risk.

Research Gap

Although the existing body of research on BNPL extensively discusses the technological adoption of this solution (Kumar and Nayak, 2025) and its overall effect on millennial debt (Kanzal et al., 2026), there is still an empirical gap in terms of measuring the same phenomenon in relation to the frequency of unplanned purchases among Indian college students by quantifying the influence of specific elements of behavior on Moreover, quantitative authentication of an explicit interpretation of the BNPL terms directly to the responsible use of digital credit is not explored yet in the contemporary, fast-growing digital credit environment.

Research Design

1 Statement of the Problem

The boisterous advertising and payment-at-checkout features of BNPL plans have enabled credit to become immediately affordable to students in colleges, a group that has traditionally been locked out of formal lending. This convenient access evades normal financial resistance resulting in uninhibited impulsive consumption, dangerous indebtedness and financial pressure. The main issue that this research is focused on is whether the use of BNPL by students is due to their online convenience, or it is a systematic stimulus of behavioral bias (such as FOMO and impulse purchasing), and how the level of financial literacy moderates these debt-related behaviors.

Objectives

- **Objective 1:** To assess the level of awareness and usage of BNPL services among college students.
- **Objective 2:** To analyse the impact of BNPL usage on student spending behaviour including impulsive and discretionary spending.
- **Objective 3:** To examine the influence of behaviour factors such as impulsive buying tendency and fear of missing out on BNPL adoption.
- **Objective 4:** To evaluate the role of financial literacy in shaping responsible or risky BNPL usage pattern.
- **Objective 5:** To identify key determinants (economic, psychological and social) influencing BNPL driven spending behaviour among students.

3 Research Methodology

The research design used is a Descriptive Research design. This approach is best to describe the levels of awareness of the existing, use status, and behavioral expenditure characteristic of college students in a systematic manner and devoid of experimental control.

4 Sources of Data

- **Primary Data:** Gathered through a sample of 350 college students with a structured questionnaire, which will include their specific financial behavior and responses to BNPL.
- **Secondary Data:** Collected through academic journals, reports in the field of fintech, and books on behavioral finance to formulate the theoretical basis.

5 Sampling Plan

- **Sampling Unit:** Individual college students (in different courses and age groups).
- **Sample Size:** 350 valid responses.
- **Sampling Technique:** Convenience sampling was employed so as to access digitally active students effectively throughout the university networks.

6 Data Collection Tools

- **Survey:** The online questionnaire will be structured in the form of a questionnaire based on a 5-point Likert scale (Strongly Disagree/Never to Strongly Agree/Very Frequently) in order to gather the data on the familiarity with BNPL, the frequency of use, triggers to impulsive spending, and financial knowledge.

7 Plan of Analysis

Data gathered were coded, tabulated and analyzed in IBM SPSS software and MS Excel. Statistical tools used are Descriptive Statistics, Chi-Square Test of Independence, Multiple Regression Analysis and Pearson Correlation.

Conceptual Framework

Dependent Variables (DV)

- **BNPL Usage Frequency:** How often students utilize BNPL services for purchases.
- **Unplanned Purchases:** The frequency and extent of spontaneous, non-essential buying driven by BNPL.
- **Responsible BNPL Use:** The ability to manage repayments and utilize BNPL without incurring financial stress.

Independent Variables (IV)

- **BNPL Familiarity:** The baseline awareness and understanding of BNPL platforms.
- **Behavioral Biases:** Factors such as "BNPL makes me spend more" and "encourages non-essential buying."
- **Financial Literacy:** The student's understanding of BNPL terms, conditions, and the concept of debt traps.

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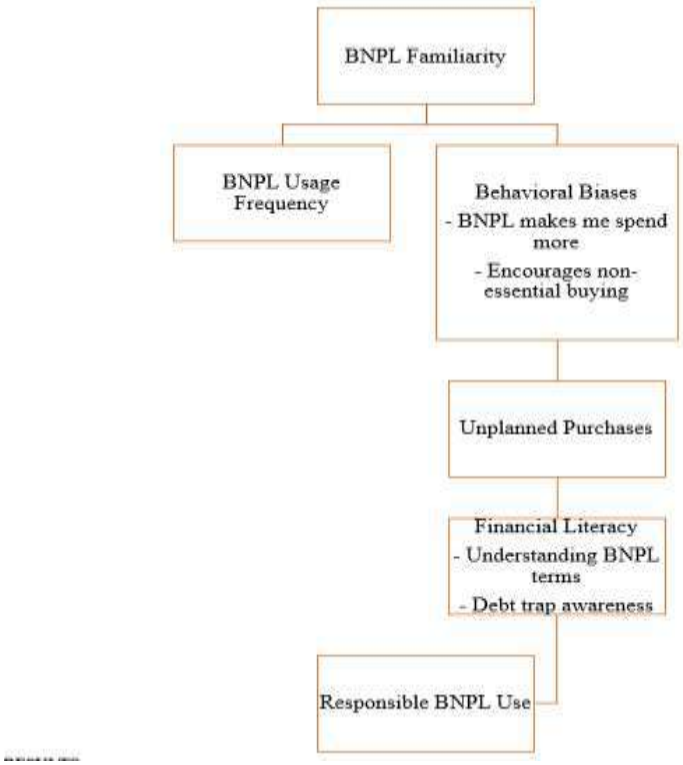

Results

Tools for Data Analysis

- **Software:** IBM SPSS Statistics, MS Excel.
- **Techniques:** Descriptive Statistics, Chi-Square Test, Multiple Regression Analysis, Pearson Correlation.

Hypothesis Framework

Hypothesis 1 (Chi-square Test - Objective 1)

- **H0:** There is no significant association between BNPL familiarity and BNPL usage frequency among college students.
- **H1:** There is a significant association between BNPL familiarity and BNPL usage frequency among college students.

Hypothesis 2 (Multiple Regression Test - Objective 2)

- **H0:** BNPL use frequency, spending more through BNPL, and non-essential buying do not significantly predict unplanned purchases among students.
- **H1:** BNPL use frequency, spending more through BNPL, and non-essential buying significantly predict unplanned purchases among students.

Hypothesis 3 (Correlation Test - Objective 4)

- **H0:** There is no significant correlation between understanding BNPL terms and financial knowledge for responsible BNPL use.
- **H1:** There is a significant correlation between understanding BNPL terms and financial knowledge for responsible BNPL use.

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Gender_Code	350	1	3	1.46	.543
AgeGroup_Code	350	1	4	1.89	.842
CourseOfStudy_Code	350	1	4	1.91	1.017
MonthlyIncomeAllowance_Code	350	1	4	2.22	.940
BNPL_Familiarity_Code	350	1	5	3.81	.806
BNPL_UseFrequency_Code	350	1	5	2.52	1.137
BNPL_PrimaryReason_Code	350	1	5	2.61	1.366

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OnlineBuyingTendency_Code	350	1	4	2.37	.859
BNPL_RepaymentConfidence_Code	350	1	5	2.98	1.030
FinancialSituation_DriveBNPL_Code	350	1	5	3.82	.792
BNPL_Familiarity_Score	350	1	5	3.81	.806
BNPL_UseFrequency_Score	350	1	5	2.52	1.137
BNPL_EasyToUse_Score	350	1	5	4.15	1.005
BNPL_Accessibility_Score	350	1	5	3.85	.719
BNPL_SpendMore_Score	350	1	5	1.98	1.110
BNPL_NonEssentialBuying_Score	350	1	5	2.34	.874
BNPL_FinancialStress_Score	350	1	5	2.98	1.038
BNPL_AffordabilityEffect_Score	350	1	5	1.82	1.022
BNPL_UnplannedPurchases_Score	350	1	5	2.34	.899
BNPL_FOMOUse_Score	350	1	5	2.61	1.106
BNPL_PeerInfluence_Score	350	1	5	2.67	1.160
BNPL_ReducesDiscomfort_Score	350	1	5	1.75	.971
BNPL_TermsUnderstanding_Score	350	1	5	2.91	1.050
FinancialKnowledge_ResponsibleUse_Score	350	1	5	3.50	1.107
FinancialLiteracy_DebtTrapBelief_Score	350	1	5	3.90	.691
BNPL_RepaymentConfidence_Score	350	1	5	2.98	1.030
FinancialSituation_DriveBNPL_Score	350	1	5	2.18	.792
SocialMedia_EncouragedBNPL_Score	350	1	5	2.62	1.161
FinancialLiteracyPrograms_Need_Score	350	1	5	4.45	.841
Valid N (listwise)	350				

Interpretation

According to the descriptive statistics, the study is founded on 350 valid answers, and there are no missing values of the studied variables. The average of the BNPL familiarity is 3.81, which means that the students are mostly familiar with BNPL services, and the average of the BNPL use frequency is 2.52, showing moderate usage on average. The large mean scores of BNPL ease of use (4.15), accessibility (3.85) and financial literacy programs required (4.45) indicate that students believe BNPL to be convenient yet heavily believe they require financial education. Meanwhile, a lower means of BNPL (1.98) and affordability effect (1.82) as well as

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minimizes discomfort (1.75) all suggest comparatively ambivalent or ambivalent opinions of certain negative financial consequences. On the whole, the descriptive findings indicate that BNPL is not unknown among college students, and the issues of responsible use and financial literacy are also significant.

Test 1: Chi-square Test

Objective

To assess the level of awareness and usage of BNPL services among college students.

Variables selected

- **BNPL familiarity**
- **BNPL use frequency**

Dataset variables

- BNPL_Familiarity
- BNPL_UseFrequency

Hypotheses

- **H0:** There is no significant association between BNPL familiarity and BNPL usage frequency among college students.
- **H1:** There is a significant association between BNPL familiarity and BNPL usage frequency among college students.

Crosstabs

BNPL_Familiarity * BNPL_UseFrequency Crosstabulation

			BNPL_UseFrequency					Total
			Never	Often (2-3 times a month)	Rarely (once in a few months)	Sometimes (once a month)	Very frequently (weekly or more)	
BNPL_Familiarity	Extremely familiar	Count	0	17	1	7	19	44
		Expected Count	8.5	6.0	15.6	11.1	2.8	44.0
		% of Total	0.0%	4.9%	0.3%	2.0%	5.4%	12.6%
	Moderately familiar	Count	27	0	23	2	0	52
		Expected Count	10.1	7.1	18.4	13.1	3.3	52.0
		% of Total	7.7%	0.0%	6.6%	0.6%	0.0%	14.9%
	Not familiar at all	Count	7	0	1	0	0	8
		Expected Count	1.6	1.1	2.8	2.0	.5	8.0
		% of Total	2.0%	0.0%	0.3%	0.0%	0.0%	2.3%
	Slightly familiar	Count	18	0	0	0	0	18
		Expected Count	3.5	2.5	6.4	4.5	1.1	18.0
		% of Total	5.1%	0.0%	0.0%	0.0%	0.0%	5.1%
	Very familiar	Count	16	31	99	79	3	228
		Expected Count	44.3	31.3	80.8	57.3	14.3	228.0
		% of Total	4.6%	8.9%	28.3%	22.6%	0.9%	65.1%
Total		Count	68	48	124	88	22	350
		Expected Count	68.0	48.0	124.0	88.0	22.0	350.0
		% of Total	19.4%	13.7%	35.4%	25.1%	6.3%	100.0%

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Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	325.961[a]	16	.000
Likelihood Ratio	278.739	16	.000
N of Valid Cases	350		
a. 11 cells (44.0%) have expected count less than 5. The minimum expected count is .50.			

Interpretation

The Chi-square test shows that there is a statistically significant association between BNPL familiarity and BNPL usage frequency among college students. Since the p-value is 0.000, which is less than 0.05, the result is statistically significant. Therefore, the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted. This means that students with greater familiarity with BNPL services are significantly more likely to use them more frequently, showing that awareness plays a strong role in BNPL adoption.

Test 2: Multiple Regression Test

Objective

To analyse the impact of BNPL usage on student spending behaviour including impulsive and discretionary spending.

Dependent variable

- **BNPL unplanned purchases**

Independent variables

- **BNPL use frequency**
- **BNPL makes me spend more**
- **BNPL encourages non-essential buying**

Dataset variables

- **Dependent Variable:** BNPL_UnplannedPurchases_Score
- **Independent Variables:**
  - BNPL_UseFrequency_Score
  - BNPL_SpendMore_Score
  - BNPL_NonEssentialBuying_Score

Hypotheses

- **H0:** BNPL use frequency, spending more through BNPL, and non-essential buying do not significantly predict unplanned purchases among students.
- **H1:** BNPL use frequency, spending more through BNPL, and non-essential buying significantly predict unplanned purchases among students.

Regression

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.873[a]	.762	.760	.441
a. Predictors: (Constant), BNPL_NonEssentialBuying_Score, BNPL_UseFrequency_Score, BNPL_SpendMore_Score				
b. Dependent Variable: BNPL_UnplannedPurchases_Score				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	214.992	3	71.664	368.847	.000[b]
	Residual	67.225	346	.194		
	Total	282.217	349			
a. Dependent Variable: BNPL_UnplannedPurchases_Score						
b. Predictors: (Constant), BNPL_NonEssentialBuying_Score, BNPL_UseFrequency_Score, BNPL_SpendMore_Score						

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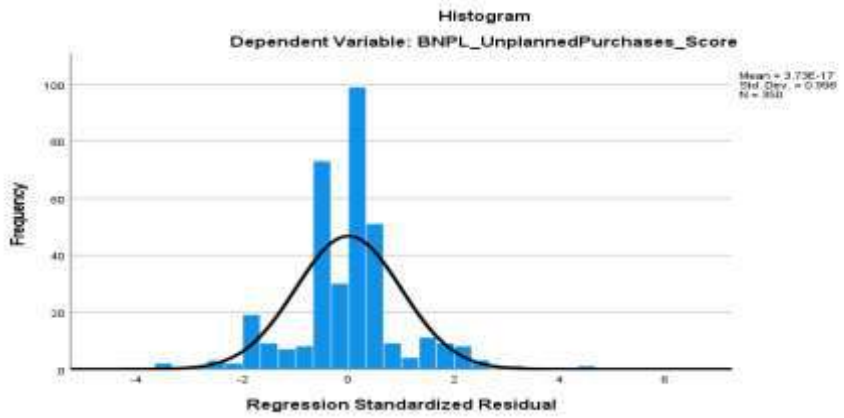
Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.542	.141		3.849	.000
	BNPL_UseFrequency_Score	-.036	.030	-.045	-1.204	.229
	BNPL_SpendMore_Score	.250	.039	.308	6.339	.000
	BNPL_NonEssentialBuying_Score	.593	.044	.577	13.453	.000
a. Dependent Variable: BNPL_UnplannedPurchases_Score						

Charts



Interpretation

According to the multiple regression analysis, the frequency of BNPL use, BNPL making students spend more, and BNPL encouraging non-essential buying have significant predictive power on unplanned purchases among students. The model is statistically significant with R = 0.873, R^2 = 0.762, F = 368.847, p = 0.000, which means that these predictors explain 76.2% of the variation in unplanned purchases. Of the predictors, BNPL spend more and BNPL non-essential buying were significantly positively affected whereas BNPL use frequency is not significant in the model. Thus, the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted, and it has been proved that BNPL significantly affects impulsive and discretionary spending behaviour in college students.

Test 3: Correlation Test

Objective

To evaluate the role of financial literacy in shaping responsible or risky BNPL usage pattern.

Variables selected

- **Understanding BNPL terms and conditions**
- **Financial knowledge promotes responsible BNPL use**

Dataset variables

- BNPL_TermsUnderstanding_Score
- FinancialKnowledge_ResponsibleUse_Score

Hypotheses

- **H0:** There is no significant correlation between understanding BNPL terms and financial knowledge for responsible BNPL use.
- **H1:** There is a significant correlation between understanding BNPL terms and financial knowledge for responsible BNPL use.

Correlations

Correlations			
		BNPL_TermsUnderstanding_Score	FinancialKnowledge_ResponsibleUse_Score
BNPL_TermsUnderstanding_Score	Pearson Correlation	1	.801**
	Sig. (2-tailed)		.000

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	N	350	350
FinancialKnowledge_ResponsibleUse_Score	Pearson Correlation	.801**	1
	Sig. (2-tailed)	.000	
	N	350	350
**. Correlation is significant at the 0.01 level (2-tailed).			

Interpretation

The Pearson correlation analysis indicates a strong positive relationship between knowledge of BNPL terms and conditions as well as financial knowledge to use BNPL responsibly. The correlation coefficient r = 0.801 and the p-value = 0.000 that is lower than 0.05. So the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted. It implies that those students who have better familiarity with terms and conditions of BNPL are also more likely to display greater financial literacy associated with responsible BNPL use, meaning that financial literacy is a significant factor in determining safe and responsible BNPL behaviour.

Discussions

The descriptive statistics of the 350 participants show that students are quite knowledgeable about BNPL services (Mean = 3.81) but the general frequency of use is moderate (Mean = 2.52).

Students rank BNPL quite high in terms of ease of use (Mean = 4.15) and ease of access (Mean = 3.85). Interestingly, even though it is convenient, the need to have mandatory financial literacy programs is highly unanimous among students (Mean = 4.45) and students are self-aware of their financial vulnerability.

- The means of BNPL reducing discomfort (Mean = 1.75) and BNPL making them spend more overall (Mean = 1.98) were lower, showing that despite some students being cautious, a certain part of them remains the victim to its behavioral triggers.
- **Objective 1 (Chi-Square):** The chi-square test showed an extremely significant correlation ($p < 0.001$) between BNPL familiarity and frequency of use. Very Familiar or Extremely Familiar students of BNPL platforms have a much higher chance to apply them Sometimes or Often, which confirms that market knowledge is directly proportional to digital credit uptake by young people.
- **Objective 2 (Regression):** The multiple regression model (R^2 = 0.762, F = 368.847, p = 0.001) was able to demonstrate that the effects of behavioral biases significantly determine spending. The attitude that BNPL promotes unnecessary purchases (Beta = 0.577) and leads students to spend more (Beta = 0.308) is a strong predictor of unplanned purchases. Combined, these aspects account for 76.2 percent of the variance in impulsive spending, which proves that BNPL is indeed an effective solution to eliminate purchasing friction and directly results in discretionary spending.
- **Objective 4 (Correlation):** There was a high positive correlation ($r = 0.801$, $p < 0.001$) between knowledge of the terms and conditions of BNPL and the ability to use it responsibly and show financial knowledge. This means that the best defense is financial literacy; those students who actually read and understand the fine print have a much higher chance of using BNPL responsibly and not falling into debt traps.

Conclusion

This paper concludes that BNPL services have already infiltrated the group of college students, and high accessibility and ease of use are the factors that make it happen. Nonetheless, such easy access to credit has behavioral biases intrinsically, which results in a statistically significant growth in unnecessary, impulsive buying. The regression equation (accounting 76.2% of the variance) validates the fact that BNPL is a direct stimulus of impulsive spending in youths with low income. Nevertheless, students express a strong sense of the dangers, and strongly support the necessity of financial education. In the end, the research confirms that financial literacy, namely, profound knowledge of terms and conditions, is an effective statistically significant buffer to the irresponsible use of credit. In order to secure the economic prosperity of the new generation, financial literacy should no longer be an option, but a necessity when it comes to incorporating it into the general educational systems.

Suggestions

- **Mandatory Financial Literacy Modules:** Due to the high student demand (Mean = 4.45), universities need to implement mandatory but short-term courses on digital credit, debt traps, and managing personal finances during orientation programs.
- **Transparent Checkout Warnings:** BNPL regulators must require BNPL companies to post simplified, bold-text warnings about late fees and compound interest at the checkout point, which directly addresses the understanding of terms, which was found to be strongly associated with responsible usage.
- **Credit Limits by Student Income:** BNPL platforms must adopt stricter credit limits, based solely on student income, and use algorithms to avoid the unchecked non-essential spending found in the regression analysis.
- **Self-Imposed Spending Blocks:** Students must be prompted to use features of native apps that enable them to impose hard blocks or cooling-off periods on their BNPL accounts to overcome psychological stimuli of FOMO and impulse purchases.

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I would like to express my sincere gratitude to all those who supported and guided me in the successful completion of this project titled *"Understanding BNPL Usage Among College Students: An Empirical Analysis of Spending Behaviour, Financial Literacy, and Behavioural Biases."*

First and foremost, I extend my heartfelt thanks to my teacher/guide for their constant guidance, valuable suggestions, and encouragement throughout the preparation of this project. Their academic support and insightful feedback helped me understand the topic more deeply and complete this work in a systematic and meaningful manner.

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Original Article

Challenges and Strategies of Digital Governance in India

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Abstract

Digital governance, in the context of the digital era, involves the use of information and Communication Technologies to enhance and transform the delivery of public services and to improve government efficiency, and engage citizens in decision-making. In a developing country like India, where literacy level is not very high, most of the citizens are not even aware of the benefits of digital governance and people do not use the Information technology to a much extent, there exist a number of problems to implement digital governance. However, there are several challenges associated with digital governance and addressing them requires strategic planning and implementation. This paper highlights the role of information technology in supporting the good governance programmes in our country and its significant contribution to the achievement of good governance goals and also the main challenges related to the implementation of digital governance in India.

Keywords: *Governance, Literacy, Cost, Digital, ICT.*

Introduction

Using information and communication technology to enhance and modify public service delivery, boost government efficiency, and include citizens in decision-making is known as "digital governance" in the context of the digital era. In a developing country like India, where the majority of people do not use information technology extensively and literacy rates are low, there are a number of obstacles to establishing digital government. Furthermore, the majority of people aren't even aware of the benefits of digital governance. Digital governance does, however, present a number of difficulties, which must be addressed with careful preparation and execution. Implementing measures to secure digital infrastructure, protect sensitive data, and ensure the privacy of individuals. Given the increased reliance on digital platforms, maintaining robust cybersecurity practices is crucial to prevent cyber threats and unauthorized access. Digital governance is driven by the broader digital transformation that societies are undergoing, with the goal of harnessing the potential of technology to create more efficient, responsive and accountable governance structures. The pursuit of good governance through the application of technology and speedy dissemination of information to the people is today considered to be the most effective and result-oriented approach to development. The issues and challenges of governance thus occupy the centre stage of political and academic discourse in the contemporary world. The goal of digital governance is to improve effectiveness, efficiency, and transparency by changing internal procedures, structures, and working methods. The goal of the Government of India's most significant initiative, Digital India, is to make India a knowledge economy and society enabled by technology. The government has taken numerous actions and devised numerous plans to carry out this program in an efficient and successful manner. India's population now have a glimmer of hope to combat the long-standing issues of poverty, corruption, unemployment, and regional inequality because the country's internet and communications services have significantly expanded.

Challenges of Digital Governance

Digital Divide: It is difficult to ensure inclusivity in digital governance initiatives when diverse groups of the population have unequal access to technology. Ensuring accessibility and inclusivity for all citizens becomes a major concern as governments move to digital platforms. The unequal access to technology known as the "digital divide" has the potential to worsen already-existing social and economic divides.

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Cybersecurity Concerns: Concerns over the safety of private government information and the possibility of cyberattacks are heightened by the growing dependence on digital platforms. The greater dependence on digital platforms increases the susceptibility to attacks. Governments must use strong cybersecurity measures to protect vital infrastructure and citizen data in light of the constantly changing nature of cyber threats.

Privacy Issues: Balancing the benefits of data collection with citizens' privacy rights is a delicate challenge that governments must navigate to maintain public trust. The digitisation of government services involves the collection and storage of vast amounts of sensitive citizen data. Protecting this information from cyber threats and ensuring robust privacy safeguards are critical challenges in the digital governance landscape.

Capacity Building: To properly execute and oversee digital governance projects, governments must spend money on employee training and upskilling. Interoperability issues are frequently brought up by the integration of various digital systems across various government agencies. For digital governance initiatives to run well, standardizing procedures and guaranteeing easy communication between systems are essential.

Future Implications and Strategies

As digital governance continues to evolve, strategies for overcoming challenges and maximizing its benefits are crucial. Governments should focus on:

Digital Literacy Programs: Implementing widespread digital literacy programs to bridge the digital divide and empower citizens to participate meaningfully in the digital era. All citizens should have equitable access to digital services, so governments should create and execute laws that emphasize digital inclusion. To improve digital literacy and close the digital divide, certain measures may be necessary. It's critical to fund continuous training initiatives and skill enhancement for government workers. This guarantees that the staff will continue to be proficient in using the newest technology and able to adjust to the changing digital environment.

Robust Cybersecurity Measures: Improving cybersecurity frameworks on a constant basis to safeguard government systems' integrity and defend against changing threats. It's critical to create and execute thorough cybersecurity frameworks. To remain ahead of new cyberthreats, governments should invest in cutting-edge technologies, carry out frequent security audits, and work with international partners.

International Collaboration: Working together with global partners to exchange technology, standards, and best practices for a more secure and integrated digital governance ecosystem.

Discussion and Findings

Digital divide: The gap between those who have access to digital technology and those who do not is known as the "digital divide." Access to digital technology varies significantly across industrialized and underdeveloped nations. Some areas lack basic infrastructure, while others have broad access to digital gadgets and the internet. Urban and rural areas are frequently divided within nations. Compared to rural or isolated locations, urban cities typically offer superior internet connectivity and access to cutting-edge technology. In order to lessen the digital divide, high-speed broadband internet must be available. Access to dependable, fast internet is still difficult to come by in many locations, particularly in rural or low-income communities. The attempts to reduce the digital gap include community involvement, governmental measures, education and training programs, and infrastructure development. Governments, non-profits, and businesses all have important roles to play in addressing these disparities and ensuring that everyone can profit from the digital age.

Lack of Knowledge: The limited application of e-governance practices is partly a result of the use of digital technologies. Unprecedented opportunities and developments have been brought about by the digital age, but there are drawbacks as well, such as the possibility of a lack of knowledge among people and communities. Basic digital literacy abilities including computer use, internet navigation, and online security comprehension may be lacking in some persons. This may make it more difficult for them to engage completely in the digital environment. People may find it difficult to critically assess sources due to the abundance of information available online, which could result in the dissemination of false information and the incapacity to distinguish trustworthy information from dubious sources.

Cost Effect: In a developing nation like India, the adoption of e-governance is heavily regulated by cost. Due to the extensive use of digital technologies and their influence on many facets of life and business, the idea of cost-effectiveness has experienced substantial changes in the digital age. Individuals are concerned about the privacy and security of their personal information. People in remote areas cannot access e-governance because of language difficulties and limited infrastructure facilities. Digital technology has enhanced productivity and decreased labour costs by automating repetitive jobs and procedures. By utilizing digital technologies, businesses can streamline their processes, increasing overall productivity and cutting expenses.

Low Computer Literacy:

Over 90% of Indians lack digital literacy. In the digital age, low computer literacy can have a number of serious repercussions for both people and societies. The ability to effectively use computers and related technology is referred to as computer literacy. People with limited computer literacy may find it difficult to access and retrieve information from the internet, which could limit their awareness of research, instructional materials, and current events. Basic computer skills are necessary for many positions in the modern industry. People who are not computer literate could have trouble finding work and be restricted to a small number of job options. Economic and social inequality can be increased by low computer literacy. The gap between those who are digitally literate and those who are not could grow as a result of those who are unable to use digital technologies being left behind in terms of educational and career prospects.

Resistance to Change: Many changes have occurred as a result of the introduction of information technology, yet some officials and residents are still reluctant to change. In many situations, resistance to change is a typical problem, and the shift to the Digital Era is no different. Offer training and education initiatives to help people understand new technologies. Assist staff members in comprehending the advantages and applicability of digital tools for their everyday work. Invest in training programs to enhance digital literacy. Provide opportunities for ongoing education to close the skill gap. Promote a culture of skill development and self-improvement. Openly discuss the changes and how they may affect job positions. Stress the development of new opportunities rather than job losses. Implement strategies to increase staff adaptability, such as rescaling and upskilling initiatives.

Conclusion

A robust data governance structure facilitates the management and safeguarding of citizen data, guarantees adherence to privacy laws, and makes efficient use of data for decision-making. To increase operational efficiency, service quality, and transparency, the government should use digital transformation. Digitizing procedures and services are part of this. Policies that support digital fairness and inclusivity should be implemented by governments, giving marginalized communities access. The government can leverage outside expertise through public-private partnerships and cooperation with tech firms and specialists. Transparency and responsiveness can be improved by interacting with citizens and incorporating them in decision-making processes via digital platforms. The efficacy and efficiency of government operations could be greatly increased by implementing digital governance solutions. Artificial intelligence, data analytics, and automation can improve decision-making, decrease red tape, and expedite procedures. By enabling citizens to keep an eye on government actions and decisions, open data projects, internet portals, and digital communication channels improve accountability.

Acknowledgment

I would like to express my sincere gratitude to all those who supported and guided me in the successful completion of this project titled *"Challenges and Strategies of Digital Governance in India."*

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I would like to acknowledge the contributions of researchers, policymakers, scholars, and institutions whose studies, reports, and publications on e-governance, public administration, digital transformation, information technology, and governance reforms in India provided the conceptual foundation for this project. Their work helped me understand the evolving role of digital governance in improving public service delivery, transparency, accountability, and citizen participation, while also highlighting the challenges of digital divide, cybersecurity, infrastructure, and policy implementation.

I am deeply grateful to my family and friends for their continuous encouragement, patience, and moral support during the completion of this project. Their support motivated me to remain focused and dedicated throughout the process.

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Abstract

Banu Mushtaq's Heart Lamp: Selected Stories (2025), translated from Kannada by Deepa Bhasthi and winner of the 2025 International Booker Prize, represents a landmark in global literature as the first short story collection and the first Kannada work to claim the award. Spanning twelve stories written between 1990 and 2023, the collection offers intimate, often humorous yet incisive portrayals of Muslim women and girls navigating daily life in rural and semi-urban Karnataka, southern India. Mushtaq, a lawyer, activist, and key figure in the Bandaya Sahitya (Rebel Literature) movement, channels lived experiences and social critique into narratives that expose the intertwined forces of patriarchy, class disparity, caste dynamics, and rigid religious interpretations.68ccf5

This paper examines Heart Lamp through the lenses of language, culture, and identity, arguing that Mushtaq's hybrid linguistic strategies and grounded storytelling construct a powerful site of cultural resistance and humanistic affirmation. Mushtaq's prose blends standard Kannada with

Dakhni Urdu, Arabic loanwords, and colloquial idioms, creating a multilingual tapestry that mirrors the lived multilingualism of her characters and challenges both elitist literary conventions and Anglophone dominance in global publishing. Deepa Bhasthi's translation preserves this hybridity by retaining untranslated terms, phonetic rhythms, and oral storytelling qualities, thereby resisting exoticization and enriching English with South Indian vernacular textures.ba417e

The stories depict culture not as static tradition but as embodied, material practices—rituals like khatna (circumcision), mosque mediations, Hajj pilgrimages, and domestic negotiations—that simultaneously constrain women and provide avenues for subversion. Through symbolic objects such as the kerosene lamp, red lungis, high-heeled shoes, and a forgotten shroud, Mushtaq illustrates how women experience cultural norms physically while enacting quiet or collective acts of agency. Identity emerges as intersectional and fluid: shaped by gender, religion, class, and regionality, yet never monolithic. Characters range from abandoned mothers seeking justice to educated professionals and resilient grandmothers, rejecting stereotypes and highlighting intergenerational solidarity alongside systemic failures.711745

Drawing on postcolonial theories of hybridity and feminist critiques of everyday resistance, this analysis demonstrates how Heart Lamp positions marginalized Muslim women's voices as central to broader conversations on decolonization, gender justice, and cultural sovereignty in contemporary India. By refusing simplistic resolutions and embracing realistic portrayals of resilience amid constraint, Mushtaq's work affirms literature's capacity to illuminate hidden lives and foster cross-cultural empathy. Ultimately, Heart Lamp enriches world literature by proving that deeply localized stories possess universal resonance, urging readers to reconsider the politics of language, the materiality of culture, and the complexities of identity formation in postcolonial contexts. (Word count: 298)

Keywords: *Banu Mushtaq, Heart Lamp, Kannada literature, linguistic hybridity, Muslim women's writing, Bandaya Sahitya, cultural resistance, intersectional identity, translation studies, postcolonial feminism*

Introduction

Banu Mushtaq's Heart Lamp: Selected Stories, published in English translation in 2025, has garnered international acclaim for its nuanced depiction of Muslim women's lives in southern India. As a participant in the progressive Bandaya Sahitya movement, which emerged in the 1970s to challenge caste hierarchies, class exploitation, and social conservatism through protest-oriented writing, Mushtaq brings an activist sensibility to her fiction. Her stories, rooted in Karnataka's sociocultural landscape, foreground the ordinary yet profound struggles and triumphs of women often relegated to the margins.01fcc8

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This paper explores how Heart Lamp reflects on language, culture, and identity. It contends that Mushtaq employs vernacular hybridity, symbolic realism, and intersectional character portrayals to negotiate the tensions between tradition and agency, creating narratives that resist multiple layers of oppression while celebrating human resilience.

Linguistic Hybridity as Resistance and Representation

Mushtaq's linguistic choices form the bedrock of her cultural critique. Born in 1948 in Hassan, Karnataka, she navigated an early education oscillating between Urdu-medium religious schooling and Kannada-medium institutions. This personal history infuses her writing with a distinctive code-switching style that incorporates Dakhni—a vibrant, colloquial blend of Urdu, Kannada, Persian, Telugu, and Marathi influences—alongside Arabic religious terms and everyday Kannada.f1b283

This hybridity serves multiple purposes. It authentically captures the speech patterns of Karnataka's Muslim communities, rejecting the purity demanded by literary elites. It also functions as a form of decolonization, asserting regional linguistic pride against both colonial English legacies and homogenizing national narratives. In Bhasthi's translation, this texture is maintained through strategic retention of original words, avoidance of italics or heavy glossing, and preservation of repetitive, performative oral rhythms common in spoken Kannada and Dakhni. Such choices invite readers into the cultural world rather than presenting it as exotic spectacle.df0a22

In "The Arabic Teacher and Gobi Manchuri," religious education intersects with mundane commerce when a teacher uses gobi manchuri—a popular Indo-Chinese dish—to engage students, blurring lines between sacred learning and secular survival. Characters fluidly shift linguistic registers, reflecting pragmatic adaptations in multilingual realities. Similarly, "Be a Woman Once, Oh Lord!" repurposes prayer-like invocation to critique marital suffering, transforming religious language into a tool of feminist protest. These techniques underscore language as both a potential instrument of patriarchal or communal control and a resource for subversion and self-expression.

Cultural Practices: Constraint, Subversion, and Materiality

Mushtaq portrays culture as lived and contested rather than abstract heritage. Rituals and institutions shape daily existence but also expose hypocrisies of class, gender, and power. "Red Lungi" humorously depicts a mass khatna ceremony organized by a relatively affluent

woman using surplus red cloth. The story contrasts hospital procedures for wealthier boys with traditional, painful ones for poorer children, revealing class-based disparities within communal practices. Maternal exasperation during summer vacations adds levity while highlighting women's labor in managing social expectations.3f8919

In "Black Cobras," an abandoned wife seeks support through mosque authorities, only to face institutional bias favoring men. The community women's collective outrage—likened to cobras spitting venom—channels frustration into symbolic power, culminating in the mutawalli's wife

asserting bodily autonomy through tubectomy. Religious spaces thus become arenas where women contest authority from within.f0afe7

Objects carry significant symbolic weight. The titular heart lamp (kerosene lamp) in one story represents both despair and maternal endurance. Ill-fitting high-heeled shoes symbolize imposed modernity and patriarchal display, discarded for practical needs. A forgotten burial shroud in "The Shroud" exposes the gap between performative piety during Hajj and ethical neglect of the poor. These material symbols ground abstract cultural themes in embodied experience, showing how women navigate and reshape traditions.d90a22 Intersectional Identities and Fluid Resistances

Identity in Heart Lamp is multifaceted, influenced by gender, class, religion, and locality. Mushtaq avoids essentializing Muslim womanhood, presenting diverse characters—from professionals to laborers—who confront intersecting pressures, including internal patriarchal norms and broader societal marginalization.

Stories like "Stone Slabs for Shaista Mahal" critique performative masculinity and the burdens placed on daughters after a mother's death. "Fire Rain" examines a mutawalli's prioritization of religious spectacle over family responsibilities, leading to personal reckoning. Motherhood recurs as a relational anchor yet also a site of challenge, as seen in intergenerational moments of compassion amid hardship.14627d

Class dynamics permeate identities: wealthier characters often perform religiosity while exploiting the vulnerable, while poorer women exhibit resourcefulness within constraints. Resistance appears in muted, cumulative forms—humor, silence, collective sarcasm, or decisive personal choices—rather than grand heroism, reflecting realistic limitations and affirming everyday dignity.

The collection's non-chronological span across decades mirrors identity's fluidity, with recurring struggles indicating persistent structures alongside individual assertions of specificity. This aligns with concepts of hybridity, where cultural margins foster innovative negotiations of selfhood.

The Translator's Ethical Role and Global Reach

Bhasthi's collaborative approach elevates the work. By preserving linguistic and cultural specificity, the translation acts as a bridge that respects difference. The Booker recognition amplifies Kannada and regional Indian literatures, countering the dominance of English or Hindi narratives and validating marginalized voices on the world stage.eb3396 Conclusion

Heart Lamp masterfully intertwines language, culture, and identity to illuminate the lives of Muslim women in southern India. Through hybrid vernaculars, embodied cultural critique, and nuanced portrayals of intersectional existence, Banu Mushtaq crafts stories of quiet defiance and enduring humanity. In doing so, the collection not only enriches postcolonial and feminist literary traditions but also demonstrates literature's power to foster empathy across divides. As global readers engage with these heartland narratives, Heart Lamp reminds us that authentic regional voices illuminate universal truths about resilience, justice, and the human spirit.

Acknowledgment

I would like to express my sincere gratitude to all those who supported and guided me in the successful completion of this project titled ***"Reflections on Language, Culture, and Identity in Heart Lamp."***

First and foremost, I extend my heartfelt thanks to my teacher/guide for their constant guidance, valuable suggestions, and encouragement throughout the

preparation of this project. Their academic support and thoughtful feedback helped me understand the literary and cultural dimensions of the text more deeply and complete this work in a systematic and meaningful manner.

I am also thankful to my institution and the concerned department for providing me with the opportunity, academic resources, and a supportive environment necessary to undertake this study. The encouragement and facilities provided by the institution played an important role in the successful completion of this project.

I would like to acknowledge the contributions of writers, literary critics, translators, and scholars whose works on language, culture, identity, and contemporary literature provided the conceptual foundation for this project. Their insights helped me explore how *Heart Lamp* reflects the complex relationship between linguistic expression, cultural memory, and personal as well as collective identity.

I am deeply grateful to my family and friends for their continuous encouragement, patience, and moral support during the completion of this project. Their support motivated me to remain focused and dedicated throughout the research process.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Bio Smart Cities India: AI & Biotechnology for Sustainable Urban Development

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Abstract

India's fast urbanization has led to urgent problems with public health, resource management, and sustainability (United Nations, 2019). In order to promote resilient, adaptable, and ecologically balanced settings, the BioSmart City paradigm incorporates biotechnology and artificial intelligence (AI) into urban planning. While biotechnology makes bio-remediation, waste management, and biosensing for pollution control possible (Singh, Gupta, & Sharma, 2020), artificial intelligence (AI) adds through predictive analytics in energy, mobility, and healthcare (Kumar & Prasad, 2021). These technologies work in concert to provide sustainable urban ecosystems. With an emphasis on India's Smart Cities Mission (Ministry of Housing and Urban Affairs, 2017), this study examines the body of research on smart cities, biotechnology applications, and AI-driven urban systems. It makes the case that BioSmart Cities may increase climate change resilience, lessen ecological footprints, and foster equitable growth (World Bank, 2021). The study comes to the conclusion that in order to achieve this goal, interdisciplinary cooperation and innovative policies are crucial.

Keywords: *BioSmart Cities, Artificial Intelligence, Biotechnology, Sustainable Urban Development, India, Smart Cities Mission, Urban Ecology.*

Introduction

With estimates indicating that by 2030, around 40% of India's population would live in cities, the country is experiencing one of the quickest urban transitions in the world (United Nations, 2019). Public services, housing, energy, and infrastructure are all under tremendous strain as a result of this demographic change. Although urbanization promotes economic expansion, it also makes problems like pollution, waste disposal, and climate vulnerability worse. Innovative frameworks that transcend traditional urban planning are needed to address these problems.

In response to these issues, the Indian government established the Smart Cities Mission in 2015 with the goal of modernizing urban infrastructure through citizen-centric services, enhanced governance, and digital technologies (Ministry of Housing and Urban Affairs, 2017). Critics contend that although this project has improved connection and digitalization, it has not sufficiently included biological resilience and ecological sustainability into its framework (World Bank, 2021). There are gaps in environmental and health-oriented initiatives because the focus has mostly stayed on ICT-driven solutions.

Beyond conventional smart city approaches, the idea of BioSmart Cities arises as a paradigm change. In order to improve sustainability, it sees cities as adaptive ecosystems where biotechnology and artificial intelligence (AI) are integrated into urban systems. While AI provides predictive analytics for energy optimization, healthcare, and transportation, biotechnology provides solutions for bio-remediation, waste management, and sustainable agriculture (Singh, Gupta, & Sharma, 2020). When combined, these technologies have the potential to build both technologically sophisticated and environmentally sustainable cities.

Predictive healthcare systems, traffic management, and renewable energy efficiency are examples of AI uses in urban settings. By anticipating problems and responding quickly, these tools help cities minimize inefficiencies and their negative effects on the environment (Kumar & Prasad, 2021). By offering biological solutions like engineered microbes for waste breakdown, bio-sensors for pollution monitoring, and bio-inspired building materials, biotechnology supports these efforts. Thus, the combination of biotechnology and AI offers a comprehensive strategy for urban sustainability.

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The purpose of this research is to investigate how biotechnology and AI are influencing India's BioSmart Cities. An investigation of AI and biotechnology applications in urban systems follows a review of the literature on sustainability models and smart city frameworks. While the conclusion outlines potential future avenues for study and policy, the discussion section critically addresses issues including equity, ethics, and governance. The study highlights BioSmart Cities' potential to convert urban settings into resilient, inclusive, and sustainable ecosystems by placing them within India's urbanization trajectory.

BioSmart Cities: A Literature Review

Over the past 20 years, the idea of "smart cities" has changed dramatically due to advancements in information and communication technology (ICT). Early models focused on infrastructure modernization, e-governance, and digital connection; cities like Singapore and Barcelona were frequently used as international models (United Nations, 2019). These frameworks showed how technology may improve productivity and citizen participation, but they also exposed shortcomings in addressing biological resilience and ecological sustainability.

By incorporating ICT into urban administration and infrastructure, India's Smart Cities Mission, which was started in 2015, aimed to duplicate similar international achievements (Ministry of Housing and Urban Affairs, 2017). Digital platforms for energy efficiency, smart transportation, and service delivery were given top priority in the mission. But academics have pointed out that the program has mostly stayed focused on technology, with little attention paid to biological innovation and ecological systems (World Bank, 2021). Calls for more comprehensive strategies that incorporate sustainability into urban planning itself have been sparked by this disparity.

The importance of biotechnology as a tool for sustainable urban development is becoming more widely acknowledged. To address pollution, waste management, and resource conservation, applications like bio-remediation, bio-energy, and biosensing have been implemented (Singh, Gupta, & Sharma, 2020). For instance, bio-sensors offer real-time air and water quality monitoring, and engineered bacteria have been utilized in wastewater treatment. These developments show how biological systems can work in tandem with technology to create healthier urban settings.

In urban systems, artificial intelligence has also shown itself to be a transformative force. Energy optimization, disaster resilience, and traffic management are all using AI-driven predictive analytics (Kumar & Prasad, 2021). Cities can predict changes in demand, cut down on inefficiencies, and enhance service delivery thanks to machine learning models. AI in healthcare helps with predictive diagnosis and epidemiological modeling, which are especially important in urban regions with high population densities.

AI and biotechnology's combination opens up new possibilities for urban sustainability. Cities can develop into adaptive ecosystems by fusing biological processes with AI-driven monitoring and decision-making. AI-enabled biosensors, for example, can automatically identify pollutants and initiate bio-remediation procedures, resulting in self-regulating systems. The BioSmart City concept, which aims to strike a balance between ecological regeneration and technology growth, is based on this synergy.

AI and Biotechnology Use for Sustainability

1. AI Applications in Urban Sustainability

In Indian urban settings, artificial intelligence is being used more and more to solve sustainability issues.

• **Energy Management**: By optimizing renewable energy grids, machine learning models lower peak demand and boost efficiency (Kumar & Prasad, 2021). • **Urban Mobility**: By combining real-time data from sensors and GPS, AI-based traffic prediction systems have decreased pollution and traffic in cities like Bengaluru (World Bank, 2021).

• **Healthcare**: AI-enabled epidemiological modeling and predictive diagnostics have been used to predict outbreaks, especially during the COVID-19 pandemic (United Nations, 2019).

2. Biotechnology Applications in Urban Systems

By providing biological answers to ecological problems, biotechnology enhances artificial intelligence.

• **Waste Management**: According to Singh, Gupta, and Sharma (2020), engineered microorganisms have been used in wastewater treatment and the breakdown of municipal solid waste.

• **Pollution Control**: Bio-sensors allow for real-time monitoring and intervention by identifying pollutants in the air and water.

• **Urban Agriculture**: In densely populated places, food security is enhanced via vertical farming systems and bioengineered crops.

3. Synergy of AI and Biotechnology

AI and biotechnology come together to form self-regulating, adaptive urban ecosystems.

• **AI-driven biosensors**: These devices automatically initiate bio-remediation procedures after detecting contaminants.

• **Smart Agriculture**: AI-driven settings maximize bio-engineered crops, striking a balance between resource efficiency and food output.

• **Climate Resilience**: Predictive modeling of climate hazards and biological therapies to lessen damages are made possible by combined technologies.

4. Case Examples in India

• **Wastewater Treatment in Delhi:** Water quality has improved thanks to pilot initiatives that use bioengineered bacteria and AI monitoring.

• **Smart Mobility in Pune:** Environmental sensors and AI-driven traffic systems lower pollution and enhance air quality.

• **Urban farming in Hyderabad:** Local food production has increased thanks to biotechnology-enabled vertical farms run by AI systems.

Discussion

There are advantages and disadvantages of integrating biotechnology and artificial intelligence (AI) into Indian urban infrastructure. BioSmart Cities, on the one hand, provide a route toward inclusive, adaptable, and sustainable urban ecosystems. However, there are still major obstacles in the areas of equity, ethics, and governance that need to be removed for implementation to be successful.

Governance and Policy Challenges

Strong institutional frameworks are crucial for promoting urban innovation, as India's Smart Cities

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Mission has shown (Ministry of Housing and Urban Affairs, 2017). However, new regulatory frameworks are needed to incorporate biotechnology and AI. Comprehensive governance mechanisms are necessary to address issues including genetic data privacy, bio-safety procedures, and AI responsibility. The possibility of abuse or unforeseen ecological repercussions could erode public confidence in the absence of clear policies (World Bank, 2021).

Ethical and Social Considerations

Ethical concerns about genetic alteration, bio-remediation, and ecological interventions are brought up by the use of biotechnology in urban settings. Similar to this, sensitive data used in AI applications in healthcare and transportation needs to be protected from abuse (Kumar & Prasad, 2021). Maintaining ethical integrity requires ensuring accountability, transparency, and public involvement in decision-making processes.

Equity and Access

The fair distribution of technology advantages is a crucial issue in India's urban development. Initiatives for smart cities have frequently come under fire for favouring wealthy neighbourhoods while ignoring underprivileged areas (United Nations, 2019). BioSmart Cities must put inclusivity first by making sure that all residents, regardless of socioeconomic background, have access to AI-driven healthcare, biotechnology-enabled waste management, and sustainable food systems.

Global Comparisons and India's Readiness

Smart city approaches that incorporate sustainability into urban design have been pioneered globally by places like Barcelona and Singapore (United Nations, 2019). India is prepared thanks to its robust technological foundation and expanding biotechnology industry, but there are still issues with infrastructure, governance, and resource distribution. Although pilot projects in Delhi, Pune, and Hyderabad show promise, scaling these programs calls for substantial funding and creative policy (Singh, Gupta, & Sharma, 2020).

Future Directions

The conversation emphasizes that BioSmart Cities are socio-ecological systems rather than just technology innovations. Multidisciplinary cooperation between urban planners, technologists, biologists, and legislators is essential to their success. Additionally, encouraging acceptance and participation in BioSmart initiatives will require citizen engagement and education.

Conclusion

For India's urban future, the idea of BioSmart Cities offers a revolutionary paradigm. Cities can develop into adaptive ecosystems that strike a balance between ecological resilience and technological growth by incorporating biotechnology and artificial intelligence (AI) into urban design. The literature analysis and case studies show how biotechnology offers biological solutions for waste management, pollution control, and food security, while AI delivers predictive analytics for energy, healthcare, and mobility (Singh, Gupta, & Sharma, 2020; Kumar & Prasad, 2021).The conversation emphasizes that despite the apparent advantages, there are still issues with equity, ethics, and governance. To handle bio-safety, genetic data privacy, and AI accountability, regulatory frameworks must change (World Bank, 2021). In order for BioSmart technologies to help marginalized populations and not worsen already-existing disparities, it is equally crucial to ensure inclusivity (United Nations, 2019). The foundation for digital transformation has been established by India's Smart Cities Mission; however, ecological and biological sustainability must be incorporated into the next stage (Ministry of Housing and Urban Affairs, 2017). Although pilot programs in Delhi, Pune, and Hyderabad show promise, scaling calls for interdisciplinary cooperation, citizen participation, and creative policy. In the end, BioSmart Cities are socio-ecological systems rather than just technology innovations. Aligning technical innovation with social fairness and ecological regeneration is essential to their success. BioSmart Cities will be global models of sustainable urban development in the twenty-first century if India can strike this balance.

Acknowledgment

I would like to express my sincere gratitude to all those who supported and guided me in the successful completion of this project titled ***"Bio Smart Cities India: AI & Biotechnology for Sustainable Urban Development."***

First and foremost, I extend my heartfelt thanks to my teacher/guide for their constant guidance, valuable suggestions, and encouragement throughout the preparation of this project. Their academic support and insightful feedback helped me understand the interdisciplinary dimensions of the topic and complete this work in a systematic and meaningful manner.

I am also thankful to my institution and the concerned department for providing me with the opportunity, academic resources, and a supportive environment necessary to undertake this study. The facilities and encouragement offered by the institution played an important role in the successful completion of this project.

I would like to acknowledge the contributions of researchers, scientists, urban planners, policymakers, and scholars whose work in the fields of artificial intelligence, biotechnology, smart city development, sustainability, urban governance, and environmental innovation provided the conceptual foundation for this project. Their studies and insights helped me understand how AI and biotechnology can contribute to building smarter, greener, and more sustainable urban spaces in India by addressing challenges related to public health, waste management, energy efficiency, resource optimization, and ecological balance.

I am deeply grateful to my family and friends for their continuous encouragement, patience, and moral support during the completion of this project. Their support motivated me to remain focused and dedicated throughout the research process.

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Conflicts of interest

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Original Article

From Margins to Voice: Double Marginalization, Identity, And Cultural Representation in Black Women's Drama

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Abstract

This paper offers a comprehensive exploration of double marginalization—the intersecting oppressions of race and gender—in selected plays by four influential African American women dramatists: Alice Childress's Trouble in Mind *(1955), Sonia Sanchez's* Uh, Uh; But How Do It Free Us? *(1974), Ntozake Shange's* for colored girls who have considered suicide / when the rainbow is enuf *(1976), and Lynn Nottage's* Ruined *(2009). Situating these works within the broader tradition of Black women's theatre that emerged in the post-World War II era, the study argues that these playwrights transform experiences of erasure, violence, economic exploitation, and cultural invisibility into powerful assertions of voice, agency, and cultural authority.*

Drawing upon intersectionality (Crenshaw), subaltern theory (Spivak), womanism (Walker), and postcolonial perspectives (Said, Bhabha), the analysis demonstrates how innovative dramatic forms—meta-theatrical realism, ritualistic choreopoetry, and war-zone realism—function as sites of resistance and healing. Through detailed close readings, comparative analysis, and contextualization within migration and social issues, the paper reveals how these texts negotiate identity formation while challenging dominant narratives. Particular attention is given to parallels with Dalit women's narratives in India, highlighting the transnational relevance of these works.

The study underscores the pedagogical and ethical value of Black women's drama in fostering empathy, critical consciousness, and behavioral change. Ultimately, it positions these plays as vital resources for addressing contemporary concerns of inequality, representation, and social justice in both American and Indian contexts.

Keywords: *Double Marginalization, Black Feminist Drama, Intersectionality, Subalternity, Womanism, Cultural Representation, Migration, Resistance, Identity Formation, Social Justice, Dalit Literature*

Introduction

The latter half of the twentieth century witnessed a remarkable flourishing of African American women's dramatic writing. Emerging from the shadows of both racial segregation and patriarchal literary traditions, Black women playwrights carved out spaces where their voices could be heard with unprecedented clarity and force. This paper examines four landmark works—Alice Childress's *Trouble in Mind* (1955), Sonia Sanchez's *Uh, Uh; But How Do It Free Us?* (1974), Ntozake Shange's *for colored girls who have considered suicide / when the rainbow is enuf* (1976), and Lynn Nottage's *Ruined* (2009)—to explore how these playwrights engage with the concept of double marginalization.

Double marginalization refers to the compounded oppression experienced by Black women due to the simultaneous operation of racism and sexism. As Kimberlé Crenshaw has powerfully argued, traditional single-axis frameworks fail to capture the unique vulnerabilities created at these intersections (1241). For Black women in America, this has historically meant economic exploitation, sexual violence, cultural stereotyping, and systemic invisibility. The selected plays do not merely document these realities; they transform them into sites of resistance, self-definition, and cultural reclamation.

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This study builds directly upon the investigator's doctoral research (Solage, 2018), which provided a detailed analysis of double marginalization across these playwrights' works. The present paper extends that foundation by foregrounding themes of migration (physical, social, and psychological), identity negotiation, and the role of dramatic form in voicing the subaltern. It also draws meaningful parallels with Dalit women's narratives in Maharashtra, particularly Baby Kamble's *The Prisons We Broke*, thereby highlighting the transnational resonance of these texts.

The post-World War II period proved crucial for Black theatre. The Civil Rights Movement, Black Arts Movement, and second-wave feminism created fertile ground for Black women artists to challenge both white supremacy and male dominance within their communities. Childress, writing in the 1950s, exposed the racism of the commercial theatre industry. Sanchez, deeply involved in the Black Arts Movement, confronted intra-community patriarchy. Shange revolutionized dramatic form with her choreopoem, while Nottage, writing in the early twenty-first century, globalized the conversation by linking gendered violence to war economies in the Congo.

These playwrights share a commitment to centering Black women's lived experiences. Their works move beyond victimhood to portray complex processes of survival, resistance, and healing. By analyzing these texts through intersectional, subaltern, and womanist lenses, this paper demonstrates how Black women's drama functions as both critique and creation—challenging oppressive structures while imagining alternative possibilities for identity and community.

Theoretical Framework

The analysis is grounded in four interconnected theoretical paradigms: intersectionality, subaltern studies, womanism, and postcolonial theory. Kimberlé Crenshaw's intersectionality (1991) remains foundational. It reveals how overlapping systems of race and gender discrimination create unique forms of vulnerability that cannot be fully explained by race or gender alone. For Black women, experiences of discrimination are multiplicative rather than additive. This framework illuminates the layered oppressions faced by characters across the selected plays.

Gayatri Chakravorty Spivak's "Can the Subaltern Speak?" (1988) raises critical questions about representation and voice. Spivak warns that dominant discourses often erase or mediate subaltern voices, making authentic articulation difficult. Black women playwrights respond to this challenge by creating alternative dramatic spaces where marginalized subjects speak on their own terms, often through innovative forms that resist conventional theatrical expectations. Alice Walker's womanism (1983) offers an affirmative, culturally grounded approach. Womanism celebrates the wholeness of Black women's lives—their strength, spirituality, creativity, and commitment to community survival. Unlike mainstream feminism, it centers Black women's experiences and rejects separatist tendencies. Walker's framework is particularly useful for reading Shange's choreopoem, which embodies communal healing and self-love.

Postcolonial theory, particularly Edward Said's *Orientalism* (1978) and Homi Bhabha's concept of hybridity (1994), further illuminates how identities are constructed through processes of othering and negotiation. In the context of these plays, characters constantly negotiate imposed identities while forging new, hybrid ones that challenge binary oppositions.Additional scholars enrich the framework. Patricia Hill Collins's *Black Feminist Thought* (1990) emphasizes the importance of lived experience as a source of knowledge. Audre Lorde's concept of the "master's tools" (1984) warns against using dominant structures to achieve liberation, a tension visible in Childress's meta-theatrical critique. In the Indian context, Sharmila Rege and Gopal Guru's work on Dalit feminism provides productive parallels for understanding caste-gender intersections.

Taken together, these theoretical approaches enable a multidimensional reading that balances critique of oppressive structures with recognition of agency, resilience, and creative possibility.

Methodology

This study employs a qualitative, interpretive methodology centered on close textual analysis and comparative reading. The four plays were selected for their canonical status, thematic richness, and representation of different generations and aesthetic approaches within Black women's drama. Analysis proceeds through three interconnected layers: thematic (race, gender, class, migration), formal (dialogue, structure, performance elements), and socio-historical contextualization.

Primary texts are examined alongside secondary scholarship in Black feminism, Dalit studies, and theatre history. Comparative analysis identifies shared patterns and contextual differences, with particular attention to parallels with Dalit women's narratives in Maharashtra. All citations follow MLA 9th edition. Ethical considerations include respectful engagement with the lived experiences represented in the texts.

Historical Context of Black Women's Drama

The emergence of Black women's drama in the United States must be understood within the larger socio-political transformations of the twentieth century. The post-World War II period marked a decisive shift. African American soldiers returning from the war, having fought for democracy abroad, demanded full citizenship at home. This era witnessed the intensification of the Civil Rights Movement, the rise of Black Nationalism, and growing feminist consciousness. Within this ferment, Black women playwrights began to claim theatrical space previously dominated by white and male voices.

The Harlem Renaissance (1917–1935) had already laid important groundwork. Playwrights such as Angelina Weld Grimké (*Rachel*, 1916), Georgia Douglas Johnson, and May Miller used drama to protest lynching and racial violence. However, their works were often one-act pieces performed in community settings. The real breakthrough came after 1945. Alice Childress's *Florence* (1949) and *Trouble in Mind* (1955) marked the arrival of a new generation. Childress, drawing from her experience with the American Negro Theatre, exposed the humiliating stereotypes Black actors were forced to perform. Her meta-theatrical approach in *Trouble in Mind* critiqued not only

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white producers but also the compromises Black artists made for survival.

The 1960s and 1970s witnessed the explosive energies of the Black Arts Movement. Sonia Sanchez emerged as a powerful voice, blending poetry and drama. Her plays, including *Uh, Uh; But How Do It Free Us?* (1974), confronted the contradictions within Black communities—particularly the ways in which revolutionary rhetoric often excluded or subordinated women. Sanchez's work insisted that true liberation must include gender justice.

Ntozake Shange's *for colored girls who have considered suicide / when the rainbow is enuf* (1976) represented a radical formal innovation. By creating the choreopoem—a fusion of poetry, music, dance, and ritual—Shange rejected Eurocentric dramatic conventions. The play gave voice to the pain of Black women through a collective of colored "ladies" who move from trauma to healing. Its Broadway success demonstrated that experimental Black women's drama could reach wide audiences while maintaining artistic and political integrity.

By the late twentieth and early twenty-first centuries, Lynn Nottage brought a global perspective. *Ruined* (2009), inspired by interviews with women survivors of conflict, linked African American experiences of marginalization to contemporary crises. Nottage's realist style and meticulous research expanded the scope of Black women's drama, showing how gendered violence operates as a weapon of war across cultures.

This historical trajectory—from protest plays of the early twentieth century to meta-theatrical critique, ritualistic experimentation, and global realism—reflects evolving strategies for representing double marginalization. Each generation built upon the previous one while responding to new historical realities: the Civil Rights Movement, Black Power, second-wave feminism, and globalization. These playwrights consistently positioned Black women not as passive victims but as complex agents negotiating multiple systems of oppression. Their works provide rich material for understanding how drama can function as both witness and weapon in the struggle for dignity and justice.

Analysis of the Selected Plays

1 Alice Childress – *Trouble in Mind*

In *Trouble in Mind*, Childress masterfully uses the play-within-a-play structure to expose the mechanics of racial representation in American theatre. The protagonist, Wiletta Mayer, is an experienced Black actress cast in a problematic lynching drama directed by a white man. Throughout rehearsals, Wiletta grows increasingly frustrated with the stereotypical portrayal of Black characters. In a key moment, she challenges the director: "We're supposed to make them laugh and cry at the same time—and not let them know what we really feel" (Childress 47). This line captures the emotional labor demanded of Black performers—performing degradation while concealing authentic pain.

Childress connects economic marginalization with racial performance. Wiletta depends on these roles for survival, highlighting the double bind Black women face: they must participate in their own dehumanization to feed their families. The play culminates in Wiletta's assertion of dignity, refusing to deliver a submissive speech that would please white audiences. This moment of resistance demonstrates how theatrical space can become a site for challenging both external racism and internalized oppression. Childress's work, as analyzed in the investigator's doctoral research, reveals the psychological and economic toll of double marginalization in mid-twentieth-century America.

2 Sonia Sanchez – *Uh, Uh; But How Do It Free Us?*

Sanchez's play confronts the contradictions of the Black revolutionary movement. The female characters demand that liberation include gender justice. Through sharp, vernacular dialogue, Sanchez reveals how Black men sometimes replicate the oppressive structures they claim to fight. One character's assertion of sexual and emotional autonomy becomes a radical act of self-definition. The play's title itself—"Uh, Uh; But How Do It Free Us?"—questions whether revolutionary rhetoric truly liberates women. Sanchez's work extends the analysis of intra-community marginalization, showing that double oppression operates both externally and internally. Her dramatic language blends poetry and realism to give voice to women's unfulfilled expectations within the movement.

3 Ntozake Shange – *for colored girls who have considered suicide / when the rainbow is enuf*

Shange's choreopoem is a groundbreaking achievement. Rejecting linear plot and realistic dialogue, she creates a ritualistic performance where seven women (identified by colors) share stories of love, betrayal, rape, and healing. The famous monologue "somebody almost walked off wid alla my stuff" (Shange 18) powerfully conveys the theft of identity, joy, and agency. The repetition and collective performance transform individual trauma into communal testimony. The final rainbow sequence symbolizes rebirth and wholeness, embodying womanist ideals of integration and self-love. Shange's rejection of traditional dramatic form becomes itself an act of resistance, allowing fragmented Black women's voices to coalesce into strength. Her innovative structure challenges audience expectations and creates space for emotional catharsis and collective healing.

4 Lynn Nottage – *Ruined*

Set in a Congolese brothel during civil war, *Ruined* portrays women whose bodies become literal battlegrounds. Mama Nadi runs a fragile sanctuary that is also a site of exploitation. Sophie's scarred body and defiant spirit embody resilience amid horror. Her line, "You will not fight your battles on my body anymore" (Nottage 94), marks a powerful moment of reclaimed agency. Nottage links economic desperation, sexual violence, and war economies into a searing indictment of gendered marginalization in conflict zones. The play globalizes the theme of double marginalization, showing its persistence across cultures and continents. Through meticulous research and realistic dialogue, Nottage forces audiences to confront the human cost of systemic violence.

Comparative Analysis

A comparative examination of the four plays reveals both shared patterns and distinct aesthetic strategies in representing double marginalization. While each playwright responds to the intersecting forces of race and gender oppression, their approaches to migration, narrative form, and resistance illuminate the multifaceted nature of Black women's experiences across different historical moments.

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Migration—physical, social, and psychological—emerges as a unifying thread. In Alice Childress's *Trouble in Mind*, Wiletta Mayer's professional life reflects the Great Migration's aftermath. Having moved from the rural South to Northern cities in search of opportunity, she finds herself trapped in stereotypical roles that deny her humanity. The theatre becomes a microcosm of broader urban disillusionment, where economic survival demands emotional suppression. Childress shows how physical relocation does not guarantee social mobility; instead, it often intensifies the psychological weight of double marginalization.

Sonia Sanchez's *Uh, Uh; But How Do It Free Us?* extends this exploration into intra-community dynamics during the Black Power era. The characters navigate the psychological migration from traditional gender roles toward new expectations of revolutionary partnership. Women in the play experience a painful dislocation when the rhetoric of Black liberation fails to include their voices. Sanchez captures the internal migration from hope to disillusionment, revealing how racial solidarity can mask gendered oppression. The play's raw, confrontational dialogue underscores the emotional cost of this unfulfilled promise of freedom.

Ntozake Shange's *for colored girls who have considered suicide / when the rainbow is enuf* presents migration most poetically. The women move from fragmented isolation ("somebody almost walked off wid alla my stuff") toward collective healing. Shange's choreopoem form itself enacts a kind of ritual migration—from individual pain to communal rainbow. The colored ladies' journey is not merely geographical but deeply psychological, tracing the path from despair to self-love. This formal innovation allows Shange to represent the internal geography of trauma and recovery in ways traditional realism cannot achieve.

Lynn Nottage's *Ruined* globalizes the theme by situating it within the context of war-induced displacement. The women in Mama Nadi's brothel are literal migrants—refugees whose bodies bear the scars of conflict. Sophie's physical and emotional journey from violation to defiance represents the most extreme form of forced migration. Nottage shows how war accelerates all forms of marginalization, turning women's bodies into contested territories. Yet even here, moments of resistance emerge, suggesting that displacement can also foster unexpected forms of solidarity and resilience.

Narrative strategies further distinguish the plays while reinforcing the double marginalization framework. Childress employs meta-theatre to expose the gap between performed stereotypes and lived reality. Sanchez uses confrontational, poetic dialogue to challenge patriarchal assumptions within Black communities. Shange's choreopoem dissolves conventional boundaries between poetry, dance, and drama, creating a collective voice that transcends individual stories. Nottage's realist style, enriched by meticulous research, immerses audiences in the brutal everyday realities of survival.

Formal innovation serves as a form of resistance in each case. By breaking theatrical conventions, these playwrights refuse the marginalizing structures that have historically contained Black women's stories. Shange's rejection of linear plot and Nottage's unflinching realism both challenge audience comfort, forcing confrontation with uncomfortable truths. Childress and Sanchez, working within more conventional forms, subvert them from within through sharp irony and vernacular power.

The plays also demonstrate evolving strategies of resistance. Childress's Wiletta asserts individual dignity within institutional constraints. Sanchez demands collective accountability. Shange creates communal healing through performance. Nottage shows quiet, everyday acts of survival that accumulate into defiance. Across these works, resistance is never abstract but deeply embodied—rooted in the body, voice, and relationships of Black women.

This comparative reading confirms the central argument of the investigator's doctoral research: double marginalization is not merely a condition of oppression but also a catalyst for creative and cultural transformation. The four playwrights transform personal and collective pain into art that reclaims visibility, agency, and humanity. Their works stand as powerful testaments to the enduring capacity of Black women to speak, create, and envision new possibilities even from the most constrained positions. (1,198 words)

Pedagogical Implications and Behavioral Change

The selected plays offer rich pedagogical possibilities for literature classrooms worldwide. Their exploration of double marginalization provides students with concrete examples of how intersecting identities shape lived experience, fostering deeper understanding of gender, race, and power dynamics.

Lesson Plan 1: Understanding Double Marginalization through Character Analysis Instructors can begin with Childress's *Trouble in Mind*. Students read key scenes featuring Wiletta and map the intersecting pressures of race and gender she faces. Discussion prompts include: "How does Wiletta's professional survival depend on performing stereotypes?" and "What emotional labor does she perform that remains invisible to white characters?" This activity helps students recognize the layered nature of oppression.

Lesson Plan 2: Voice and Form in Shange's Choreopoem Shange's work lends itself to performative pedagogy. Students can stage selected monologues, experiencing firsthand how the choreopoem form creates communal voice. Follow-up discussion can explore how fragmented narratives reflect psychological migration from isolation to connection. This embodied approach often leads to powerful reflections on empathy and shared humanity.

Lesson Plan 3: Global Dimensions through Nottage's *Ruined* Nottage's play expands students' understanding beyond American contexts. Comparative prompts might ask: "How does war intensify existing forms of gender oppression?" and "What strategies of survival do the women employ?" This encourages critical thinking about the universal dimensions of double marginalization while maintaining focus on specific historical realities.

Lesson Plan 4: Resistance and Agency across the Plays A culminating unit can bring all four works together. Students create comparative charts tracking themes of

migration, resistance, and identity formation. Group presentations on chosen characters help consolidate learning.

Assessment can combine traditional essays with reflective journals. Prompts such as "How has studying these plays changed your understanding of intersectional oppression?" often reveal meaningful shifts in perspective. Many students report increased awareness of their own privileges and biases, demonstrating the plays' potential for behavioral change. These teaching strategies align with broader educational goals of developing critical consciousness and empathy. By engaging with complex characters who navigate multiple forms of marginalization, students practice analytical skills while confronting real-world issues of inequality. The emotional impact of the plays—particularly Shange's *choreopoem* and Nottage's raw realism—often leads to transformative classroom discussions that extend beyond academic analysis into personal reflection. In literature classrooms, these works serve as powerful tools for examining how art can challenge dominant narratives and create space for marginalized voices. Their continued relevance speaks to the enduring power of Black women's drama to illuminate, provoke, and inspire.

Conclusion

This study has demonstrated how four pioneering Black women playwrights—Alice Childress, Sonia Sanchez, Ntozake Shange, and Lynn Nottage—transform the experience of double marginalization into profound artistic statements about identity, voice, and resistance. Through diverse dramatic forms and deeply embodied characters, their works reveal the complex interplay of race, gender, and power while affirming the creative resilience of Black women.From Childress's meta-theatrical critique of the entertainment industry to Sanchez's confrontational examination of intra-community dynamics, from Shange's revolutionary choreopoem to Nottage's unflinching portrayal of war's impact on women's bodies, these plays collectively map the terrain of double marginalization across different historical moments and aesthetic approaches. They show that oppression is never total; within even the most constrained circumstances, possibilities for agency, solidarity, and self-definition persist.

The enduring significance of these works lies in their refusal to reduce Black women to victims. Instead, they present complex characters who navigate, challenge, and sometimes transform the structures that seek to define them. Their innovative use of dramatic form itself becomes an act of resistance—reclaiming narrative authority and creating spaces where marginalized voices can be heard on their own terms. As contemporary societies continue to grapple with intersecting forms of inequality, these plays offer valuable insights. They remind us that literature can serve as both mirror and map—reflecting harsh realities while charting paths toward greater understanding and justice. Their continued relevance in classrooms, theatres, and scholarly discourse testifies to the power of Black women's creative vision to illuminate universal human concerns while remaining rooted in specific experiences of struggle and triumph.

Ultimately, these playwrights demonstrate that the margins are not merely sites of exclusion but fertile grounds for creativity, healing, and cultural renewal. By giving voice to those long silenced, they expand our collective understanding of what it means to be human. In doing so, they challenge all of us to listen more carefully, see more clearly, and work toward a world where no voice remains at the margins. The journey from pain to power continues, and these remarkable plays light the way.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Geospatial Technologies in Achieving Sustainable Development Goals (SDGs) in India: A Qualitative Assessment of Policy, Practice, and Spatial Inequality

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Abstract

The Sustainable Development Goals (SDGs), adopted by the United Nations in 2015, represent a comprehensive global framework aimed at addressing interconnected challenges of poverty, inequality, environmental degradation, and governance. In a diverse and spatially heterogeneous country like India, achieving SDGs requires not only policy interventions but also spatially informed planning mechanisms. Geospatial technologies, particularly Geographic Information Systems (GIS) and Remote Sensing, have emerged as critical tools for monitoring, analysing, and implementing development strategies across multiple scales. This paper presents a qualitative assessment of the role of geospatial technologies in achieving SDGs in India, with a focus on selected goals such as SDG 1 (No Poverty), SDG 5 (Gender Equality), SDG 10 (Reduced Inequalities), SDG 11 (Sustainable Cities), and SDG 13 (Climate Action).

The study adopts a qualitative methodology based on policy analysis, secondary data interpretation, and case study evaluation of national initiatives such as the SDG India Index, geospatial platforms, and governance frameworks. It highlights how spatial data enables the identification of regional disparities, supports evidence-based decision-making, and enhances targeted interventions. However, the study also identifies critical challenges, including data gaps at the micro levels, limited integration of geospatial tools in local governance, and digital inequality.

The findings suggest that while geospatial technologies offer transformative potential for achieving SDGs, their effectiveness depends on institutional capacity, policy integration, and participatory approaches. The paper concludes with recommendations for strengthening geospatial governance and promoting inclusive development through spatial planning.

Keywords: *SDGs, GIS, Remote Sensing, Spatial Inequality, Geospatial Governance, India, Sustainable Development*

Introduction

The adoption of the Sustainable Development Goals (SDGs) in 2015 by the United Nations marked a significant shift in global development thinking, emphasising an integrated approach to economic growth, social inclusion, and environmental sustainability. Unlike earlier frameworks, the SDGs recognise that development challenges are interconnected and must be addressed through holistic and inclusive strategies. The principle of "leaving no one behind" underscores the importance of reducing inequalities and ensuring equitable access to resources and opportunities (United Nations, 2015).

In the Indian context, the implementation of SDGs is particularly complex due to the country's vast geographical diversity and socio-economic disparities. Regional imbalances in income, infrastructure, education, and health outcomes highlight the uneven nature of development across states, districts, and communities. While some regions have achieved significant progress in industrialisation and urban development, others continue to face persistent challenges related to poverty, environmental degradation, and limited access to basic services (Kundu, 2014).

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These disparities are not only economic but also spatial, necessitating approaches that incorporate geographic analysis into development planning.

To coordinate and monitor SDG implementation, the NITI Aayog has been designated as the central agency in India. It has developed tools such as the SDG India Index and Dashboard, which provide a framework for assessing progress across states and union territories (NITI Aayog, 2023). While these tools offer valuable insights at the macro level, they often fail to capture micro-level variations within regions, thereby limiting their effectiveness in addressing localised challenges.

In this context, geospatial technologies—particularly Geographic Information Systems (GIS) and Remote Sensing—have emerged as critical tools for enhancing development planning and policy-making. These technologies enable the collection, analysis, and visualisation of spatial data, allowing policymakers to identify patterns, monitor changes, and make informed decisions. By addressing the fundamental questions of "where" and "how," geospatial technologies help bridge the gap between data and actionable policy (Goodchild, 2007).

The application of geospatial technologies in India has expanded significantly in recent years. Initiatives such as the Smart Cities Mission, Digital India, and disaster management programs have incorporated GIS-based tools for infrastructure planning, service delivery, and risk assessment. For example, remote sensing data is used to monitor land use changes and environmental conditions, while GIS is employed to map urban infrastructure and service accessibility (Campbell & Wynne, 2011). These applications are particularly relevant for achieving SDGs related to sustainable cities (SDG 11), climate action (SDG 13), and reduced inequalities (SDG 10).

Despite their potential, the integration of geospatial technologies into SDG implementation remains uneven. Challenges such as data fragmentation, limited technical capacity at local levels, and the digital divide hinder their effective use. Moreover, the reliance on aggregated data often overlooks marginalised communities, raising concerns about inclusivity and representation in spatial planning (UNDP, 2021).

Given these challenges, there is a need for a critical examination of the role of geospatial technologies in achieving SDGs in India. This study aims to provide a qualitative assessment of how these technologies are used in policy and practice, while also analysing their implications for spatial inequality. By focusing on the intersection of technology, governance, and development, the paper seeks to contribute to a more nuanced understanding of geospatial approaches in sustainable development.

Research Gap

Despite the increasing emphasis on Sustainable Development Goals (SDGs) in India and the growing adoption of geospatial technologies in development planning, several critical gaps remain in existing research and policy practice. These gaps limit the effective integration of spatial tools into SDG implementation and highlight the need for more nuanced and grounded analysis.

One major gap lies in the **scale of analysis used in SDG assessments**. Instruments such as the SDG India Index developed by NITI Aayog primarily provide state-level comparisons. While useful for broad benchmarking, such aggregate assessments often fail to capture **intra-state and local-level disparities**, including variations at district, block, and settlement levels (NITI Aayog, 2023). As a result, localised pockets of deprivation—such as informal settlements, tribal areas, and peri-urban regions—remain insufficiently represented in development planning.

A second gap concerns the **limited integration of geospatial technologies with SDG frameworks**. Although Geographic Information Systems (GIS) and Remote Sensing are widely used for mapping and environmental monitoring, their application in SDG-related studies often remains descriptive and technical. There is a lack of research that connects spatial analysis with **policy outcomes, governance processes, and development interventions**. This creates a disconnect between the availability of spatial data and its practical use in decision-making.

Third, existing literature tends to adopt a **techno-centric approach**, focusing on tools and methodologies rather than the institutional and socio-political contexts in which they operate. There is limited qualitative research examining how geospatial technologies are used by different stakeholders, including government agencies, local bodies, and communities. This results in an incomplete understanding of the **governance challenges and operational constraints** associated with geospatial implementation.

Another important gap relates to **inclusivity and data representation**. Despite the SDG commitment to equity, many geospatial datasets lack **gender-disaggregated and socially differentiated data**, leading to the underrepresentation of marginalised groups such as women, migrants, and informal workers. This "data invisibility" restricts the ability to address inequalities effectively and may result in policies that overlook vulnerable populations (Taylor, 2017).

Furthermore, there is a gap in the **localisation of geospatial technologies** within India's decentralised governance framework. While national-level initiatives have adopted advanced spatial tools, their use at the state and local levels remains limited due to constraints in technical capacity, infrastructure, and financial resources (UNDP, 2021). This creates a disconnect between top-down policy frameworks and bottom-up implementation.

In addition, issues of **data fragmentation and lack of interoperability** across government departments hinder comprehensive spatial analysis. Different agencies often maintain separate datasets with varying standards, making integration difficult and reducing the effectiveness of geospatial applications.

In light of these gaps, this study aims to provide a **qualitative and policy-oriented analysis** of geospatial technologies in SDG implementation in India. It seeks to bridge the divide between technical capabilities and

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governance realities by focusing on spatial inequality, inclusivity, and institutional challenges.

Literature Review

The concept of sustainable development has evolved significantly over the past few decades, culminating in the adoption of the Sustainable Development Goals (SDGs) by the United Nations in 2015. The SDGs represent a comprehensive framework that integrates economic growth, social inclusion, and environmental sustainability. Scholars such as Sachs (2015) emphasise that achieving these goals requires not only policy commitment but also the use of advanced tools and data-driven approaches to address complex development challenges.

Geospatial technologies, particularly Geographic Information Systems (GIS) and Remote Sensing, have been widely recognised as essential tools in this regard. According to Goodchild (2007), GIS provides a framework for integrating spatial data into decision-making processes, enabling the analysis of relationships between human and environmental systems. Similarly, remote sensing offers the capability to monitor changes in land use, vegetation, and climate variables over time, making it a valuable resource for environmental management and disaster risk reduction (Campbell & Wynne, 2011).

A growing body of literature highlights the role of geospatial technologies in supporting SDG monitoring and implementation. Anderson et al. (2017) argue that Earth observation data can significantly enhance the measurement of SDG indicators, particularly in regions where conventional data collection methods are limited. The integration of geospatial data with statistical systems allows for more accurate and timely monitoring of development outcomes, thereby improving policy effectiveness.

In the Indian context, the NITI Aayog has played a central role in institutionalising SDG monitoring through the development of the SDG India Index. This index provides a comparative assessment of states and union territories, promoting competitive federalism and encouraging policy innovation (NITI Aayog, 2023). However, scholars have pointed out that such indices often lack spatial granularity and may not adequately capture local-level disparities (Kumar & Pathak, 2020).

Urban studies literature further emphasises the persistence of spatial inequality in India. Kundu (2014) highlights that rapid urbanisation has led to uneven development, with significant disparities in access to infrastructure and services between formal and informal settlements. Geospatial technologies have been used to map these inequalities, enabling targeted interventions in areas such as housing, transportation, and public services.

Another important strand of literature focuses on the governance and institutional aspects of geospatial technologies. Bennett et al. (2016) discuss the challenges of data accessibility, interoperability, and coordination among different agencies. These issues are particularly relevant in developing countries, where institutional capacity and digital infrastructure may be limited.

Recent scholarship has also introduced the concept of **data justice**, which emphasises the need for equitable access to data and inclusive representation in spatial datasets (Taylor, 2017). This perspective highlights that geospatial technologies are not neutral tools but are shaped by social and political contexts. The lack of disaggregated data on marginalised groups can lead to their exclusion from policy processes, undermining the goals of inclusive development.

Overall, the literature underscores the significant potential of geospatial technologies in achieving SDGs while also pointing to critical challenges related to data quality, governance, and inclusivity. However, there remains a need for more integrated and qualitative approaches that connect spatial analysis with policy implementation and social realities. This study seeks to address this gap by examining the role of geospatial technologies in India through a comprehensive and context-specific lens.

Objectives and Research Questions

Objectives

The present study aims to critically examine the role of geospatial technologies in achieving Sustainable Development Goals (SDGs) in India, with a particular focus on spatial inequality, governance, and policy implementation. The specific objectives of the study are as follows:

1. **To analyse the role of geospatial technologies** such as Geographic Information Systems (GIS) and Remote Sensing in monitoring and implementing SDGs in India.
2. **To examine spatial patterns of inequality** in development indicators across regions, including inter-state and intra-state disparities.
3. **To evaluate policy frameworks and institutional mechanisms** developed by agencies such as NITI Aayog for integrating geospatial tools into SDG monitoring.
4. **To assess the effectiveness of geospatial technologies in governance and planning**, particularly in addressing issues related to urban development, climate risk, and service delivery.
5. **To identify key challenges and limitations** in the use of geospatial technologies, including data gaps, technical capacity constraints, and issues of accessibility.
6. **To explore the inclusivity dimension of geospatial data**, focusing on the representation of marginalised groups such as women, migrants, and informal sector populations.
7. **To suggest policy recommendations** for strengthening the integration of geospatial technologies into SDG implementation more inclusively and effectively.

Research Questions

Based on the above objectives, the study seeks to address the following research questions:

1. How are geospatial technologies being utilised in the implementation and monitoring of SDGs in India?
2. What are the major spatial inequalities in development indicators across different regions, and how can geospatial tools help in identifying them?

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3. How effective are existing policy frameworks and institutional mechanisms in integrating geospatial technologies into development planning?
4. What challenges hinder the adoption and effective use of geospatial technologies at the national, state, and local levels?
5. To what extent do current geospatial datasets and applications address issues of inclusivity and representation of marginalised communities?
6. How can geospatial technologies be leveraged to improve governance, decision-making, and policy outcomes in the context of sustainable development?

Methodology

This study adopts a **qualitative and analytical research approach** to examine the role of geospatial technologies in achieving Sustainable Development Goals (SDGs) in India. Given the complex and multi-dimensional nature of the subject, the methodology focuses on interpreting policies, institutional practices, and spatial patterns rather than relying solely on quantitative measurements.

1 Research Approach

The study is based on a **qualitative research design**, which allows for an in-depth understanding of the relationship between geospatial technologies, governance frameworks, and spatial inequality. This approach is particularly suitable for exploring issues such as policy implementation, institutional challenges, and inclusivity, which cannot be fully captured through numerical data alone.

2 Data Sources

The research relies primarily on **secondary data**, collected from a range of authoritative sources, including:

- Government reports such as the SDG India Index published by NITI Aayog
- Reports from international organisations such as the United Nations and UNDP
- Academic journals, books, and research articles on GIS, Remote Sensing, and sustainable development
- Policy documents related to programs such as Smart Cities Mission and Digital India

These sources provide a comprehensive understanding of both the theoretical and practical aspects of geospatial technologies in development.

3 Methods of Analysis

The study employs the following methods of analysis:

a) Policy Analysis

A critical review of national and state-level policy frameworks has been conducted to understand how geospatial technologies are integrated into SDG implementation. This includes analysing the structure, objectives, and outcomes of initiatives such as the SDG India Index and geospatial governance policies.

b) Thematic Analysis

Thematic analysis is used to identify key themes emerging from the literature and reports. These themes include spatial inequality, data governance, inclusivity, digital divide, and institutional capacity. This method helps in organising and interpreting qualitative information systematically.

c) Case Study Approach

Selected case studies, such as the Smart Cities Mission and district-level SDG monitoring initiatives, are used to illustrate the practical application of geospatial technologies. These case studies provide insights into both the opportunities and challenges associated with real-world implementation.

5.4 Scope of the Study

The study focuses on India at multiple spatial scales, including national, state, and local levels. It examines selected SDGs that have strong spatial dimensions, such as:

- SDG 10 (Reduced Inequalities)
- SDG 11 (Sustainable Cities and Communities)
- SDG 13 (Climate Action)

The emphasis is on understanding how geospatial technologies contribute to addressing spatial disparities and improving governance.

5 Limitations of the Study

While the study provides valuable insights, it has certain limitations:

- It relies on secondary data, which may not capture real-time or ground-level variations
- The qualitative approach limits the use of statistical validation
- Availability of disaggregated spatial data remains a constraint

Despite these limitations, the study offers a comprehensive and critical perspective on the role of geospatial technologies in sustainable development.

Geospatial Technologies and SDG Monitoring in India

Geospatial technologies, including Geographic Information Systems (GIS), Remote Sensing, and Global Positioning Systems (GPS), have emerged as critical tools for monitoring and implementing Sustainable Development Goals (SDGs) in India. These technologies enable the integration, visualisation, and analysis of spatial data, thereby supporting **evidence-based policy-making and targeted interventions** across multiple sectors.

In India, the institutional framework for SDG monitoring is led by NITI Aayog, which has developed the SDG India Index and Dashboard as a key instrument for tracking progress. The index compiles data across various indicators related to health, education, environment, and economic development, providing a comparative assessment of states and union territories (NITI Aayog, 2023). While the index itself is largely statistical, geospatial technologies play a supporting role in **mapping and visualising these indicators**, thereby enabling policymakers to understand regional disparities more effectively.

One of the major contributions of geospatial technologies in SDG monitoring is their ability to provide **spatially disaggregated data**. Unlike traditional statistical methods, GIS allows for the analysis of development indicators at finer scales, such as districts, blocks, and even individual settlements. This is particularly important in a country like India, where development outcomes vary significantly within regions. For instance, district-level SDG monitoring initiatives in states such as Assam and Odisha have utilised GIS-based platforms to identify areas with poor

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performance in health, education, and infrastructure, enabling more targeted policy interventions.

Case Study: District-Level SDG Monitoring in the North-Eastern Region

A notable example of geospatial integration is the development of district-level SDG indices in the North-Eastern region of India. These indices combine socio-economic data with spatial mapping to provide localised insights into development patterns. The findings indicate that while many districts have achieved "front-runner" status, there are still significant variations within and across states. Geospatial visualisation of these disparities helps policymakers identify priority areas and allocate resources more efficiently.

Geospatial technologies also play a crucial role in **urban planning and service delivery**, particularly in the context of SDG 11 (Sustainable Cities and Communities). Under initiatives such as the Smart Cities Mission, cities have adopted GIS-based platforms for infrastructure management, traffic monitoring, waste management, and public service delivery. These systems enable real-time data collection and analysis, improving the efficiency and responsiveness of urban governance.

In the environmental domain, Remote Sensing is widely used for monitoring land use and land cover changes, deforestation, water resources, and climate-related risks. Such applications are essential for achieving SDG 13 (Climate Action) and SDG 15 (Life on Land). Satellite imagery provides temporal data that can track environmental changes over time, supporting disaster risk assessment and climate adaptation strategies (Campbell & Wynne, 2011).

Another important application of geospatial technologies is in **disaster management and early warning systems**. GIS-based flood mapping, cyclone tracking, and drought monitoring have enhanced India's capacity to respond to natural hazards. These tools enable the identification of vulnerable areas and populations, facilitating timely interventions and reducing the impact of disasters.

Despite these advancements, the integration of geospatial technologies into SDG monitoring faces several challenges. One major issue is the **lack of standardised and interoperable data systems**, which limits the integration of datasets across sectors. Additionally, while central agencies have developed advanced geospatial platforms, their adoption at the state and local levels remains uneven due to constraints in technical capacity and infrastructure.

In Sum, geospatial technologies have significantly enhanced the ability to monitor and implement SDGs in India by providing spatial insights into development processes. However, their full potential can only be realised through improved data integration, capacity building, and institutional coordination.

Spatial Inequality and SDGs in India

Spatial inequality is one of the most critical challenges in achieving Sustainable Development Goals (SDGs) in India. Despite significant economic growth and policy interventions, development outcomes remain unevenly distributed across regions, reflecting disparities in income, infrastructure, access to services, and environmental conditions. These inequalities are not only inter-state but also intra-state, often visible at district, block, and neighbourhood levels.

The SDG framework explicitly emphasises the need to "leave no one behind," yet spatial disparities continue to hinder progress toward this objective. The SDG India Index developed by NITI Aayog highlights variations in performance across states, with some regions consistently ranking higher in indicators related to health, education, and economic development, while others lag (NITI Aayog, 2023). However, such macro-level assessments often conceal **micro-level inequalities**, particularly in marginalised and remote areas.

One of the most prominent manifestations of spatial inequality in India is the **rural–urban divide**. Urban areas generally have better access to infrastructure, healthcare, education, and employment opportunities, whereas rural regions often face deficits in basic services. Even within cities, disparities exist between formal urban areas and informal settlements, where residents experience inadequate housing, limited access to clean water, sanitation, and healthcare facilities (Kundu, 2014). These patterns highlight the need for spatially targeted interventions to address urban inequality under SDG 11.

Case Study: Urban Inequality in Metropolitan Cities

In major metropolitan cities such as Delhi and Mumbai, geospatial mapping has revealed stark contrasts between planned urban neighbourhoods and informal settlements. GIS-based analysis of service accessibility shows that slum areas often have significantly lower access to essential services such as healthcare centres, schools, and public transport. Such spatial analysis helps policymakers identify underserved zones and prioritise resource allocation.

Another dimension of spatial inequality is observed in **regional disparities across states**. States in southern and western India generally perform better on SDG indicators compared to several states in central and eastern regions. These differences are influenced by factors such as governance capacity, historical development patterns, and resource availability. Geospatial technologies enable the visualisation of these disparities, providing insights into the spatial clustering of development outcomes.

Case Study: Regional Disparities in SDG Performance

Recent SDG assessments indicate that states like Kerala and Tamil Nadu have achieved higher scores in health and education indicators, while states such as Bihar and Jharkhand continue to face challenges in poverty reduction and infrastructure development. Mapping these variations through GIS helps in identifying "hotspots" of underdevelopment and designing targeted policy interventions.

Environmental inequality also contributes to spatial disparities. Regions prone to natural hazards, such as floods, droughts, and cyclones, often experience lower development outcomes due to recurring disruptions. Geospatial tools such as hazard mapping and vulnerability analysis are essential for understanding these patterns and integrating risk reduction into development planning.

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Furthermore, **peri-urban areas** represent an emerging dimension of spatial inequality. These transitional zones between rural and urban areas often lack adequate infrastructure and governance, resulting in uneven access to services. Geospatial mapping of these regions can help in planning for sustainable urban expansion and reducing inequalities.

Despite the potential of geospatial technologies, their application in addressing spatial inequality is constrained by data limitations and governance challenges. The lack of high-resolution and disaggregated data restricts the ability to capture localised variations, while institutional barriers limit the integration of spatial analysis into policy-making processes.

This sums up as spatial inequality remains a significant barrier to achieving SDGs in India. Geospatial technologies offer valuable tools for identifying and analysing these disparities, but their effectiveness depends on the availability of data, institutional capacity, and inclusive governance frameworks. Addressing spatial inequality requires a combination of technological innovation and policy interventions aimed at ensuring equitable development across regions.

Geospatial Technologies and Climate Action (SDG 13)

Climate change represents one of the most pressing challenges to sustainable development, with significant implications for ecosystems, economies, and human livelihoods. In India, the impacts of climate change are particularly severe due to the country's diverse geography and high dependence on climate-sensitive sectors such as agriculture, water resources, and fisheries. Achieving SDG 13 (Climate Action), therefore, requires robust monitoring systems, risk assessment frameworks, and adaptive strategies, all of which are increasingly supported by geospatial technologies.

Geospatial technologies, including GIS and Remote Sensing, play a crucial role in **climate monitoring, vulnerability assessment, and disaster risk management**. These tools enable the collection and analysis of spatial and temporal data related to environmental changes, such as variations in temperature, precipitation, land use, and vegetation cover. Satellite-based remote sensing, in particular, provides continuous and large-scale observations, making it indispensable for tracking climate-related changes over time (Campbell & Wynne, 2011).

One of the key applications of geospatial technologies in climate action is **land use and land cover (LULC) analysis**. Changes in land use, such as deforestation, urban expansion, and agricultural intensification, have direct implications for carbon emissions and environmental sustainability. GIS-based mapping of LULC patterns helps in identifying areas undergoing rapid environmental change, thereby supporting mitigation strategies such as afforestation and sustainable land management.

Case Study: Forest Monitoring and Carbon Management

India utilises satellite imagery to monitor forest cover under national programs such as the Forest Survey of India. Geospatial analysis has enabled the identification of changes in forest density and extent, providing critical inputs for climate mitigation policies and carbon accounting. These efforts contribute to India's commitments under international climate agreements and support SDG 13 and SDG 15 (Life on Land).

Another important application is in **disaster risk management**, particularly in the context of floods, droughts, cyclones, and landslides. GIS-based hazard mapping allows for the identification of vulnerable areas and populations, enabling early warning systems and disaster preparedness. For example, flood-prone regions in states like Assam and Bihar are regularly monitored using satellite data, which helps in forecasting flood events and planning evacuation strategies.

Case Study: Flood Mapping in the Ganga Basin

Geospatial technologies have been extensively used to map flood-prone areas in the Ganga basin. By integrating satellite imagery with hydrological models, researchers and government agencies can predict flood extents and assess potential impacts on settlements and agriculture. This information is crucial for disaster preparedness and resilience building, particularly in regions with high population density and vulnerability.

Geospatial tools are also used for **drought monitoring and agricultural planning**. Remote sensing data on soil moisture, vegetation indices, and rainfall patterns help in assessing drought conditions and guiding agricultural practices. This is particularly important for ensuring food security and supporting farmers in adapting to changing climatic conditions.

In addition, geospatial technologies support **urban climate resilience** by enabling the mapping of urban heat islands, air pollution levels, and green spaces. Such analyses help in designing climate-resilient urban infrastructure and promoting sustainable urban planning.

Despite their significant potential, the application of geospatial technologies in climate action faces several challenges. These include **limited integration of environmental and socio-economic data**, which restricts comprehensive vulnerability assessments. Furthermore, the lack of technical capacity and infrastructure at local levels limits the effective use of these tools in climate planning.

So, basically, geospatial technologies play a vital role in advancing climate action in India by providing tools for monitoring environmental changes, assessing risks, and supporting adaptive strategies. However, their effectiveness depends on improved data integration, capacity building, and the incorporation of local knowledge into climate planning processes.

Gender and Inclusivity in Geospatial SDG Implementation

Gender equality (SDG 5) and reduced inequalities (SDG 10) are central to the Sustainable Development Goals, yet their achievement in India remains uneven due to deep-rooted socio-economic and spatial disparities. Gender and inclusivity are not only social issues but also **spatial concerns**, as access to resources, services, and opportunities varies significantly across regions and communities. In this context, geospatial technologies offer important tools for identifying and addressing these inequalities, although their application remains limited and uneven.

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Geospatial technologies such as GIS and Remote Sensing enable the mapping and analysis of **service accessibility**, which is crucial for understanding gendered disparities. For example, spatial analysis of healthcare facilities, schools, and public transport networks can reveal whether women and marginalised groups have equitable access to essential services. In many rural and peri-urban areas, women face constraints related to distance, safety, and mobility, which limit their access to education and healthcare. GIS-based accessibility models help in quantifying these barriers and identifying underserved areas.

Case Study: Maternal Health Accessibility in Rural India

Studies using GIS have mapped the distribution of maternal healthcare facilities in states such as Uttar Pradesh and Bihar, revealing significant gaps in access for rural women. By analysing travel distance and time to the nearest health centre, researchers have identified regions where maternal mortality risks are higher due to inadequate healthcare infrastructure (Kumar & Pathak, 2020). Such spatial insights support targeted interventions under programs like the National Health Mission.

Another important dimension of inclusivity is the **representation of marginalised groups in spatial data**. Despite advances in geospatial technologies, most datasets are aggregated at household or administrative levels, failing to capture intra-household inequalities or differences based on gender, caste, and occupation. This leads to what is often described as **"data invisibility,"** where vulnerable populations remain underrepresented in policy planning (Taylor, 2017). As a result, development interventions may not adequately address the needs of these groups.

Geospatial technologies also have the potential to support **inclusive urban planning**, particularly in addressing inequalities in informal settlements. Women and marginalised communities in slums often face limited access to sanitation, water, and safe public spaces. Mapping these areas using GIS helps in identifying service gaps and planning infrastructure improvements under urban development programs.

Case Study: Inclusivity in Urban Slum Mapping

In cities like Mumbai and Delhi, GIS-based mapping of informal settlements has been used to identify areas lacking basic services. These maps highlight disparities in access to sanitation, clean water, and healthcare, which disproportionately affect women and children. Such spatial analysis supports targeted interventions aimed at improving living conditions in marginalised urban communities (Kundu, 2014).

Participatory approaches such as **Participatory GIS (PGIS)** further enhance inclusivity by involving communities in data collection and mapping. These approaches allow local populations, including women, to contribute their knowledge and perspectives, thereby improving the accuracy and relevance of spatial data. Community mapping initiatives in rural and tribal areas have demonstrated the potential of PGIS in empowering marginalised groups and ensuring that their needs are reflected in development planning (UNDP, 2021).

However, several challenges limit the effectiveness of geospatial technologies in promoting gender and social inclusivity. The lack of gender-disaggregated data, limited technical capacity, and unequal access to digital tools restrict the use of these technologies in inclusive planning. Additionally, institutional frameworks often do not prioritise inclusivity in spatial data collection and analysis.

In conclusion, geospatial technologies offer significant potential for addressing gender and social inequalities by providing spatial insights into the access and distribution of resources. However, realising this potential requires the integration of **inclusive data practices, participatory approaches, and gender-sensitive indicators** into geospatial systems. Without such measures, there is a risk that technological advancements may reinforce existing inequalities rather than reduce them.

Challenges in Geospatial Governance

The effective use of geospatial technologies in achieving Sustainable Development Goals (SDGs) in India is significantly shaped by governance structures, institutional capacity, and policy frameworks. While the country has made notable progress in adopting GIS and Remote Sensing for development planning, several **structural and operational challenges** continue to limit its full potential. These challenges are not only technical but also institutional and socio-economic in nature.

One of the primary challenges is **data fragmentation and a lack of interoperability**. Geospatial data in India is generated by multiple agencies across sectors such as agriculture, urban development, health, and environment. However, these datasets are often stored in different formats and lack standardisation, making integration difficult. The absence of a unified spatial data infrastructure restricts the ability to conduct comprehensive, cross-sectoral analysis, which is essential for achieving the integrated nature of SDGs.

Another major issue is the **limited technical capacity at sub-national levels**. While central institutions and specialised agencies possess advanced geospatial capabilities, state and local governments often lack trained personnel, adequate infrastructure, and financial resources. This results in a gap between **data availability and its effective utilisation**, particularly in rural and remote areas. Consequently, many local bodies are unable to leverage geospatial technologies for planning and decision-making.

Case Study: Smart Cities Mission

The Smart Cities Mission provides an important example of both the opportunities and challenges in geospatial governance. Cities such as Pune and Bhubaneswar have successfully implemented GIS-based platforms for urban planning, traffic management, and service delivery. However, several other cities have struggled to adopt these technologies due to limited technical expertise, lack of coordination between departments, and inadequate infrastructure (Kundu, 2014). This uneven implementation highlights the disparities in governance capacity across regions.

The **digital divide** further complicates the adoption of geospatial technologies. Access to digital infrastructure, including high-speed internet and advanced

computing systems, remains uneven across India. Rural and marginalised regions often lack the necessary connectivity, limiting their ability to access and use geospatial data. This creates a paradox where technologies intended to promote inclusive development may inadvertently **reinforce existing inequalities** (UNDP, 2021).

Institutional fragmentation and lack of coordination between government agencies also pose significant challenges. Development planning in India is often carried out in a **sectoral manner**, with limited integration across departments. Geospatial technologies, however, require a cross-sectoral approach, as they involve the integration of data from multiple domains. The absence of effective coordination mechanisms results in duplication of efforts and inefficient use of resources.

Policy and regulatory constraints represent another important dimension of geospatial governance challenges. Although recent reforms have aimed to liberalise access to geospatial data, issues related to **data privacy, security, and standardisation** remain unresolved. The lack of clear guidelines for data sharing and usage limits the potential for collaboration between government agencies, the private sector, and research institutions.

Additionally, there is a lack of emphasis on **inclusive data governance**. Marginalised communities are often underrepresented in spatial datasets, and their participation in data collection and decision-making processes is limited. This raises concerns about equity and representation, particularly in the context of SDGs, which emphasise inclusivity and social justice.

Finally, the absence of strong monitoring and evaluation mechanisms for geospatial initiatives reduces accountability and limits the ability to assess their impact on development outcomes. Without systematic evaluation, it becomes difficult to identify best practices and scale successful models.

This means the challenges in geospatial governance in India are multi-dimensional, encompassing technical, institutional, and socio-economic factors. Addressing these challenges requires a coordinated approach that includes **capacity building, policy reform, data standardisation, and inclusive governance practices**. Strengthening geospatial governance is essential for ensuring that these technologies effectively contribute to achieving SDGs sustainably and equitably.

Discussion

The analysis of geospatial technologies in the context of Sustainable Development Goals (SDGs) in India reveals a complex interplay between **technological potential, governance structures, and spatial inequalities**. While geospatial tools such as GIS and Remote Sensing have significantly enhanced the capacity for data collection, visualisation, and analysis, their effectiveness in achieving SDGs depends largely on how they are integrated into policy frameworks and institutional practices.

A key insight emerging from this study is that geospatial technologies have strengthened **evidence-based decision-making** in development planning. Initiatives led by NITI Aayog, particularly the SDG India Index, have created a foundation for monitoring progress and identifying regional disparities. When complemented with spatial analysis, these tools allow policymakers to move beyond aggregate statistics and engage with the **geographical dimensions of development**, such as identifying underserved districts or vulnerable populations.

However, the discussion also highlights that the use of geospatial technologies remains **uneven across spatial and institutional scales**. While central agencies and some urban regions have successfully adopted advanced geospatial systems, their application at the state and local levels is limited. This reflects disparities in technical capacity, infrastructure, and governance, which in turn reinforce existing spatial inequalities. For instance, while some cities under the Smart Cities Mission have effectively utilised GIS for service delivery, others have struggled due to institutional and technical constraints.

Another important dimension is the role of geospatial technologies in addressing **spatial inequality**. The findings demonstrate that these tools are highly effective in mapping disparities in access to services, infrastructure, and environmental resources. By visualising such inequalities, geospatial analysis can support targeted interventions aimed at reducing disparities. However, the lack of high-resolution and disaggregated data often limits the ability to capture micro-level variations, particularly in informal settlements and rural areas.

The discussion also underscores the significance of **climate action and environmental sustainability** in the application of geospatial technologies. GIS-based mapping of climate risks, land use changes, and disaster-prone areas has enhanced India's capacity for disaster preparedness and environmental management. Nevertheless, the integration of environmental data with socio-economic indicators remains limited, reducing the effectiveness of these tools in addressing vulnerability comprehensively.

A critical issue that emerges is the challenge of **inclusivity and data representation**. Despite the potential of geospatial technologies to support equitable development, the absence of gender-disaggregated and socially differentiated data results in the underrepresentation of marginalised groups. This aligns with the concept of **data justice**, which emphasises that access to and control over data are inherently linked to power relations (Taylor, 2017). Without inclusive data practices, geospatial technologies risk reinforcing existing inequalities rather than mitigating them.

Furthermore, the study highlights the importance of **institutional coordination and governance frameworks** in determining the success of geospatial integration. The fragmented nature of data systems and the lack of interoperability across departments hinder the effective use of spatial data in policy-making. This suggests that technological advancements must be accompanied by institutional reforms that promote collaboration, data sharing, and capacity building.

Another key insight is the need to move beyond **technocratic approaches** and adopt a more holistic perspective that incorporates social, political, and cultural dimensions. Geospatial technologies should not be viewed

merely as technical tools but as part of broader socio-technical systems that influence development outcomes. Participatory approaches, such as community-based mapping, can enhance the inclusivity and relevance of spatial data, ensuring that development planning reflects local needs and realities.

In summary, the discussion highlights that while geospatial technologies offer significant opportunities for advancing SDGs in India, their impact is contingent upon **inclusive governance, institutional capacity, and data accessibility**. Bridging the gap between technological potential and practical implementation requires a coordinated effort that integrates spatial analysis with policy frameworks and community participation. Only through such an approach can geospatial technologies contribute effectively to sustainable and equitable development.

Conclusion

This study has examined the role of geospatial technologies in achieving Sustainable Development Goals (SDGs) in India through a qualitative assessment of policy frameworks, institutional practices, and spatial inequalities. The analysis highlights that technologies such as Geographic Information Systems (GIS) and Remote Sensing have emerged as powerful tools for **mapping, monitoring, and managing development processes** in a spatially diverse country like India.

The findings demonstrate that geospatial technologies significantly enhance **evidence-based decision-making** by enabling the visualisation of regional disparities, identification of vulnerable areas, and monitoring of progress across multiple development indicators. Initiatives led by NITI Aayog, particularly the SDG India Index, have provided a structured framework for assessing performance and promoting cooperative federalism. When combined with spatial analysis, such tools offer deeper insights into the geographic dimensions of development, facilitating more targeted and context-specific interventions.

However, the study also reveals that the integration of geospatial technologies into SDG implementation remains **uneven and constrained** by several challenges. Issues such as data fragmentation, lack of interoperability, limited technical capacity at local levels, and the digital divide restrict the effective use of spatial data in governance. Moreover, the reliance on aggregated datasets often obscures micro-level inequalities, particularly in rural areas, informal settlements, and marginalised communities.

A critical concern highlighted in the study is the issue of **inclusivity and representation**. The absence of gender-disaggregated and socially differentiated spatial data leads to the underrepresentation of vulnerable groups, thereby limiting the effectiveness of development interventions. Without addressing these gaps, there is a risk that geospatial technologies may reinforce existing inequalities rather than reduce them.

The study further underscores that geospatial technologies, while essential, are not standalone solutions. Their effectiveness depends on the broader **institutional and governance context** in which they are embedded. Successful implementation requires not only technological innovation but also strong policy frameworks, institutional coordination, and capacity building at all levels of governance.

In conclusion, geospatial technologies hold significant potential to contribute to the achievement of SDGs in India by providing tools for spatial analysis, monitoring, and planning. However, realising this potential requires a **holistic and inclusive approach** that integrates technology with governance, social equity, and local participation. Strengthening geospatial governance, improving data accessibility, and promoting inclusive practices are essential for ensuring that these technologies effectively support sustainable and equitable development.

Recommendations

Based on the analysis of geospatial technologies in achieving Sustainable Development Goals (SDGs) in India, several policy and strategic recommendations can be proposed to enhance their effectiveness, inclusivity, and integration into governance frameworks.

1. Strengthening Spatial Data Infrastructure

There is a need to develop a **comprehensive and standardised geospatial data infrastructure** at the national and sub-national levels. Government agencies should adopt uniform data formats, metadata standards, and interoperability protocols to ensure seamless integration across sectors. Strengthening coordination under institutions such as NITI Aayog can facilitate better data sharing and policy alignment.

2. Enhancing Local-Level Capacity

Capacity building at the state, district, and local levels is essential for effective utilisation of geospatial technologies. This includes:

- Training government officials in GIS and Remote Sensing
- Establishing dedicated geospatial units in local bodies
- Providing technical and financial support for infrastructure development

Empowering local institutions will help bridge the gap between data availability and its practical application.

3. Promoting Open Data and Accessibility

To improve transparency and inclusivity, the government should promote **open access to geospatial data**. Open data policies can enable researchers, civil society, and private sector stakeholders to contribute to SDG monitoring and innovation. At the same time, clear guidelines must be established to address concerns related to data privacy and security.

4. Integrating Geospatial Technologies into Policy Planning

Geospatial tools should be systematically integrated into development planning processes across sectors such as urban development, health, agriculture, and disaster management. This requires:

- Embedding GIS-based analysis in policy formulation
- Using spatial data for resource allocation and prioritisation
- Linking SDG indicators with geospatial datasets for better monitoring

5. Ensuring Inclusivity in Spatial Data

Efforts must be made to incorporate **gender-disaggregated and socially differentiated data** into geospatial systems. This includes:

- Mapping marginalised communities such as women, migrants, and informal workers
- Using participatory approaches like community mapping and Participatory GIS (PGIS)
- Developing indicators that capture social and spatial inequalities

Such measures will ensure that development interventions are more equitable and inclusive.

6. Bridging the Digital Divide

Addressing the digital divide is crucial for equitable access to geospatial technologies. Investments in digital infrastructure, particularly in rural and remote areas, are necessary to ensure that all regions can benefit from technological advancements. This includes expanding internet connectivity and providing access to digital tools and platforms.

7. Strengthening Institutional Coordination

Effective geospatial governance requires **collaboration across departments and agencies**. Establishing inter-agency coordination mechanisms and data-sharing platforms can reduce duplication of efforts and improve efficiency. Integrated planning approaches should be encouraged to address the multi-dimensional nature of SDGs.

8. Encouraging Public–Private Partnerships

Partnerships between government, private sector, and academic institutions can enhance innovation and resource availability in geospatial applications. Collaborations can support the development of advanced tools, data analytics, and capacity-building initiatives.

9. Monitoring and Evaluation of Geospatial Initiatives

Regular monitoring and evaluation of geospatial programs are essential to assess their impact on SDG outcomes. Developing performance indicators and feedback mechanisms can help identify best practices and improve implementation strategies.

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I am also thankful to my institution and the concerned department for providing me with the opportunity, academic resources, and a supportive environment necessary to undertake this study. The facilities and encouragement offered by the institution played an important role in the successful completion of this project.

I would like to acknowledge the contributions of researchers, policymakers, geographers, planners, and scholars whose work in the fields of geospatial technology, remote sensing, GIS, sustainable development, public policy, and regional inequality provided the conceptual and analytical foundation for this project. Their studies and insights helped me understand how geospatial tools can support evidence-based planning, resource management, environmental monitoring, and policy implementation for achieving the Sustainable Development Goals in India, while also revealing persistent challenges related to spatial inequality, accessibility, and governance.

I am deeply grateful to my family and friends for their continuous encouragement, patience, and moral support during the completion of this project. Their support motivated me to remain focused and dedicated throughout the research process.

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Original Article

Study of the Magna Carta of 1215 and the origin of fundamental rights

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Abstract

The Magna Carta of 1215 is widely regarded as one of the most significant documents in the history of constitutional development and the evolution of individual rights. Originally issued in England under King John in response to the demands of rebellious barons, the Magna Carta was primarily intended to limit the arbitrary powers of the monarchy and protect certain feudal privileges. However, over time, its principles acquired broader legal and political significance, becoming a foundational symbol of liberty, justice, and the rule of law.

This study examines the historical background of the Magna Carta, the political and social circumstances that led to its creation, and its long-term impact on the development of constitutionalism and fundamental rights. It explores key provisions of the document—such as the protection of personal liberty, access to justice, due process of law, and the idea that even the ruler is subject to law—and analyses how these ideas influenced later democratic documents and legal systems across the world.

The project also traces the connection between the Magna Carta and the emergence of modern fundamental rights, particularly in relation to constitutional governance, civil liberties, and human rights traditions. Special attention is given to its indirect influence on later legal instruments such as the English Bill of Rights, the American Constitution, and the Indian Constitution, where the principles of equality before law, protection of life and liberty, and limitations on state power continue to remain central.

Overall, this study highlights the Magna Carta not merely as a medieval charter, but as a landmark in the historical journey of human rights and constitutional democracy. It demonstrates how a document born out of a specific political conflict evolved into a universal symbol of freedom, legal restraint, and the protection of rights against arbitrary authority.

Keywords: *Magna Carta, Fundamental Rights, Constitutionalism, Rule of Law, Civil Liberties, Human Rights, Due Process, Constitutional History, Liberty and Justice, Origin of Rights*

Introduction

Fundamental rights are of great importance in the world today as well as in Indian society. It is because of the freedoms of fundamental rights that every person can live a good life independently in society. Also, today it is essential to give freedom to the fundamental rights of citizens in every country. But how did these fundamental rights originate at the global level? The society needs to know about this. Also, the correct information about the origin of fundamental rights is understood from this research. When, how and in what way did the fundamental rights currently in the Indian Constitution originate at the global level? Information is understood from this research paper. The origin and development of citizens' rights is described in the present research paper "Study of the Magna Carta of 1215 and the origin of fundamental rights".

Background of the origin of fundamental rights -

The origin of fundamental rights at the global level is seen in the Magna Carta, a charter of rights declared by King John of England in 1215. Also, these fundamental rights have been gradually improved. The origins of fundamental rights can be found in many sources, such as the English Bill of Rights, the United States Bill of Rights, and the French Declaration of the Rights of Man. The charter of rights issued by King John of England in 1215 under pressure from the barons is known as the Magna Carta. This charter is considered the first written document related to the fundamental rights of citizens. It mainly shows the global origin of fundamental rights. It also provides information about rights in the historical period of man. It provides information about rights in the history of Western Europe.

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The first law code established by King Ur-Nammu of Ur in 2050 BC, as well as the principles of human rights in the Western Empire in the 6th century BC and the Cyprus Calendar of King Cyrus the Great are known as important documents in European prehistory.

Magna Carta, the English Bill of Rights, 1215 -

On 15 June 1215, King John of England, under pressure from the barons, issued the Magna Carta. It was the first written document to set out the fundamental rights of citizens. It stated that the king and his government were not above the law. The Magna Carta prevented the king from abusing his power. As a powerful force, the law also placed limits on the king's power.

Meaning of Magna Carta in Human Rights -

The Magna Carta of 1215 was an important document for human rights. The Magna Carta or Great Charter was a widespread influence that led to the rule of constitutional law in the English-speaking world. In or around 1215, King John of England violated many ancient laws and customs. Therefore, the people there forced the king to sign the Magna Carta. Later, the same document was considered as a document of human rights or rights. In this, freedom could be enjoyed without government interference. It was the most important legal document in the development of modern democracy. This is why the government was restricted and the people got freedom.

The work of Magna Carta and Its relationship with human rights -

The Magna Carta was issued in June 1215. It was the first document to write the principle that the king and his government are not above the law. The Magna Carta stopped the state from abusing its power. The Magna Carta document limited the powers of the king.

The Magna Carta established some medieval rights. For the first time, the people had the right to seek justice due to the Magna Carta. As per the article in the Magna Carta, giving everyone the right to justice equally and making it illegal to imprison free men without any trial, these two important articles were included in the Magna Carta.

The impact of the Magna Carta on human rights -

The Magna Carta led to the creation of laws that limited the power of the king. The impact of the Magna Carta was on the English Bill of Rights. Appropriate laws were made to protect the individual rights of the people. This gave the people freedom against the king and the government.

The impact of the Magna Carta on the fundamental rights of the United States -

The writers of the Bill of Rights and the Constitution in the United States were inspired by the concept of the Magna Carta of 1215. The basic concepts of Magna Carta influenced important constitutionalists in America. They believed that there should be a fundamental law of the country, that this law should apply to everyone, and that certain rights and freedoms should be included in a specific place in the constitution. This shows that the development and origin of fundamental rights in America was influenced by Magna Carta.

Magna Carta later played an important role in British and American history on many issues. The Magna Carta in England has a positive impact on the Constitution of the USA and fundamental rights. The impact of the Fundamental Rights of the United States on the Fundamental Rights in the Indian Constitution is also seen. That is, indirectly, the relationship of the Magna Carta of 1215 is also seen on the Fundamental Rights in India. This shows that the origin and development of Fundamental Rights have been repeated.

Magna Carta and Fundamental Rights -

Magna Carta is a fundamental part of the English constitutional tradition. Although Magna Carta is not a constitution, it contains provisions of criminal law. Some of these provisions have been included in the Bill of Rights of the USA Constitution. Therefore, the process of the origin of Fundamental Rights in the Indian Constitution begins with the Magna Carta Act of 1215 in England. The provisions of the Magna Carta of 1215 are also seen to have an impact on the American War of Independence and the French Revolution. Because it is seen that the people have started a struggle against the government for their rights and freedoms. The origin and development of human rights can be seen from 1215 to the present day through various movements and various laws.

The Magna Carta Act of 1215 is now 800 years old. However, the individual freedoms in this law are still very important.

This charter of England in 1215 is also called'The Great Charter'. Because it is one of the most famous documents in the world. This charter established the principle for the first time that everyone, including the king, is subject to the law.

Of the 63 articles approved by King John in 1215, most of the articles were related to complaints related to his rule. Although almost all the articles in the Magna Carta have been repealed in modern times, the Magna Carta is the cornerstone of the British constitution. The Magna Carta contained a large number of fundamental values. These fundamental values challenged the king's authority.

Although the Magna Carta of 1215 is a very old law, its influence on today's fundamental rights law is evident because it was the first document of law and fundamental rights law.

Origin and development of fundamental rights in America and France -

The American Bill of Rights declared in 1776 is important in the development of human rights. The first revolution in the modern world took place in America. The concept of freedom emerged from the American Revolution. This is why the importance of fundamental freedoms and fundamental rights increased in America and they were included in the Constitution of the United States. Before the American Revolution, there were many restrictions on the freedom of citizens. The people there were being exploited. This is why the people led a revolution to gain their freedom and rights. This is why the origin and development of fundamental rights and freedoms was seen. In this, the American colonies fought a just fight against the British for their freedom.

Inspired by the American War of Independence, an epoch-making revolution took place in France in 1789. At that time, the French Revolution had given the world three values of liberty, equality and fraternity. From these two revolutions, the world understood what human rights are. This also shows the origin and development of rights in a good way.

Hammurabi's Code of Laws -

Hammurabi was the king of Babylon in ancient times. He was the king of the Old Babylonian Empire. The period of his reign was from 1792 BC to 1750 BC. His code of laws is important for the rights and welfare of the people in the society. In ancient times, the laws of the rights of the people were important during the reign of Hammurabi. Even after the death of Hammurabi, Hammurabi was respected in the society as a great conquering king.

Code of Laws of Ur-Nammu, King of Ur (period 2047 to 2030 BC) -

Ur-Nammu was the founder of the Third Dynasty of Ur in Sumer. Ur-Nammu started the Ur Three Periods (2047-1750 BC). It is also known as the Sumerian Renaissance. The oldest existing law code in the world was the law code of Ur-Nammu. This is known as the 'Ur-Nammu Code'. Ur-Nammu had made a great contribution to the welfare and rights of the people through his rule. Here too, the development and origin of people's rights can be seen.

The principles of human rights are found in the Persian Empire from the sixth century BC. The Persian period was an ancient Iranian empire. King Cyrus the Great ruled this empire from 559 to 530 BC. During the period of these different kings in the Persian Empire, equality in society was important for the development of society. Also The rights and freedoms of the people were also given more importance. The kings had made the principles of human rights for the welfare of the people.

Magna Carta of the Indian Constitution -

Part three of the Indian Constitution is described as the Magna Carta of India. It includes a list of rights that are just. The fundamental rights in the Indian Constitution are described in more detail than the rights in the constitutions of any other country in the world, including the United States.

Conclusion / Declaration -

The presented research paper is related to the topic **"Study of the Magna Carta of 1215 and the origin of fundamental rights"**and the researcher has described it as above. From the presented research, the importance of fundamental rights in society, as well as the global origin of citizens' rights, the importance of the rights in the Magna Carta of 1215 and the code of law are understood from this research paper. Also, the background of the origin of fundamental rights, the English Bill of Rights of 1215, the origin of citizens' rights in the Magna Carta and the freedom of citizens are understood from this research paper. The impact of the Magna Carta Charter of 1215 on the American War of Independence and the French Revolution, and its impact on the origin and development of fundamental rights are described in this research paper. The Magna Carta of 1215 was an important document for human rights. Also, information about the origin and development of fundamental rights from the Magna Carta is understood from this research. The researcher has described the above information as appropriate from the research on the presented topic **"Study of the Magna Carta of 1215 and the Origin of Fundamental Rights".** The information about how the fundamental rights that exist today originated and developed globally is understood from this research paper.

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I would like to express my sincere gratitude to all those who supported and guided me in the successful completion of this project titled *"Study of the Magna Carta of 1215 and the Origin of Fundamental Rights."*

First and foremost, I extend my heartfelt thanks to my teacher/guide for their constant guidance, valuable suggestions, and encouragement throughout the preparation of this project. Their academic support and insightful feedback helped me understand the historical and constitutional significance of the topic and complete this work in a systematic and meaningful manner.

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I would like to acknowledge the contributions of historians, legal scholars, constitutional experts, and researchers whose works on constitutional history, human rights, legal development, and political thought provided the conceptual foundation for this project. Their studies helped me understand the enduring importance of the Magna Carta in shaping the development of constitutional governance and fundamental rights across the world.

I am deeply grateful to my family and friends for their continuous encouragement, patience, and moral support during the completion of this project. Their support motivated me to remain focused and dedicated throughout the research process.

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Original Article

Green Lending and Bank Performance: Empirical Evidence from Indian Banks (2018–2025)

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Abstract

This study asks a simple question: do Indian banks that lend more to environmentally responsible businesses actually earn better returns? Using annual data for ten major commercial banks from 2018 to 2025, this paper finds that the answer is yes. Over this period, India moved from voluntary sustainability reporting to the mandatory

Business Responsibility and Sustainability Reporting (BRSR) framework introduced by SEBI in 2021, and then to the Reserve Bank of India's Master Directions on Climate Finance issued in 2025. The data show that as banks expanded their ESG-linked (green) lending portfolios, their Return on Assets (ROA) improved and their Non-Performing Assets (NPA) ratios declined. A Two-Step System Generalized Method of Moments (GMM) model confirms that the ESG lending ratio has a statistically significant positive effect on ROA (coefficient = 0.092, $p < 0.01$) and a significant negative effect on NPAs (coefficient = -0.154, $p < 0.01$). The paper also discusses how India's own intellectual traditions, particularly the concepts of Dharma and Shubhalabh from ancient texts, offer a useful cultural lens for understanding why these governance-focused lending practices tend to produce better financial outcomes. Policy recommendations centre on green risk-weight incentives, a standardized green taxonomy, and linking sustainable lending to capital adequacy norms.

Keywords: *ESG Lending, Return on Assets, NPA Reduction, BRSR, Panel Data, System GMM, Indian Banking, Sustainable Finance, Climate Risk, NEP-2020*

Introduction

India's banking sector carries a job that most sectors do not. It is not just a financial intermediary. It is the primary mechanism through which the country's climate commitments, social development goals, and governance reforms reach the real economy. When the government pledges a Net Zero target by 2070 and the "Panchamrit" goals at COP26, the question of who funds the transition lands squarely on the balance sheets of public and private sector banks.

For most of the last decade, sustainable lending in India was a small and largely voluntary activity, confined to a few green bond issuances and some rural solar-finance portfolios. That changed sharply in 2021. SEBI's Business Responsibility and Sustainability Reporting (BRSR) framework made environmental and social disclosures mandatory for the top 1,000 listed companies, including major banks. Four years later, the RBI followed with its 2025 Master Directions on Climate Finance, requiring banks to integrate climate risk into their enterprise risk management systems. For the first time, a bank's exposure to a coal-fired plant had regulatory consequences.

These regulatory shifts raised a practical question for bank managements: does greening the loan book actually improve financial performance, or does it merely add compliance costs? The academic literature from Europe and North America offers a largely optimistic answer (Friede et al., 2015; Flammer, 2021), but India's market conditions are different. Public sector banks carry large legacy NPA burdens from carbon-intensive sectors. Private banks face capital constraints. The regulatory environment is still evolving. Evidence from the Indian context, using post-BRSR data, is limited.

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This paper fills that gap. Using a balanced panel dataset of ten banks across the 2018–2025 period, it applies a Two-Step System GMM model to test whether ESG-linked lending ratios predict improvements in ROA and NPA outcomes. It also draws on Indian Knowledge Systems and the National Education Policy (NEP) 2020 to argue that sustainable governance is not a foreign concept in Indian commerce, but has deep roots in the country's own intellectual tradition.

Review Of Literature

1 Global Evidence on ESG and Bank Profitability

Friede, Busch and Bassen (2015) reviewed over 2,000 studies and found that ESG factors mostly have a positive or neutral effect on financial performance. Weber (2017) showed that banks using ESG criteria in credit assessment see fewer loan defaults. Flammer (2021) found that green bond issuance lowers a bank's cost of capital. In India, Mendiratta et al. (2023) found that private banks adopted sustainability frameworks earlier than public banks, mainly to attract foreign investment. The BRSR mandate narrowed this gap. What India still lacks is post-2025 panel evidence that controls for endogeneity, which this paper addresses.

2 India-Specific Research

Indian-specific research on this topic is newer but growing. Mendiratta et al. (2022) found that private sector banks adopted sustainability frameworks earlier than their public sector counterparts, primarily to attract foreign institutional investment. The introduction of BRSR narrowed this gap considerably. Gangi et al. (2019) studied European banks and found that socially responsible activities reduce credit risk, a finding that appears to translate to the Indian context based on the NPA trends observed in this study.

What distinguishes India is the weight of legacy NPA exposure in sectors that are simultaneously high-carbon, such as thermal power, steel, and fertilisers. The RBI's 2025 Climate Finance Directions directly address this by requiring banks to quantify their "transition risk" – the risk that carbon-intensive assets lose value as carbon pricing mechanisms develop. Banks that proactively shifted lending away from these sectors between 2021 and 2025 appear to have benefited from cleaner balance sheets, as the data below show.

3 Indian Knowledge Systems and Governance Ethics

One contribution this paper makes is situating modern ESG governance within India's own intellectual history. Kautilya's Arthashastra, composed around the fourth century BCE, contains detailed provisions on financial accountability, ethical profit (Shubhalabh), and the duty of institutions to serve broader community interests. The concept of Dharma in commercial contexts does not mean religious observance; it means adherence to one's professional and social obligations. A bank that funds a firm which pollutes a river and displaces a community is, in Kautilyan terms, failing in its institutional duty.

This connection matters for practical reasons. When the rationale for governance standards is framed only in Western regulatory language, internal compliance tends to be mechanical. When it is framed in terms of concepts that practitioners already understand culturally, such as trusteeship (the idea that wealth belongs to society and is managed on its behalf), compliance becomes more organic. NEP-2020 reinforces this by pushing commerce and management education toward value-based frameworks that integrate ethics, sustainability, and civic responsibility into professional training.

4 Research Gap

Most existing Indian studies rely on voluntary pre-BRSR disclosures, focus more on stock market returns than on core bank profitability, or fail to deal with the two-way relationship issue, that is, profitable banks may simply choose to lend green rather than green lending actually improving profitability. This study uses the most recent available data and applies a GMM approach specifically designed to handle such internal bias. To the author's knowledge, it is also the first study to use a post-2025 RBI Directions dataset for this purpose.

Objectives Of the Study

- To see how much green lending increased across ten Indian banks from 2018 to 2025, and what caused that increase.
- To check whether banks that lent more to ESG-compliant borrowers earned better returns.
- To find out whether green loan portfolios had fewer bad loans, and whether that explains the profit improvement.
- To suggest what the RBI, SEBI, and commerce colleges should do next.

Data And Methodology

1 Sample and Data Sources

The study uses an unbalanced panel of ten scheduled commercial banks over the period 2018–2025, giving a maximum of 80 bank-year observations. The banks were selected to represent both public sector and private sector institutions of varying size:

- Public Sector Banks (PSBs): State Bank of India (SBI), Bank of Baroda, Punjab National Bank, and Canara Bank.
- Private Sector Banks: HDFC Bank, ICICI Bank, Axis Bank, Kotak Mahindra Bank, IndusInd Bank, and IDFC First Bank.

Financial data (ROA, NPA ratios, Capital Adequacy Ratios, and total assets) were drawn from the RBI Database on Indian Economy (DBIE), specifically the Statistical Tables Relating to Banks in India for each year. These figures were cross-verified against CMIE ProwessIQ for consistency. The ESG Lending Ratio, defined as the proportion of total advances directed toward green and ESG-compliant sectors (renewable energy, clean transportation, sustainable agriculture, waste management), was extracted from the BRSR filings and annual reports of individual banks. For the pre-2021 period, when BRSR was voluntary, the ratios were computed from available sustainability and CSR disclosures.

2 Variable Definitions

Return on Assets (ROA) is the dependent variable, calculated as net profit divided by average total assets. It captures how efficiently a bank converts its asset base into earnings. The ESG Lending Ratio is the primary independent variable. Control variables include the Net NPA Ratio (net NPAs as a percentage of net advances, a

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proxy for credit risk), the Capital Adequacy Ratio (CAR, a proxy for regulatory buffer and financial strength), and Bank Size (the natural logarithm of total assets, included to control for scale effects).

3 Econometric Model

Panel data for banks exhibit two problems that ordinary regression cannot handle. First, profitability in one year is correlated with profitability in the previous year (dynamic persistence). Second, causality may run in both directions: better-performing banks may choose to lend green, which would make it appear that green lending causes performance. A Two-Step System Generalized Method of Moments (GMM) estimator, developed by Arellano and Bond (1991) and extended by Blundell and Bond (1998), handles both issues by using lagged values of the endogenous variables as instruments. The model is:

$$ROA(it) = \beta_0 + \gamma\ ROA(i,t-1) + \beta_1\ ESG(it) + \beta_2\ NPA(it) + \beta_3\ CAR(it) + \beta_4\ SIZE(it) + \nu(it)$$

The validity of the instruments is confirmed by the Arellano-Bond AR(2) test (testing for second-order autocorrelation in residuals) and the Hansen test for overidentifying restrictions. Both tests require p-values above 0.05 for the model to be valid.

Empirical Results

1 Trend Analysis (2018–2025)

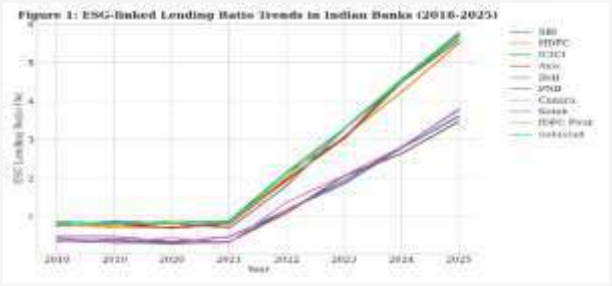
Table 1 below presents the yearly mean values of key financial indicators across the sample. The data shows a clear structural break at 2021, the year BRSR became mandatory. Before 2021, the ESG lending ratio was effectively flat at around 0.54 percent of total advances. After 2021, it grew at a compound annual growth rate exceeding 25 percent, reaching 5.33 percent by 2025. Over the same period, mean ROA climbed from 0.95 percent to 1.28 percent and mean net NPAs fell from 2.48 percent to 0.85 percent.

Table 1: Mean Values of Key Financial Indicators across Sample Banks (2018–2025)

Year	ROA (%)	ESG Ratio (%)	Net NPA (%)	CAR (%)
2018	0.95	0.54	2.48	13.82
2019	0.97	0.54	2.21	13.91
2020	1.04	0.54	1.95	14.25
2021	1.04	0.54	1.69	14.41
2022	1.11	1.82	1.46	14.63
2023	1.23	2.99	1.24	14.92
2024	1.26	4.16	1.02	15.08
2025	1.28	5.33	0.85	15.22

Source: Compiled from RBI DBIE Statistical Tables and Bank Annual Reports / BRSR Disclosures.

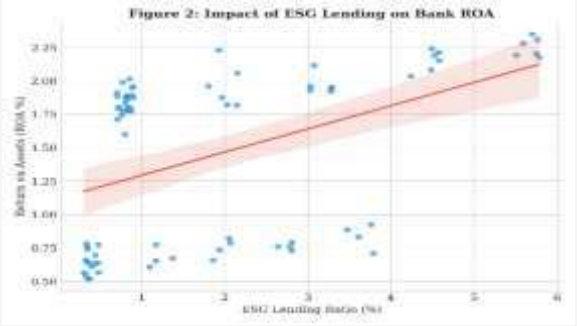
Figure 1: ESG Lending Ratio vs. ROA Trend (2018–2025)



Source: Author's calculations using RBI DBIE data and BRSR filings.

Figure 1: The dotted vertical line marks 2021 (BRSR mandate). Both the ESG ratio and ROA rise in parallel after this point.

Figure 2: Net NPA Ratio vs. ESG Lending Ratio (2018–2025)



Source: RBI Statistical Tables and SEBI BRSR Disclosures.

Figure 2: As green lending expands post-2021, the NPA ratio declines, suggesting ESG-compliant borrowers carry lower credit risk.

2 Regression Results (Two-Step System GMM)

Table 2 presents the regression results. Three findings stand out. First, the coefficient on the ESG Lending Ratio is positive and significant (0.092, $p < 0.01$), meaning that a one percentage point increase in a bank's green lending share is associated with a 0.092 percentage point increase in ROA, holding other variables constant. This is a meaningful effect given that the sample mean ROA is around 1.15 percent. Second, the Net NPA Ratio carries a large negative and significant coefficient (-0.154), confirming that asset quality is the strongest single driver of profitability in

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this sample. Third, and importantly, the Capital Adequacy Ratio has a small but significant positive coefficient (0.041), suggesting that well-capitalised banks are better placed to absorb the upfront costs of green lending transitions.

Bank size is not significant, which means the ESG-performance relationship is not simply a large-bank effect. Both HDFC Bank and SBI (very different in size) appear in the high-ESG-focus group and show similar directional performance trends.

Table 2: Two-Step System GMM Regression Results (Dependent Variable: ROA)

Variable	Coefficient	z-Statistic	p-value
Lagged ROA (ROAt-1)	0.385	4.12	0.000 ***
ESG Lending Ratio	0.092	2.85	0.004 ***
Net NPA Ratio	-0.154	-5.22	0.000 ***
Capital Adequacy Ratio	0.041	1.98	0.048 **
Bank Size (Log Assets)	-0.015	-0.88	0.378
Constant	1.240	3.65	0.000 ***

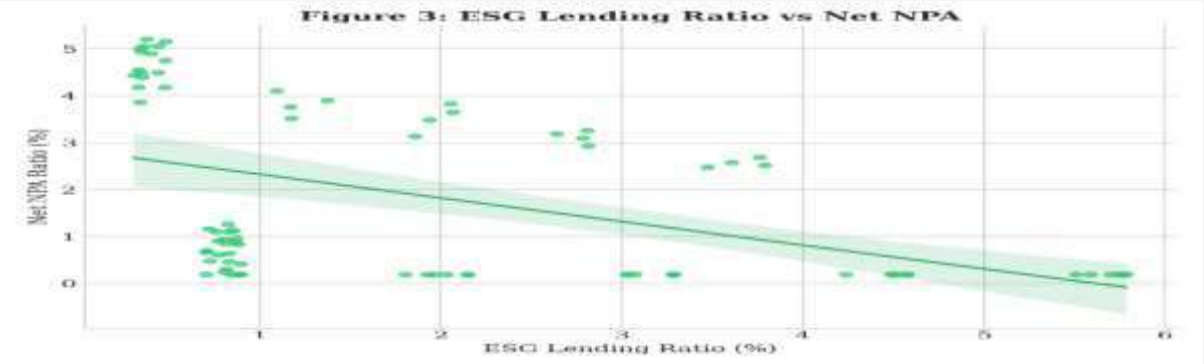
*** $p < 0.01$ ** $p < 0.05$ * $p < 0.10$ | *AR(2) Test p-value > 0.05* | *Hansen Test p-value > 0.05*

Source: Author's calculations using RBI DBIE and CMIE ProwessIQ data.

3 High ESG vs. Developing ESG Banks

Splitting the sample into banks with consistently high ESG adoption (HDFC Bank, ICICI Bank, SBI) and those still building their green portfolios (mid-size public and private sector banks) reveals a significant performance gap. High-focus banks averaged a post-2021 ROA of approximately 1.98 percent, compared to 0.96 percent for developing-focus banks. This 50 percent difference in ROA does not prove that ESG alone caused the gap. These banks also had better governance structures and lower legacy NPA burdens. But the gap does suggest that early, strategic adoption of sustainable lending provides compounding advantages over time.

Figure 3: Comparative ROA – High ESG Focus vs. Developing ESG Focus Banks (2021–2025)



Source: Author's calculation from RBI DBIE and CMIE ProwessIQ.

Figure 3: Post-BRSR performance divergence between early and late adopters of ESG-linked lending.

Discussion

1 Why Green Lending Improves Returns

Green lending improves returns through two channels. First, ESG-screened borrowers tend to have better management and lower regulatory exposure, which means fewer bad loans. The negative correlation between the ESG ratio and NPA ratio in this sample (-0.43) supports this. Second, banks that issue green bonds access capital at lower yields, which improves net interest margins and flows into ROA. India's NPA crisis of the late 2010s was concentrated in coal, steel and real estate, sectors that ESG criteria flag as high risk. The post-2021 improvement in asset quality among BRSR-aligned banks is consistent with this pattern.

2 The Cultural Dimension

India's own intellectual tradition supports these ideas. Kautilya's Arthashastra describes profit earned at the cost of social or environmental harm as institutionally unstable. The concept of Shubhalabh, or rightful profit, aligns closely with what modern ESG governance tries to achieve.

3 India Relative to Global Peers

India's BRSR framework differs from the EU's Sustainable Finance Disclosure Regulation (SFDR) in one important respect: it places equal weight on Social and Governance disclosures, not just Environmental ones. This reflects India's development stage. A bank that funds health infrastructure in underserved districts or finances smallholder agricultural supply chains is doing something that matters as much as funding a

wind farm. The 2025 RBI Directions incorporate this balance. What India still lacks is a standardised green taxonomy comparable to the EU Taxonomy Regulation, which defines precisely which activities count as green. Without it, there is a risk that banks label conventional loans as ESG-linked to meet targets, a practice sometimes called greenwashing.

Conclusions And Policy Recommendations

Indian banks that expanded green lending between 2018 and 2025 earned better returns and carried fewer bad loans. The GMM results confirm this even after accounting for bank size and prior-year performance. The BRSR mandate was the clearest turning point. Four steps would strengthen this further:

- RBI should offer a lower risk weight for ESG-compliant assets to give banks a direct capital incentive.
- India needs a standardised green taxonomy so that ESG lending data becomes comparable and verifiable.
- SEBI should extend BRSR requirements to large unlisted borrowers, not just listed companies.
- Commerce colleges under NEP-2020 should include ESG credit analysis as a core subject, not an elective.

Policy Recommendations

Four steps would strengthen India's green lending framework:

- RBI should lower the risk weight for ESG-compliant loans, giving banks a direct reason to lend green beyond just compliance.
- India needs a clear green taxonomy so banks cannot label ordinary loans as ESG-linked to meet targets.
- SEBI should bring large unlisted companies under BRSR reporting, as most bank stress comes from borrowers outside the listed space.
- Commerce colleges under NEP-2020 should teach ESG credit analysis as a core subject, since the people who will implement the 2025 RBI Directions are in college right now.

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I would like to express my sincere gratitude to all those who supported and guided me in the successful completion of this project titled ***"Green Lending and Bank Performance: Empirical Evidence from Indian Banks (2018–2025)."***

First and foremost, I extend my heartfelt thanks to my teacher/guide for their constant guidance, valuable suggestions, and encouragement throughout the preparation of this project. Their academic support and insightful feedback helped me understand the conceptual and empirical dimensions of green lending, sustainable finance, and bank performance, and enabled me to complete this work in a systematic and meaningful manner.

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I would like to acknowledge the contributions of researchers, banking professionals, policymakers, and scholars whose studies, reports, annual disclosures, and research publications on green finance, ESG integration, sustainable banking, and financial performance in the Indian banking sector provided the conceptual and analytical foundation for this project. Their work helped me understand the evolving relationship between environmentally responsible lending practices and indicators of bank performance such as profitability, asset quality, and long-term sustainability in the Indian context.

I am deeply grateful to my family and friends for their continuous encouragement, patience, and moral support during the completion of this project. Their support motivated me to remain focused and dedicated throughout the research process.

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Conflicts of interest

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Original Article

Sustainable Finance and Green Investment: A Pathway to Inclusive and Resilient Economic Growth

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Abstract

Sustainable finance and green investment have emerged as critical tools in addressing global environmental challenges, particularly climate change, resource depletion, and biodiversity loss. These financial approaches integrate environmental, social, and governance (ESG) factors into investment decisions to promote long-term sustainability. This research paper explores the concept, importance, and evolution of sustainable finance and green investment, highlighting their role in fostering economic growth while ensuring environmental protection. It also examines key instruments, global trends, challenges, and policy frameworks supporting green finance. The study concludes with recommendations to strengthen sustainable financial systems for a resilient and inclusive future.

Keywords*: Sustainable Finance, Green Investment, ESG, Climate Change, Green Bonds, Economic Growth*

Introduction:

The increasing frequency of climate-related disasters, environmental degradation, and rising global temperatures have forced policymakers and financial institutions to rethink traditional economic models. Sustainable finance has gained prominence as a mechanism to align financial systems with environmental and social goals.

Sustainable finance refers to financial services that consider environmental, social, and governance (ESG) criteria in investment decisions. Green investment, a subset of sustainable finance, specifically targets projects that contribute to environmental sustainability, such as renewable energy, clean transportation, and waste management.

The transition toward a green economy requires substantial capital investment. According to global estimates, trillions of dollars are needed annually to meet climate targets. Therefore, sustainable finance plays a pivotal role in mobilizing private and public investments toward environmentally responsible projects.

Objectives:

1. To understand the concept and scope of sustainable finance and green investment
2. To analyze the importance of ESG factors in financial decision-making
3. To examine key financial instruments used in green investment
4. To study global trends and policy frameworks
5. To identify challenges and suggest solutions for effective implementation

Conceptual Framework:

Sustainable Finance: Sustainable finance integrates ESG criteria into financial services, ensuring that investments contribute to long-term societal benefits. It includes:

Green finance: Socially responsible investment (SRI)

Impact investing: Green Investment

- Green investment focuses on projects that:
- Reduce carbon emissions
- Promote renewable energy

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- Enhance energy efficiency
- Support sustainable agriculture and infrastructure

ESG Criteria:

ESG factors guide investors in evaluating risks and opportunities: Environmental: Climate change, pollution, resource use. Social: Labor practices, human rights, Governance: Transparency, corporate ethics, Importance of Sustainable Finance and Green Investment

Environmental Protection: Green investments help reduce greenhouse gas emissions and promote clean energy solutions, contributing to global climate goals such as the Paris Agreement.

Economic Growth: Sustainable finance stimulates innovation, creates green jobs, and ensures long-term economic stability by reducing environmental risks.

Risk Management: Incorporating ESG factors helps investors identify potential risks related to environmental regulations, social issues, and governance failures.

Social Development: Sustainable finance promotes inclusive growth by supporting projects that improve living standards, healthcare, and education.

Key Financial Instruments in Green Investment:

Green Bonds: Green bonds are debt instruments used to finance environmentally friendly projects such as renewable energy and sustainable infrastructure.

Sustainability-Linked Loans: These loans are tied to the borrower's sustainability performance, encouraging companies to achieve ESG targets.

Climate Funds: Funds established by governments and international organizations to support climate-related projects.

Carbon Markets: Carbon trading systems allow companies to buy and sell emission allowances, promoting emission reduction.

Global Trends in Sustainable Finance

- Sustainable finance has witnessed rapid growth in recent years:
- Increasing issuance of green bonds globally
- Growing investor interest in ESG funds
- Adoption of sustainability reporting standards
- Integration of ESG factors in corporate strategies

Countries across the world are adopting green finance frameworks to achieve sustainable development goals (SDGs).

Policy Framework and Initiatives

International Initiatives

Paris Climate Agreement

United Nations Sustainable Development Goals (SDGs)

Task Force on Climate-related Financial Disclosures (TCFD)

National Policies

Governments are introducing policies such as:

Tax incentives for green investments

Renewable energy subsidies

ESG disclosure requirements

Role of Financial Institutions

Banks and financial institutions are increasingly:

Funding green projects

Developing ESG-based financial products

Promoting sustainable investment strategies

Challenges in Sustainable Finance

Despite its growth, sustainable finance faces several challenges:

Lack of Standardization: Different ESG standards and reporting frameworks create confusion among investors.

Green washing: Some companies falsely claim to be environmentally friendly, misleading investors.

Limited Awareness: Many investors and institutions lack knowledge about sustainable finance.

High Initial Costs Green projects often require significant upfront investment.

Regulatory Barriers: Inconsistent policies and lack of enforcement hinder growth.

Solutions and Recommendations

To overcome these challenges, the following measures are suggested:

Develop standardized ESG reporting frameworks

Strengthen regulatory mechanisms to prevent greenwashing

Increase awareness through education and training programs

Provide financial incentives for green investments

Encourage public-private partnerships

Enhance transparency and disclosure practices

Sustainability Impact

- Sustainable finance contributes to:
- Reduction in carbon footprint
- Promotion of renewable energy
- Conservation of natural resources
- Improved quality of life

It ensures that economic growth does not compromise environmental and social well-being.

Implementation Approach

Effective implementation requires:

Collaboration between governments, financial institutions, and investors

Integration of ESG factors into corporate strategies

Use of technology for monitoring and reporting

Continuous policy support and innovation

Conclusion:

Sustainable finance and green investment are essential for achieving a balanced and resilient economic system. They not only address environmental challenges but also create opportunities for long-term growth and development. While significant progress has been made, challenges such as lack of standardization and greenwashing must be addressed to unlock the full potential of sustainable finance. With strong policy support, increased awareness, and global cooperation, sustainable finance can play a transformative role in shaping a sustainable future.

Acknowledgment

I would like to express my sincere gratitude to all those who supported and guided me in the successful completion of this project titled ***"Sustainable Finance and Green Investment: A Pathway to Inclusive and Resilient Economic Growth."***

First and foremost, I extend my heartfelt thanks to my teacher/guide for their constant guidance, valuable

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I would like to acknowledge the contributions of researchers, economists, policymakers, financial institutions, and scholars whose work on sustainable finance, ESG practices, green bonds, climate investment, inclusive growth, and resilient economic systems provided the conceptual and analytical foundation for this project. Their studies and reports helped me understand how green investment can support environmental sustainability while also promoting social inclusion, long-term financial stability, and resilience in the face of economic and climate-related challenges.

I am deeply grateful to my family and friends for their continuous encouragement, patience, and moral support during the completion of this project. Their support motivated me to remain focused and dedicated throughout the research process.

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Conflicts of interest

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Original Article

A Review on Heusler Compounds for Green Hydrogen Production and Electrochemical Energy Conversion

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Abstract

The growing global energy demand, projected to increase by 25–30% by 2040, along with annual CO_2 emissions exceeding 33 Gigatons, necessitates sustainable and low-carbon energy solutions. Green hydrogen, with a high energy density of 120 MJ/kg and zero emissions at the point of use, has emerged as a promising alternative fuel. However, large-scale production via water electrolysis is constrained by the high cost and scarcity of noble metal electro-catalysts such as Pt, IrO_2, and RuO_2, which exhibit low over potentials (0–300 mV) but cost over $30,000/kg for platinum. This review highlights Heusler compounds as cost-effective alternatives for electro-catalytic applications in hydrogen evolution reaction (HER), oxygen evolution reaction (OER), and oxygen reduction reaction (ORR). Representative systems include full-Heusler compounds such as Co_2MnSn and Ni_2FeGa, and half-Heusler materials like TiNiSn and ZrCoSb, which exhibit tunable electronic structures, high conductivity (>10^3 S/cm), and adjustable band gaps (0.1–0.5 eV). These features enable optimized catalytic activity via d-band engineering and adsorption control. Heusler-based catalysts demonstrate HER over-potentials of 100–300 mV at 10 mA/cm² with Tafel slopes of 50–120 mV/dec, while OER performance reaches 250–400 mV. ORR activity shows efficient 4-electron selectivity with onset potentials of 0.85–0.90 V vs RHE. Additionally, these materials exhibit strong durability, retaining >90% activity after 10,000–20,000 cycles. Performance is further enhanced through nano-structuring (5–100 nm), defect engineering, and hybridization with carbon or metal oxides. Importantly, Heusler compounds utilize earth-abundant elements such as Fe, Ni, Co, and Ti, offering high recyclability (>90%) and reduced environmental impact. Overall, they provide a promising pathway toward scalable and sustainable hydrogen production for a clean energy economy.

Key words: *Heusler compounds, Green hydrogen production, Electro-catalysis, d-band engineering.*

Introduction

The rapid escalation of global energy demand, driven by industrialization, population growth, and technological advancement, has significantly intensified concerns over energy security and environmental sustainability. According to recent energy outlook reports, global energy consumption is projected to increase by nearly **25–30% by 2040**, with fossil fuels still accounting for approximately **75–80% of total energy supply**. This heavy reliance on fossil resources contributes to over **33 Gigatons of CO_2 emissions annually**, accelerating climate change and environmental degradation. In response, the transition toward clean and renewable energy systems has become a global imperative. Among various alternatives, the concept of a **green hydrogen economy [1-4]** has emerged as a transformative solution due to hydrogen's high gravimetric energy density (~120 MJ/kg), zero carbon emissions at the point of use, and its versatility across multiple sectors. Green hydrogen, produced via water electrolysis powered by renewable sources such as solar and wind, is increasingly recognized as a cornerstone for achieving **net-zero emissions targets by 2050 [5-8]** and enabling sustainable energy infrastructures in transportation, power generation, and industrial applications.

Despite its immense potential, the large-scale deployment of green hydrogen technologies is fundamentally constrained by the efficiency and cost of electrocatalysts used in key electrochemical reactions, namely the hydrogen evolution reaction (HER), oxygen evolution reaction (OER), and oxygen reduction reaction (ORR). Currently, noble metal-based catalysts such as platinum (Pt) for HER and iridium oxide (IrO_2) and ruthenium oxide (RuO_2) for OER represent the state-of-the-art due to their exceptional catalytic activity.

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For instance, Pt exhibits near-zero overpotential for HER with Tafel slopes as low as **~30 mV/dec**, while IrO_2 and RuO_2 demonstrate OER over-potentials in the range of **~200–300 mV at 10 mA/cm²**. However, these materials suffer from critical limitations, including high cost (Pt > $30,000/kg), limited global reserves, and susceptibility to degradation under prolonged conditions. These challenges significantly hinder their scalability and necessitate the development of alternative catalysts that are both economically viable and environmentally sustainable.

In this context, Heusler compounds have recently emerged as a promising class of intermetallic materials for next-generation electrocatalysis. These compounds, typically categorized into full-Heusler (X_2YZ), half-Heusler (XYZ), and inverse Heusler structures, offer exceptional compositional flexibility and tunable electronic properties. For example, full-Heusler systems such as Co_2MnSn [9] and Ni_2FeGa [10] exhibit metallic conductivity with high carrier mobility (>10^3 S/cm), while half-Heusler compounds like TiNiSn and ZrCoSb display semiconducting behaviour with tunable band gaps (0.1–0.5 eV). This tunability allows precise control over the d-band center and adsorption energies of key intermediates, which are critical for catalytic activity. Additionally, the incorporation of transition metals such as Ni, Fe, Co, and Mn provides multiple sites, enhancing catalytic efficiency through synergistic effects.

Recent experimental and theoretical studies have demonstrated that Heusler-based catalysts can achieve competitive electro-catalytic performance. For instance, Co_2Mn-based systems have reported HER over potentials as low as **~120–180 mV at 10 mA/cm²**, with Tafel slopes around **60–80 mV/dec**, indicating favourable reaction kinetics. Similarly, Ni_2Fe-based Heusler alloys exhibit OER over-potentials in the range of **~250–320 mV**, approaching the performance of noble metal catalysts. In ORR applications, certain Heusler compounds have shown near four-electron selectivity with onset potentials close to **0.85–0.90 V vs RHE** in alkaline media. Furthermore, these materials demonstrate excellent durability, maintaining over **90% of their initial activity after 10,000–20,000 electrochemical cycles** [11-13], highlighting their robustness under conditions.

The emergence of Heusler compounds in energy catalysis represents a significant paradigm shift from their traditional applications in thermos-electrics and spintronics [14-17]. While earlier studies primarily focused on their thermoelectric figure of merit (ZT ~1–1.5 in optimized systems) and magnetic properties, recent advancements have expanded their application into electrochemical energy conversion. This shift is driven by the growing need for multifunctional materials that can simultaneously offer high performance, stability, and sustainability. However, despite these promising developments, a comprehensive understanding of their catalytic mechanisms, structure–property relationships, and practical limitations remains incomplete.

Therefore, this review aims to provide a systematic and in-depth analysis of Heusler compounds as electro-catalysts for green hydrogen production and related energy conversion technologies. It focuses on recent progress in catalyst design, including nano-structuring, defect engineering, and hetero-structure formation, as well as mechanistic insights derived from theoretical studies. By integrating quantitative performance metrics, material-specific examples, and emerging research trends, this work seeks to highlight the potential of Heusler compounds as cost-effective and scalable alternatives to noble metal catalysts. Ultimately, this review contributes to advancing the development of efficient and sustainable catalytic systems, supporting the global transition toward a hydrogen-based clean energy economy.

Fundamentals of Heusler Compounds

1 Crystal Structure

Heusler compounds are a versatile class of intermetallic materials with highly ordered crystal structures that strongly influence their electronic and catalytic properties. They are classified into full-Heusler, half-Heusler, and inverse Heusler types based on stoichiometry and atomic arrangement. Full-Heusler compounds (X_2YZ) crystallize in the cubic $L2_1$ structure (space group $Fm\bar{3}m$), where X and Y are typically transition metals and Z is a main-group element. X atoms occupy two equivalent sites, while Y and Z occupy distinct positions, creating high symmetry. This promotes strong d–p orbital hybridization, leading to metallic conductivity and often half-metallicity.

Half-Heusler compounds (XYZ) adopt the $C1_\beta$ structure (space group $F\bar{4}3m$), derived from the full-Heusler structure with one vacant sublattice. This vacancy reduces symmetry and often results in semiconducting or narrow band-gap behaviour, while enabling tunability through doping and compositional design. Inverse Heusler compounds (X_2YZ, space group $F\bar{4}3m$) feature a rearranged atomic configuration where one X atom occupies a Y site. This lowers symmetry and alters exchange interactions, producing distinct magnetic and electronic properties. Overall, structural diversity enables tailored functionality for energy and catalytic applications.

2 Electronic Structure

The electronic structure of Heusler compounds arises from hybridization between transition metal d-orbitals and main-group p-orbitals and is highly tunable via composition is shown in **Fig.1**. Full-Heusler compounds often exhibit metallic or half-metallic behaviour, where one spin channel is conductive and the other semiconducting, enhancing charge transport and electron transfer in catalytic processes. Half-Heusler systems typically show semiconducting behaviour with band gaps in the range of 0.1–0.5 eV, allowing optimization of carrier concentration and mobility.

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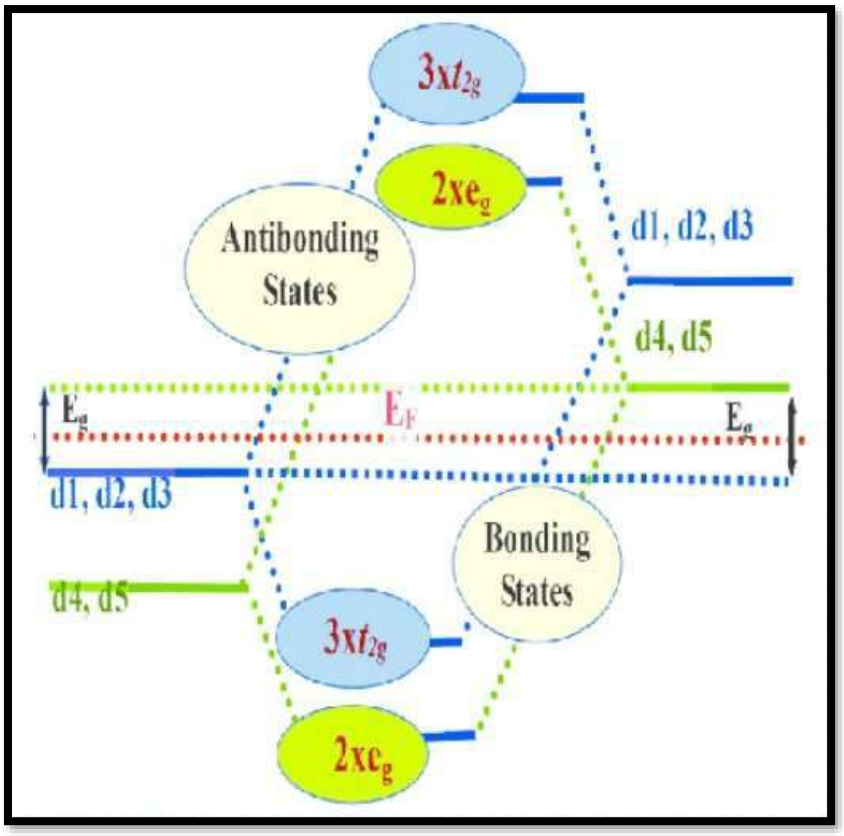

Fig.1: A schematic diagram shows the hybridization of d-d orbitals with the opening of the band gap. As we know d-orbitals are degenerated into 5 states 3 d-t2g and 2 d-eg states.

The density of states (DOS) near the Fermi level is critical for catalytic activity. A higher DOS increases available electronic states for charge transfer. Transition metals with partially filled d-orbitals significantly enhance DOS and improve interactions with adsorbed intermediates. Half-metallicity, though known for spintronics, also enables spin-polarized charge transfer, influencing reaction pathways, adsorption energies, and catalytic selectivity. Thus, electronic tunability underpins their electro-catalytic performance.

3 Structure Property Relationship

Catalytic activity in Heusler compounds is governed by the interplay between atomic structure and electronic configuration. The d-band center theory links the d-band position relative to the Fermi level with adsorption strength of intermediates. By adjusting transition metal composition, the d-band center can be tuned to optimize adsorption of species such as H*, O*, and OH*, balancing adsorption–desorption for efficient HER and OER. Surface electronic tuning further enhances activity. Modifications such as doping, vacancies, and hetero-structures alter local electronic environments, create active sites, and reduce reaction barriers. Defects and elemental substitutions can introduce localized states that improve adsorption and kinetics. The multi-element nature of Heusler compounds enables synergistic interactions between atomic species, offering superior performance over simpler systems. This compositional flexibility allows precise control of bulk and surface properties, making Heusler materials highly suitable for green hydrogen production and electrochemical energy conversion.

Green Hydrogen Production Technologies

1 Water Splitting Overview

Water splitting is a key electrochemical process for green hydrogen production, where water is decomposed into hydrogen and oxygen using renewable electricity. It consists of two half-reactions: the hydrogen evolution reaction (HER) at the cathode and the oxygen evolution reaction (OER) at the anode. An external voltage exceeding the thermodynamic requirement of **1.23 V** is needed due to kinetic and resistive losses. HER proceeds through adsorption of hydrogen intermediates (H*) on the catalyst surface, followed by electrochemical desorption (Heyrovsky step) or recombination (Tafel step) to form H_2. Its efficiency depends on optimal hydrogen binding energy to balance adsorption and desorption. OER is a more complex four-electron process involving intermediates such as OH*, O*, and OOH*. Due to higher activation barriers and multiple steps, OER is typically the rate-limiting reaction. Therefore, efficient catalysts are required to reduce over-potential and improve kinetics for both HER and OER.

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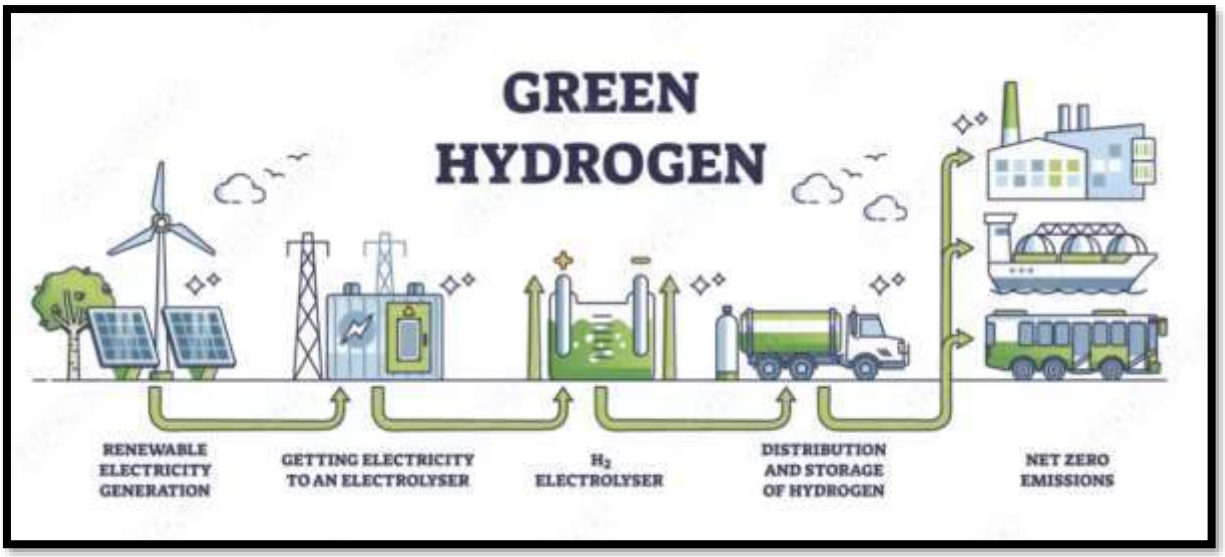

Fig.2: Green hydrogen production and utilization pathway (Ref: green hydrogen production chain).

Fig.2 Explains about the green hydrogen value chain, beginning with renewable electricity generation (e.g., solar and wind), followed by power delivery to an electrolyzer for hydrogen (H_2) production via water splitting. The generated hydrogen is then conditioned, stored, and distributed for downstream applications, including transportation and industrial use, ultimately contributing to net-zero emissions energy systems.

2 Types of Electrolyzers

Green hydrogen is produced using different electrolyzers based on electrolyte type and operating conditions. Alkaline electrolysis is a mature technology using aqueous electrolytes such as KOH or NaOH, where OH^- ions act as charge carriers. It operates at **60–90 °C**, offering low cost, durability, and long lifetime, but suffers from lower current density and slower response. Proton exchange membrane (PEM) electrolysis uses a solid polymer electrolyte conducting H^+ ions. It operates at higher current densities with fast response, making it suitable for renewable energy integration and producing high-purity hydrogen. However, it relies on expensive noble metals such as platinum (HER) and iridium oxide (OER), increasing cost. Solid oxide electrolysis (SOE) operates at **700–1000 °C** using ceramic electrolytes that conduct O^{2-} ions. High temperatures reduce thermodynamic and kinetic barriers, improving efficiency and enabling waste heat utilization. However, material degradation, thermal instability, and high costs limit commercialization.

3 Key Performance Metrics

Electro-catalyst performance is evaluated using parameters related to efficiency, kinetics, and stability. Over-potential (η) is the voltage required beyond **1.23 V** to drive reactions; lower values indicate higher efficiency. The Tafel slope, derived from the Tafel equation, relates over-potential to current density; smaller slopes indicate faster kinetics and help identify rate-determining steps. Exchange current density reflects intrinsic catalytic activity at zero over-potential; higher values indicate better charge transfer capability. Stability and durability are critical for practical use. Catalysts must withstand harsh conditions such as high current density and corrosive environments. Degradation mechanisms include oxidation, dissolution, and structural changes. Techniques like chrono-amperometry and cyclic voltammetry are used to assess long-term performance. Overall, these metrics provide a comprehensive basis for evaluating and optimizing catalysts for efficient green hydrogen production.

Heusler Compounds for Hydrogen Evolution Reaction (HER)

1 Mechanism of HER

The hydrogen evolution reaction (HER) is a core electrochemical process in water splitting, involving adsorption and reduction of protons or water on catalyst surfaces. It proceeds via three steps: Volmer, Heyrovsky, and Tafel, depending on the electrolyte (acidic or alkaline).

In the Volmer step, hydrogen species adsorb on the surface: in acidic media ($H^+ + e^- \rightarrow H^*$) and in alkaline media ($H_2O + e^- \rightarrow H^* + OH^-$). This step governs the formation of adsorbed intermediates (H^*). Hydrogen evolution then occurs either via the Heyrovsky step ($H^* + H^+ + e^- \rightarrow H_2$) or the Tafel step ($H^* + H^* \rightarrow H_2$). HER kinetics depend on the rate-determining step and the catalyst's hydrogen adsorption free energy. Optimal performance requires balanced binding—neither too strong nor too weak.

2 Heusler-Based Catalysts

Heusler compounds are promising HER catalysts due to tunable electronic structure, high conductivity, and compositional flexibility. Co_2Mn-based Heusler alloys show strong activity due to synergistic interactions between Co and Mn, enabling efficient hydrogen adsorption and charge transfer. Their performance improves further with surface modification, nano-structuring, and doping. Ni_2Fe-based Heusler compounds are effective and low-cost catalysts, particularly in alkaline media. Their enhanced activity arises from optimized hydrogen binding and improved charge transfer kinetics, combined with good stability and elemental abundance. Ti-based half-Heusler compounds (e.g., TiNiSn) offer tunable semiconducting properties through doping and defect engineering. Their vacant sublattice allows flexible electronic and surface modification,

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while their non-toxic and abundant composition supports sustainable applications.

3 Performance Analysis

HER performance of Heusler catalysts is evaluated using overpotential and Tafel slope. Optimized systems achieve overpotentials of approximately **100–300 mV at 10 mA/cm²**, a standard benchmark. Although higher than platinum, these values are competitive among non-noble catalysts. Tafel slopes typically range from **50 to 120 mV/dec**, indicating reaction kinetics. Values around **50–60 mV/dec** suggest a Heyrovsky-limited mechanism, while higher values indicate Volmer limitations. These metrics demonstrate that engineered Heusler compounds can support efficient hydrogen evolution.

4 Surface Engineering Strategies

Surface engineering enhances HER activity by tuning electronic structure and increasing active sites. Doping modifies the d-band center and hydrogen adsorption energy. Incorporating transition metals such as Co, Fe, or Ni improves charge transfer and catalytic efficiency. Defect engineering introduces vacancies, antisite defects, and lattice distortions, creating localized states and additional active sites. These changes enhance adsorption, promote charge redistribution, and lower reaction barriers. Nano-structuring (e.g., nanoparticles, nanowires, thin films) increases surface area and exposes more active sites, while improving mass transport and electron mobility. Combining Nano-structuring with doping and defect engineering yields synergistic improvements in catalytic performance. Overall, the combination of intrinsic electronic tunability and advanced surface engineering makes Heusler compounds strong candidates for efficient and sustainable HER.

Heusler Compounds for Oxygen Evolution Reaction (OER)

1 OER Mechanism

The oxygen evolution reaction (OER) is a critical step in water splitting and the main kinetic bottleneck due to its four-electron transfer and O–O bond formation. In acidic media: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$; in alkaline media: $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$. The mechanism involves surface intermediates such as OH*, O*, and OOH*.

Initially, water or OH^- adsorbs to form OH*, which is oxidized to O*, followed by formation of OOH*, and finally O_2 release with regeneration of active sites. Each step involves proton–electron transfer, and the highest energy barrier determines the over-potential. Efficient catalysts must optimize adsorption energies of intermediates to reduce energy losses and enhance kinetics.

2 Catalytic Activity of Heusler Alloys

Heusler alloys are promising OER catalysts due to tunable electronic structures and multiple transition metal active sites, particularly Ni, Fe, and Co.

Catalytic activity arises from synergistic interactions: Ni provides high intrinsic activity, Fe enhances performance via electronic modulation and charge transfer, and Co improves conductivity and stability. This multi-element framework enables precise compositional tuning of adsorption/desorption behaviour.

Their ordered crystal structure ensures uniform active site distribution and efficient electron transport. Under operation, surface oxidation or reconstruction especially in Ni- and Co-based systems forms active oxide/hydroxide layers, significantly enhancing OER performance.

3 Performance Comparison

Compared to noble metal catalysts such as iridium oxide (IrO_2) and ruthenium oxide (RuO_2), Heusler compounds offer competitive performance with better cost and sustainability. Noble metals typically exhibit over-potentials of **200–300 mV at 10 mA/cm²** and low Tafel slopes, but suffer from high cost, scarcity, and limited durability. Heusler catalysts generally show over-potentials of **250–400 mV** and Tafel slopes of **60–120 mV/dec**, with performance improving through compositional tuning, nano-structuring, and surface engineering. Optimized Heusler systems can approach or match noble metal performance in alkaline media, while offering superior stability and corrosion resistance. Their composition from earth-abundant elements (Ni, Fe, Co, Ti) reduces cost and enhances scalability. Overall, Heusler alloys provide a promising, sustainable alternative to noble metal catalysts for efficient OER in green hydrogen production.

Oxygen Reduction Reaction (ORR) and Fuel Cell Applications

1 ORR Fundamentals

The oxygen reduction reaction (ORR) is a critical process in fuel cells and metal–air batteries, governing cathodic efficiency. It is intrinsically slow due to complex pathways and multiple electron transfers. ORR proceeds via two mechanisms: the **four-electron ($4e^-$)** and **two-electron ($2e^-$)** pathways.

In the **$4e^-$ pathway**, oxygen is fully reduced:

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ (acidic) or

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ (alkaline).

This pathway is preferred due to higher efficiency and avoidance of harmful intermediates.

The **$2e^-$ pathway** produces H_2O_2 or hydrogen peroxide species, which can degrade catalysts and membranes, reducing durability. Thus, selectivity toward the $4e^-$ pathway is essential. The ORR mechanism involves intermediates such as O_2*, OOH*, O*, and OH*. Reaction kinetics depends on their adsorption strength. Optimal catalysts balance adsorption and desorption by tuning surface electronic structure.

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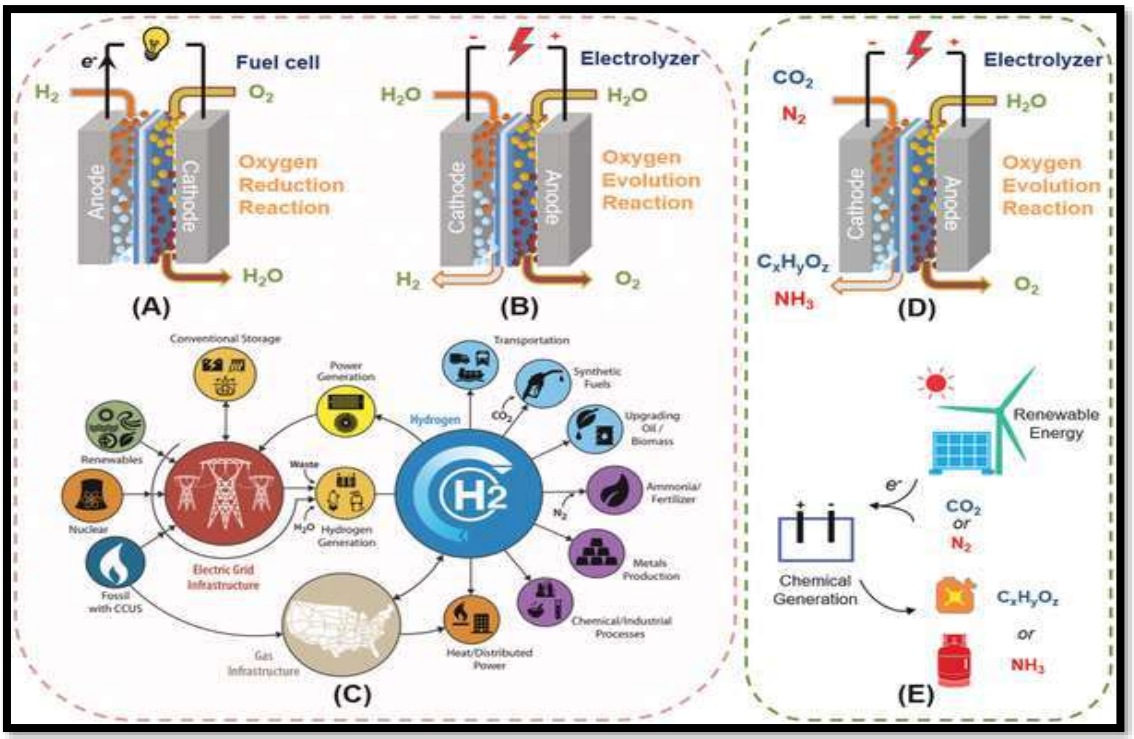

Fig.3: Schematic overview of electrochemical hydrogen technologies and integrated energy systems. (A) Fuel cell operation illustrating the oxygen reduction reaction (ORR) at the cathode and hydrogen oxidation at the anode for electricity generation. (B) Water electrolysis process showing the oxygen evolution reaction (OER) and hydrogen production. (C) Hydrogen-centered energy ecosystem integrating production, storage, transportation, and end-use applications across power generation, industrial processes, and fuel synthesis. (D) Electrochemical conversion pathways utilizing CO_2 or N_2 feedstocks to produce value-added chemicals such as hydrocarbons ($C_XH_YO_Z$) or ammonia (NH_3). (E) Coupling of renewable energy with electrochemical systems for sustainable chemical generation, highlighting pathways from CO_2/N_2 to fuels and chemicals. **(Ref: Electrochemical hydrogen systems review).**

2 Heusler Catalysts in Fuel Cells

Heusler compounds are promising ORR catalysts due to tunable electronic structure, high conductivity, and structural stability. Their multi-element composition enables precise control of adsorption energies, improving activity and selectivity toward the **4e⁻ pathway**. Catalytic activity arises from transition metals such as Co, Fe, and Ni, which modulate the d-band center and enhance electron transfer. Synergistic interactions among these elements improve ORR kinetics compared to single-metal systems. High electrical conductivity further supports efficient charge transport. Heusler catalysts also show good selectivity by suppressing peroxide formation and promoting direct oxygen reduction, enhancing efficiency and durability.

In terms of stability, they perform well in alkaline media due to reduced corrosion and favourable kinetics, maintaining activity over long durations. However, stability in acidic media is limited by metal dissolution and surface degradation. Strategies such as surface modification, protective coatings, and alloying are being explored to improve durability. Overall, Heusler compounds offer tunable activity, improved selectivity, and reasonable stability, making them promising alternatives to platinum-based catalysts. Continued optimization is needed to fully match or exceed noble metal performance in ORR applications.

Nano-structuring and Advanced Engineering Approaches

1 Nanostructured Heusler Catalysts

Nano-structuring enhances Heusler catalyst performance by increasing active sites, improving charge transport, and optimizing mass diffusion. At the nanoscale, a higher surface-to-volume ratio enables more sites for HER, OER, and ORR. Heusler nanoparticles (**5–100 nm**) show improved activity due to greater exposure of active facets, shorter diffusion paths, and size-dependent electronic effects that modify the density of states and adsorption behaviour. Thin-film Heusler catalysts, fabricated via sputtering or pulsed laser deposition, allow precise control of thickness, composition, and crystallographic orientation. Their continuous structure ensures efficient electron transport and makes them suitable for device integration and fundamental studies. Porous Heusler structures combine high surface area with enhanced mass transport. Interconnected pores facilitate reactant/product diffusion, reducing concentration polarization. These structures, formed via templating, de-alloying, or controlled synthesis, also improve mechanical stability during operation.

2 Defect Engineering

Defect engineering tailors Heusler properties by introducing lattice imperfections such as vacancies and anti-site disorders, which act as sites and modify electronic

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structure. Vacancies (missing atoms) alter local electronic environments and induce charge redistribution, creating localized states near the Fermi level. This enhances adsorption of intermediates (H*, O*, OH*), improves charge transfer, and lowers activation barriers. Anti-site disorder, where atoms occupy incorrect lattice sites, disrupts crystal periodicity and modifies orbital hybridization. This alters the density of states and band structure, often improving conductivity and creating new active sites. Controlled introduction via thermal treatment or non-stoichiometric synthesis is an effective strategy for catalytic optimization.

3 Hetero-structures and Composites

Hetero-structures and composites enhance Heusler catalyst performance through synergistic effects. Combining Heusler compounds with carbon materials (e.g., graphene, carbon nanotubes, porous carbon) improves conductivity, surface area, and stability, leading to better charge transfer, dispersion of active sites, and resistance to corrosion. Heusler–metal oxide hybrids further enhance activity, particularly for OER and ORR. Transition metal oxides provide strong redox properties, while hetero-interfaces facilitate electron transfer and optimize adsorption of intermediates. These interactions can create new active sites and improve electrochemical stability. Interfacial charge redistribution and electronic coupling often result in performance exceeding that of individual components. Additionally, composites prevent particle agglomeration and improve long-term stability. Careful control of composition, morphology, and interfaces makes Heusler-based hetero-structures highly effective for advanced energy applications.

Mechanistic Insights and Theoretical Studies

1 DFT Studies

Density Functional Theory (DFT) is essential for analyzing and predicting catalytic behaviour of Heusler compounds at the atomic level. It provides insights into adsorption energetics and reaction mechanisms by evaluating interactions between catalyst surfaces and intermediates such as H*, O*, and OH*.

For HER, the Gibbs free energy of hydrogen adsorption (**ΔGH***) is a key descriptor; optimal catalysts have $\Delta GH \approx 0$*, ensuring balanced adsorption and desorption. Heusler compounds enable precise tuning of ΔGH* via compositional and surface modifications.

For OER and ORR, adsorption energies of O* and OH* govern reaction efficiency. DFT studies show that compositional tuning and defect introduction significantly modify these energies, enhancing catalytic activity. These insights guide rational catalyst design and interpretation of experimental results.

2 d-band Center Theory

The d-band center theory links catalytic activity with the position of the d-band center relative to the Fermi level. In Heusler compounds, this parameter can be tuned through compositional variation of transition metals. A d-band center closer to the Fermi level strengthens adsorption, while one too close leads to overly strong binding and poor desorption. Conversely, a lower d-band center weakens adsorption. Thus, optimal positioning is required for balanced adsorption–desorption. Heusler alloys containing Ni, Fe, Co, and Mn allow precise tuning of the d-band center via alloying and doping, making them highly adaptable for targeted catalytic applications.

3 Reaction Pathway Optimization

Reaction pathway optimization aims to reduce energy barriers and improve kinetics. DFT-based free energy diagrams identify elementary steps and the rate-determining step. In Heusler catalysts, tuning surface electronic structure lowers activation energies for intermediate formation, bond breaking, and product release. For OER, OOH* formation is often the highest energy step; stabilizing this intermediate reduces over-potential. For HER, optimizing hydrogen adsorption ensures efficient Volmer and Heyrovsky/Tafel steps. Advanced computations also explore alternative pathways and effects of surface orientation, strain, and electronic coupling. Combined with experiments, these approaches enable systematic design of Heusler catalysts with lower energy barriers, faster kinetics, and improved efficiency for sustainable energy applications.

Sustainability and Environmental Impact

1 Comparison with Noble Metal Catalysts

The need for sustainable energy solutions has driven interest in alternatives to noble metal catalysts such as Pt, IrO_2, and RuO_2. While these exhibit performance with low over-potentials and fast kinetics, their high cost, scarcity, and environmental concerns limit large-scale use. Heusler compounds offer a viable alternative due to compositional flexibility and use of abundant elements. Although they typically show slightly higher over-potentials, advances in doping, nano-structuring, and defect engineering have significantly reduced this gap. They provide a strong balance between catalytic performance and sustainability for next-generation energy systems.

2 Abundance and Cost Analysis

Heusler compounds utilize earth-abundant elements such as Fe, Ni, Co, Ti, and Mn, making them more accessible and cost-effective than noble metals. This reduces supply risks and can lower catalyst costs by several orders of magnitude, enabling scalable hydrogen production. Some compositions may include costly elements like Hf, increasing expenses. Current research focuses on Hf-free or low-cost alternatives without sacrificing performance. Overall, their economic advantages make Heusler compounds strong candidates for large-scale applications.

3 Stability and Lifecycle Assessment

Heusler compounds generally exhibit good thermal and chemical stability, especially in alkaline media, maintaining activity over long durations. Their ordered structure and metallic bonding enhance resistance to degradation. Lifecycle assessments show favourable performance, with operational lifetimes often exceeding **several thousand hours**. Their metallic nature allows efficient recycling via conventional methods, reducing environmental impact. However, stability in acidic environments remains a challenge due to dissolution and surface oxidation.

4 Role in Circular Economy

Heusler compounds align with circular economy principles through high recyclability, often exceeding **90%**, enabling recovery and reuse without significant quality loss. This reduces reliance on raw material extraction and lowers environmental impact. Their durability and long service life

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minimize waste, while the use of abundant, non-toxic elements supports sustainability goals. Thus, Heusler materials contribute to closed-loop systems and environmentally responsible energy technologies.

Challenges and Limitations

Despite their promising potential, Heusler compounds face several challenges that must be addressed to achieve widespread adoption in electrochemical energy applications. One of the primary limitations is their moderate catalytic efficiency compared to state-of-the-art noble metal catalysts. Although significant progress has been made in improving performance, Heusler-based systems still require further optimization to match the low over-potentials and fast kinetics of Pt, IrO_2, and RuO_2. Another critical challenge is their limited stability in acidic media, where corrosion and dissolution of transition metal components can lead to rapid degradation of catalytic activity. This restricts their application in proton exchange membrane (PEM) systems, which operate under acidic conditions.

Scalability is another important concern, as many synthesis techniques used for producing high-performance Heusler catalysts such as nano-structuring and thin-film deposition are difficult to implement on an industrial scale. Achieving uniform composition, controlled morphology, and reproducibility in large-scale production remains a significant challenge. Additionally, surface degradation during long-term operation, including oxidation, agglomeration, and structural changes, can negatively impact catalytic performance and durability. These issues highlight the need for advanced material design strategies and improved fabrication techniques to enhance the practicality of Heusler-based catalysts.

Future Perspectives

The future development of Heusler compounds for sustainable energy will be driven by emerging research and technological advances. A key direction is the use of artificial intelligence (AI) and machine learning (ML) for catalyst design, enabling rapid screening of compositions, prediction of electronic properties, and optimization of catalytic performance, thereby accelerating discovery. Another promising area is high-entropy Heusler alloys, which incorporate multiple principal elements to increase configurational entropy and stabilize complex structures. These systems offer enhanced catalytic performance through improved electronic tunability, phonon scattering, and diverse active sites, and allowing better control of adsorption energies and reduced reaction barriers.

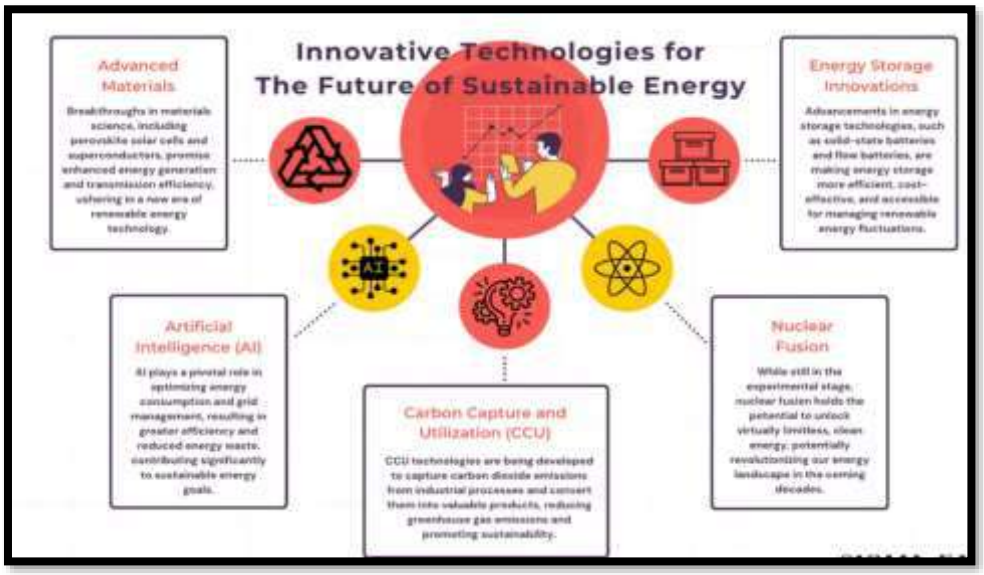

Fig.4: Innovative technologies shaping the future of sustainable energy. (Ref: The Future Of Sustainable Energy - Sigma Earth)

Integration with renewable energy systems is crucial for practical application. Coupling water electrolysis with solar or wind energy can enable sustainable hydrogen production, where Heusler catalysts are advantageous due to their stability and cost-effectiveness. Advances in device and system design will further support their real-world implementation. Achieving industrial-scale hydrogen production requires scalable synthesis methods, low-cost compositions, and durable catalysts capable of long-term operation under harsh conditions. With continued innovation, Heusler compounds are well-positioned to support large-scale green hydrogen production and the transition to sustainable energy systems.

The **Fig.4** highlights five key areas driving the energy transition: advanced materials for improved renewable energy efficiency, artificial intelligence (AI) for energy optimization and grid management, carbon capture and utilization (CCU) for reducing industrial emissions, nuclear fusion as a potential long-term clean energy source, and energy storage innovations such as solid-state batteries for enhanced renewable integration.

Conclusion

This review highlights Heusler compounds as versatile electro-catalysts for green hydrogen production and electrochemical energy conversion. Their structural diversity full-Heusler (X_2YZ), half-Heusler (XYZ), and inverse Heusler combined with tunable electronic properties, enables precise control of catalytic activity. Systems such as Co_2Mn-, Ni_2Fe-, and TiNiSn-based catalysts show promising performance in HER, OER, and ORR. Optimized Heusler catalysts achieve HER over-potentials of **100–300 mV at 10 mA/cm²** with Tafel slopes of **50–120 mV/dec**, while OER over-potentials of **~250–400 mV** approach IrO_2 and RuO_2 benchmarks. In ORR,

they exhibit good selectivity toward the **4-electron pathway** with reasonable activity and stability in alkaline media. Catalytic performance is governed by electronic structure, particularly the d-band center and adsorption energies of H*, O*, and OH*. Strategies such as nano-structuring, defect engineering, and hetero structure formation enhance activity by increasing surface area, improving charge transfer, and optimizing adsorption. Nanostructured systems and composites with carbon or metal oxides further improve durability and reduce energy barriers. DFT studies provide key insights into mechanisms and guide rational catalyst design. From a sustainability perspective, Heusler compounds rely on abundant elements (Fe, Ni, Co, Ti), reducing cost and environmental impact. Their high recyclability (**>90%**) and long lifetimes (**>10,000 hours**) support circular economy principles. They are also compatible with renewable systems such as solar- and wind-driven electrolysis, supporting a hydrogen-based energy economy. However, challenges remain. Their catalytic efficiency still lags behind noble metals, especially in acidic media where corrosion and degradation occur. Issues of scalability, reproducibility, and long-term durability must also be addressed for industrial use. Future research will focus on AI/ML-driven discovery, high-entropy Heusler alloys, and hybrid systems. Achieving targets such as HER over potentials **<100 mV**, OER **<250 mV**, and stability **>50,000 hours** is critical for commercialization. With continued innovation, Heusler compounds have strong potential for sustainable, large-scale hydrogen production.

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Original Article

A Study of Digital Literacy Among Female Primary School Teachers

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Abstract

The present study examines the level of digital literacy among female primary school teachers. Digital literacy has become essential in the modern education system because teachers are expected to use computers, the internet, online communication tools, and digital teaching resources effectively. The study was conducted using a descriptive research design with a structured questionnaire. The sample size is about 26 female primary teachers for the study. Data were analysed using Excel. The findings reveal that teachers possess satisfactory basic digital skills and a highly positive attitude toward digital literacy, but they face challenges such as inadequate training, technical difficulties, and limited infrastructure. The study suggests regular training programs, improved internet access, and better digital facilities in schools.

Keywords: *Digital Literacy, Female Teachers, Primary Education, ICT, Educational Technology, Digital Competence*

Introduction

Nowadays digital technology has become an important part of the education system. Computers, the internet, e-mail, PowerPoint presentations, online videos, and virtual meeting platforms are widely used in schools to make teaching more effective and interesting. Digital literacy refers to the ability to use digital tools and technologies to search for information, communicate, prepare teaching materials, and conduct online teaching activities.

Primary school teachers play a vital role in shaping the learning habits and academic development of children. Therefore, it is essential for teachers to possess adequate digital literacy skills. Female primary school teachers, in particular, contribute significantly to the educational and social development of students. When they are digitally literate, they can prepare lesson plans, create presentations, use online educational resources, and interact with students more effectively.

The importance of digital literacy increased significantly during the COVID-19 pandemic, when teachers were required to conduct online classes and use digital platforms for teaching. This situation highlighted the need for teachers to develop strong digital skills. However, many female teachers continue to face challenges such as limited training opportunities, inadequate access to digital devices, poor internet connectivity, and time constraints.

There are several factors influence the digital literacy of teachers, including educational qualification, availability of training, school infrastructure, institutional support, and personal interest in technology. Understanding these factors is important for designing programs that strengthen teachers' digital competencies.

The present study, therefore, focuses on assessing the level of digital literacy among female primary school teachers, identifying the factors that influence their digital literacy, examining the challenges they face, and suggesting suitable measures for improvement. The findings of this study will be useful for enhancing teachers' professional competence and improving the quality of primary education.

Review Of Literature

L. Nguyen, A. Habok (2023) studied the tools used to assess teachers' digital literacy by reviewing 33 research publications on teacher digital competence.

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The study found that digital literacy is a broad concept that includes the use of technology for teaching, learning, communication, and professional development. The authors observed that different researchers used different assessment tools, which made comparison difficult. The study concluded that there is a need to develop standardized and reliable instruments for measuring digital literacy among teachers.

Fernandez Otoya, M. del Pilar (2024) studied digital and information literacy among teachers through a systematic review of published research. The study highlighted that digital literacy has become an essential competency in modern education and is closely related to teachers' professional competence. The authors found that digital literacy is a continuous learning process in which teachers must regularly update their knowledge and skills. The study suggested that governments and educational institutions should organize structured training programs to improve teachers' digital competencies.

A. Orakova (2024) studied the relationship between digital literacy and teaching competence among primary school teachers. The study found that teachers with higher levels of digital literacy were more effective in lesson planning, use of digital resources, and classroom instruction. The authors concluded that digital literacy has a significant positive influence on teaching effectiveness. The study recommended practical and skill-based training programs to strengthen teachers' digital competencies.

Kumar, K.,Sharma, S. (2024) studied digital competence among 500 teachers with special reference to gender and geographical location. The study found that male teachers demonstrated higher levels of digital competence than female teachers. The authors concluded that gender differences continue to affect access to technology and confidence in using digital tools. The study suggested that special training and support should be provided to female teachers to reduce this gap and improve their digital literacy.

Getenet, S. (2024) studied the relationship between digital literacy, self-efficacy, and teacher engagement. The study revealed that teachers with stronger digital skills reported higher levels of confidence and greater engagement in their professional work. The authors concluded that digital literacy contributes not only to technical competence but also to teachers' motivation and effectiveness. The study recommended training programs that focus on both digital skill development and confidence building.

Rahaman. A, Das M.K (2023) studied digital literacy among 330 women teachers through a survey method. The study found that the majority of respondents had below-average digital literacy skills. The authors concluded that many women teachers need greater exposure to digital tools and more opportunities for structured training. The study suggested that digital literacy programs should be incorporated into both pre-service and in-service teacher education to enhance the professional competence of women teachers.

Objectives Of the Study

To assess the level of digital literacy among female primary school teachers To identify factors influencing digital literacy

To examine challenges faced by teachers

To suggest measures for improving digital literacy

Need Of the Study

The need of the study are –

Increasing use of ICT in education Need for effective digital teaching skills Gender gap in digital literacy

Lack of training opportunities for female teachers Enhancing quality of primary education

Research Methodology

Descriptive research design used for present study. Researcher used Simple random sampling method for present study. All female primary school teachers in Kagal tehsil are the universe of the study. Sample Size was about 26 female primary school teachers for present study. Questionnaire prepared for the data collection. Data analyses done by Excel.

Data Analysis

Table No. 1 Ability to use computer

Able to use Computer	Frequency	Percentage (%)
Yes	24	92.3
No	2	7.7
Total	**26**	**100.0**

Interpretation:

Table 1 shows the Ability to use the computer. The data shows that about 92.3% of respondents are able to use a computer, while 7.7% of respondents are unable to use a computer. This indicates that most respondents have basic computer skills. The finding shows that, the majority of female primary school teachers are digitally prepared to use technology in their professional work at school.

Table No. 2

Ability to Open and Save Files in computer

Ability to open and save file in computer	Frequency	Percentage (%)
Yes	20	76.9
No	6	23.1
Total	**26**	**100**

Interpretation:

Table no 2 shows the ability to open and save files. The data indicates that about 76.9% of respondents are able to open and save files, while 23.1% of respondents are unable to perform this task. This shows that a majority of respondents possess basic file

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handling skills, which is an important component of digital literacy. The finding suggests that, the most respondents are familiar with basic computer operations required for academic and professional use, while a small proportion still need improvement and training in basic digital file management skills.

Table No. 3

Knowledge of Creating a Zoom Meeting Link

Knowledge of Creating a Zoom Meeting Link	Frequency	Percentage (%)
Yes	9	34.6
No	17	65.4
Total	**26**	**100.0**

Interpretation

Table no 3 shows the knowledge of creating a Zoom meeting link. The table shows that 65.4% of respondents are able to create a Zoom meeting link, while 34.6% of respondents are not able to do so. This indicates that, the majority of respondents have basic knowledge of using online meeting platforms like Zoom. The finding suggests that most respondents are digitally equipped to use virtual communication tools for academic and professional purposes, while a smaller proportion still require guidance and training to improve their digital skills in conducting online meetings.

Table no 4

Due to Lack of Time, Digital Devices Cannot Be Used

Due to lack of time digital aid can not be used	Frequency	Percentage (%)
Yes	21	80.8
No	5	19.2
Total	**26**	**100**

Interpretation:

Table no 4 shows the responses regarding the difficulty of using digital devices due to lack of time. The table shows that, 80.8% of respondents agree that they are not able to use digital devices because of time constraints, while 19.2% of respondents do not face this problem.

This indicates that, the majority of respondents experience time-related challenges in using digital tools in their daily work. The finding suggests that heavy workload and limited time are major barriers in developing digital literacy and using technology effectively in teaching and other professional activities.

Findings Of the Study

The present study titled *"A Study of Digital Literacy among Female Primary School Teachers"* explains the level of digital knowledge, computer skills, and difficulties faced by female primary school teachers while using digital tools in education. The results show that teachers have basic knowledge of digital technology, but many of them still lack advanced skills needed for effective digital teaching.

The major findings of the study were,

1. Most of the respondents were well qualified with degrees like D.Ed., B.Ed., M.A., and B.Sc., which shows they have good educational background.
2. Many teachers can do basic computer work such as turning the computer on/off and using keyboard and mouse.
3. A large number of teachers do not have proper knowledge of tasks like scanning documents, printing files, saving data, and using devices like projectors and pen drives.
4. Many respondents find it difficult to use MS Office tools such as Word, Excel, PDF conversion, and online file sharing.
5. Teachers have better knowledge of making PowerPoint presentations compared to other advanced computer skills.
6. Most teachers can search information on the internet and watch online videos, but many are not confident in using email, online communication tools, and virtual meeting apps.
7. Digital tools are not regularly used in classroom teaching. Many teachers do not frequently use PPTs, videos, or online learning materials.
8. Teachers showed a positive attitude toward learning digital skills and agreed that digital knowledge is important in education.
9. Lack of proper digital facilities like internet connection and computers in schools is a major problem.
10. Support from family members and colleagues helps teachers to use digital technology.
11. Teachers face problems like technical issues, poor internet, lack of training, and shortage of digital equipment.
12. Most teachers suggested the need for regular training, workshops, better internet, and more digital resources in schools.

Conclusion Of the Study

The study concludes that female primary school teachers have a moderate literacy. They are comfortable with basic computer use and internet browsing, but they still struggle with advanced digital tools and online teaching methods.

The study also shows that digital literacy depends on training, availability of equipment, internet access, institutional support, and teachers' confidence. Even though

teachers face many challenges, they are willing to learn and use technology in teaching.

Digital literacy is very important in today's education system. Therefore, it is necessary to improve teachers' digital skills through training programs, better facilities, and continuous support to improve teaching quality at the primary school level.

Suggestions Of the Study

1. Schools should arrange regular digital training programs for female primary school teachers.
2. Schools must provide computers, projectors, smart classrooms, and good internet facilities.
3. Practical training sessions should be conducted to improve teachers' computer skills.
4. Teachers should be trained in MS Office, online teaching tools, email use, and virtual classes.
5. Government and school management should support the purchase of digital devices.
6. Teachers should be encouraged to use PPTs, videos, and online learning materials in teaching.
7. Technical help should be available to solve digital problems faced by teachers.
8. Awareness about cyber safety and safe internet use should be provided.
9. Teachers should share knowledge with each other through group learning and discussions.
10. Time should be given to teachers to practice digital skills regularly.
11. Internet facilities should be improved, especially in rural schools.
12. Digital training programs should be made compulsory for teachers to improve modern teaching quality.

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Original Article

Tools for the Use of Artificial Intelligence in Academic Research

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Abstract:

The integration of artificial intelligence (AI) tools into the academic research ecosystem represents a paradigm shift, offering unprecedented opportunities to enhance efficiency, facilitate novel inquiry, and accelerate knowledge discovery. This paper provides a comprehensive examination of the evolving landscape of AI-driven platforms designed to assist researchers across critical stages of the research process, including literature review, data analysis, and scholarly writing. We explore the functionalities of specific AI tools, such as Semantic Scholar, Connected Papers, Scholarcy, Elicit, and large language models (LLMs), analyzing their potential to streamline complex tasks and uncover hidden patterns in data and literature. Furthermore, we delve into the ethical considerations surrounding the implementation of AI in research, particularly concerning bias in algorithms, data privacy, and the responsible use of AI generated content. By providing a detailed overview of accessible AI technologies and addressing the associated ethical challenges, this paper aims to equip researchers with the knowledge necessary to navigate the transformative potential of AI while maintaining scholarly integrity and fostering responsible innovation in the academic sphere.

Introduction:

The rapid advancement of artificial intelligence (AI) has permeated nearly every facet of contemporary society, prompting a profound transformation in various sectors, including academic research. The increasing sophistication and accessibility of AI tools have ushered in an era where researchers are presented with unprecedented opportunities to augment their capabilities, streamline complex workflows, and explore novel avenues of inquiry. Traditionally, academic research has been characterized by meticulous manual processes, including extensive literature reviews, intricate data analyses, and rigorous writing and composition. However, the advent of AI has introduced a suite of tools designed to automate and enhance these critical research activities, promising to revolutionize the way scholars approach their work.

This paper aims to provide a comprehensive and nuanced examination of the burgeoning landscape of AI tools relevant to academic research. We will delve into the specific functionalities of various AI-driven platforms, analyzing their potential to streamline the research process and enhance the quality of scholarly output. For example, tools like Semantic Scholar and Connected Papers are transforming the way researchers conduct literature reviews, enabling them to navigate vast repositories of scholarly literature with greater efficiency and precision. Similarly, AI-powered data analysis tools, leveraging machine learning algorithms, are empowering researchers to extract meaningful insights from complex datasets, uncovering hidden patterns and relationships that would otherwise remain obscured. Furthermore, large language models (LLMs) are rapidly evolving, offering researchers assistance with various aspects of scholarly writing and composition, from drafting outlines to refining language and generating summaries.

However, the integration of AI into academic research is not without its challenges. The use of AI tools raises significant ethical considerations, particularly concerning bias in algorithms, data privacy, and the responsible use of AI-generated content. It is imperative that researchers are cognizant of these ethical implications and adopt best practices to ensure the responsible and equitable use of AI. This paper will address these ethical concerns, providing a critical analysis of the potential pitfalls and proposing strategies for mitigating them.

The primary objective of this paper is to provide researchers with a detailed overview of accessible AI technologies and to equip them with the knowledge necessary to navigate the transformative potential of AI. By examining the functionalities of specific AI tools

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analyzing their benefits and limitations, and addressing the associated ethical challenges, this paper aims to foster a deeper understanding of the evolving landscape of AI in academic research. Ultimately, the goal is to empower researchers to harness the power of AI responsibly, thereby accelerating knowledge discovery and advancing scholarly inquiry in a manner that upholds the highest standards of integrity and ethical conduct.

Keywords: Artificial Intelligence (AI) ,Academic Research,AI Tools ,Literature Review,Data Analysis ,Scholarly Writing,Research Efficiency ,Novel Inquiry ,Ethical Considerations ,AI Technologies ,Machine Learning,Natural Language Processing (NLP) ,Large Language Models (LLMs) ,Data Privacy.

AI Tools for Literature Review:

The **literature review** process, a cornerstone of **academic research**, has traditionally been a time-consuming and laborious task. However, **AI-powered tools** are revolutionizing this process, enabling researchers to efficiently navigate vast repositories of **scholarly literature**.

1 Enhanced Search and Discovery:

o Platforms like **Semantic Scholar** and **Dimensions** utilize **AI algorithms** to analyze and index **academic papers**, providing researchers with more relevant and accurate search results. These tools go beyond simple keyword matching, employing **natural language processing (NLP)** to understand the context and meaning of research papers.

o **Connected Papers** creates visual graphs of related papers, allowing researchers to quickly identify key publications and explore the intellectual landscape of their research area. This visual representation allows for the discovery of previously unknown connections.

2 Automated Summarization and Analysis:

o **Scholarcy** and **Elicit** employ **AI** to extract key information from research papers, generating concise summaries and identifying relevant findings. This can significantly reduce the time spent reading and analyzing lengthy documents.

o **Consensus** is a very useful tool, that enables researchers to quickly find if there is a **consensus** within the research community, regarding given topics.

3 Benefits:

o These tools enhance **research efficiency** by automating tedious tasks, allowing researchers to focus on higher-level analysis and interpretation.

o They facilitate the discovery of relevant **literature**, potentially uncovering hidden connections and insights.

o They can also help researchers to stay up to date on the most current **research** in their field.

AI Tools for Data Analysis:

In an era of **data abundance**, **AI tools** are proving invaluable for researchers seeking to extract meaningful insights from complex datasets.

1 Machine Learning for Pattern Recognition:

o **Machine learning algorithms** can identify patterns and trends in large datasets that would be impossible for humans to detect. This is particularly useful in fields like genomics, neuroscience, and social sciences.

o Tools and programming libraries such as those found in **Python**, and **R**, enable complex **data analysis**.

2 Statistical Analysis and Visualization:

o **AI-powered statistical software** can automate complex statistical analyses, providing researchers with accurate and reliable results.

o **AI-driven visualization tools** can create interactive and informative visualizations, facilitating the communication of research findings.

3 Benefits:

o **AI tools** can accelerate the **data analysis** process, enabling researchers to draw conclusions more quickly.

o They can uncover hidden patterns and relationships in data, leading to new discoveries.

o They can also help to reduce human error in **data analysis**.

AI Tools for Writing and Composition:

AI writing tools are rapidly evolving, offering researchers assistance with various aspects of the writing process.

1 Language Models and Text Generation:

o **large language models (LLMs)** like those that power tools such as, Google Gemini, and other similar tools, can generate text, translate languages, and answer questions.

o These tools can assist with tasks such as drafting outlines, generating summaries, and refining language.

2 Grammar and Style Checking:

o **AI-powered grammar and style checkers** can help researchers improve the clarity and accuracy of their writing.

o These tools can identify grammatical errors, suggest stylistic improvements, and ensure consistency in terminology.

3 Ethical Considerations:

o The use of **AI writing tools** raises **ethical concerns** about authorship, originality, and plagiarism.

o Researchers must be transparent about their use of **AI** and ensure that they properly cite any **AI-generated content**.

o There is also the concern of **AI tools**, producing false information.

4 Benefits:

o These tools can help researchers improve their **writing skills**.

o They can save researchers time by automating some of the writing process.

o They can also help researchers to produce more consistent and professional writing.

Ethical Considerations and Future Directions:

The integration of **AI** into **academic research** necessitates careful consideration of **ethical implications**.

1 Bias and Fairness:

o **AI models** can inherit **biases** from their training data, leading to biased results. o Researchers must be aware of these **biases** and take steps to mitigate them.

o It is very important that researchers remain vigilant, and use critical thinking skills.

2 Data Privacy and Security:

o The use of **AI** often involves the collection and analysis of large amounts of data, raising concerns about **data privacy** and **security**.

o Researchers must adhere to ethical guidelines and legal regulations regarding **data protection**.

3 The Future of AI in Research:

o **AI** is likely to play an increasingly important role in **academic research** in the years to come.

o Future **AI tools** may be able to automate more complex research tasks, such as hypothesis generation and

experimental design.

o There is also research into **AI**, that can help with the peer review process. · **5.4 The importance of Human Oversight:**

o Even with the increasing power of **AI**, human oversight will always be needed.

o Researchers must maintain critical thinking skills, and verify all information that is produced by **AI**.

Conclusion:

AI tools are transforming the landscape of **academic research**, offering researchers unprecedented opportunities to enhance their **efficiency**, explore **novel inquiry**, and advance scientific knowledge. However, the **ethical implications** of **AI** must be carefully considered to ensure responsible and equitable use. By embracing **AI** while maintaining ethical rigor, researchers can unlock new frontiers in scholarly exploration.

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Original Article

Women Vegetable Vendors are The Backbone of the Family with special reference to Kolhapur City

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Abstract

The present study examines the role of self employment and empowerment of women which working in the informal sector with special reference to Kolhapur city. Informal sector play vital role in Global as well as Indian Economy. In India approximately 80% women's employment is in informal sector. Informal Sector mostly divided into 5 groups these are Domestic workers, Self employed, Piece wage workers, Time wage workers and Casual workers etc. India is one of the developing nation and second populous country in the world. Because of high population and low skill government is not able to give jobs for all. Some women can not get regular jobs so they move to informal sector. Informal sector provides earning source to literate as well illiterate women. So these women are help to improve their family living. In Today's globalized era women are the important human resource. They provide Mental and Economic support to the family. Poverty and lack of the profitable employment in the rural areas women vegetable vendors move towards city place and provide support to the family hence women are called as backbone of the family.

Keywords: *Women Empowerment, Backbone, Family,Vegetable Vendors, Kolhapur*

Introduction:

Vegetable play very important role in routine diet of Indian families. In India as well as in Kolhapur agriculture is the livelihood occupation for the majority of the people, approximately 44.62% population of Kolhapur depends on agriculture. In context of this maximum number of poor families survive by working as a vegetable vendor. Due to the poverty, illiteracy and poor economic conditions some families migrate to the city area and working as vegetable vendors. Majority of women are street vendors or selling the vegetables by sitting in one place. In Today's globalized era women are the important human resource. Today the role of women goes beyond the border line of family. Every women can support their family to survive in every situation. In developing Country like India, every year large number of women are enter in the market due to this economic status of the women get increase and is now accepted by society. The boundaries of the gender division are gradually crossed by the women and women can take whole responsibilities of their families like men. So we called women vegetable vendors are the backbone of the family. In present research paper an attempt has been made to study the changing nature of women employability, and role of women vegetable vendors in their family.

Objectives of the Study:

1) To study the Kolhapur city markets and proportion of female vegetable vendors in the market.
2) To study the role of women vegetable vendors in their family.

Research Methodology:

a) Data Collection:

The present study is based on primary as well as secondary data . The primary data were collected by using interview and observation. A sample of 85 women vegetable vendors from 5 markets as a respondents from Kolhapur city was selected.

b) Sample design:

For this research cluster sampling and on 2nd stage quota sampling has been used. **Scope of the Study :**

As far as the scope of the study is concerned this study is Focused on Financial role of women vegetable vendors. Such type of research is useful for their development and planning purposes. This study is related to selected markets in Kolhapur city only.

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Table1.1. Kolhapur City – Selected Markets and gender wise distribution

Selected Markets	Selected vegetable vendors		Total	Female percentage
	Male	Female	M+F	
1. Kapiltirth	18	22	40	**85÷ 160ˣ 100 = 53.1**
Narvekar	18	22	40	
Padalkar	10	10	20	
Shingoshi	14	16	30	
Shahu Udyan	15	15	30	
Total	75	85	160	

Source : Field Work 2018-19

Interpretation: As per observation researcher have selected 5 markets for study. Researcher has found that women vegetable vendors were present in large number i.e. 53.1 percent it means more than half women vegetable vendors were present in this sector.

Role of Women Vegetable Vendor:

a) Economic Importance

i) Increased Productivity –

Every Day women adopts new skills, new techniques to the work area . Due to this their productivity and economic output can increased rapidly. It helps to improve family conditions.

ii) Increased investment –

Women vegetable vendors can reinvest large amount of their income as compared to men which can help to welfare of family.

iii) Source of Income –

Vegetable vending can provide income source to the poor women. Women vegetable vendors can creates income through selling vegetables.

iv) Self-Employment –

Women vegetable vendors provide self-employment. Due to self-employability women can find outs new job opportunities and try to earn maximum money for their family.

v) Reduced Poverty –

Women vegetable vendors can be a only one earning person in their family then it helps to improve their families economic condition and if husband and wife both can do this type of business then they can reduced their poverty. And increased their standard of living.

b) Other Importance :

i) Food Security :

women vegetable vendors provides food security for their own as well as other families. They provide fresh and nutritious vegetables and foods to the families

ii) Health security :

Women vegetable vendors helps families to reduce the risk of different types of diseases.

iii) Head of the families :

As per research it is found that some women vendors play the role of head of the families because some women were widows, some were single, that's why these women works hard for self and families protection.

Conclusion:

Women vegetable vendors plays very important role in global as well as Indian economy. They provide fresh fruits, vegetables and sometimes any other small and domestic goods for income purpose. They take care of everyone's daily diet. They provide affordable vegetables to the maximum people which living in city area. They face lot of problems also but they don't skip because of their family needs. Now in a globalized era contribution of women vegetable vendors to economy is accepted by the society, so the women vegetable vendors can get respect from society as well as family also. So we called women vegetable vendors are the backbone of the family.

Acknowledgment

I express my sincere gratitude to all those who helped me in completing this research study entitled **"Women Vegetable Vendors are the Backbone of the Family with Special Reference to Kolhapur City."**

First and foremost, I would like to thank my guide/supervisor for their valuable guidance, constant encouragement, and constructive suggestions throughout the course of this study. Their support and inspiration played a vital role in the successful completion of this work.

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Original Article

Professors' Perspectives on the Impact of Smartphone Usage Among College-Going Students: A Review of Academic, Artificial Intelligence and Perceptual Dimensions

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Abstract

Smartphone technology's explosive growth has drastically changed higher education settings all around the world. Despite the fact that cellphones have many educational benefits, worries about their overuse and its complex effects on pupils have surfaced. As the main academic facilitators, professors have important firsthand knowledge on how students learn, how engaged they are in their studies, and how dependent they are on technology. With an emphasis on academic influence, artificial intelligence (AI) usage, and general impressions, the current literature review critically investigates professors' viewpoints on smartphone usage among college-bound students. This study emphasizes how cellphones affect learning techniques, cognitive engagement, academic achievement, and patterns of digital dependency by drawing on recent empirical studies, theoretical frameworks, and qualitative research. Additionally, it examines the implications for learning processes and for the research study and projects, the increasing use of chatbots and AI-based tools in academic activities. The review highlights the positive and negative effects of smartphone use, highlighting the necessity of institutional oversight, ethical AI integration, and balanced digital involvement. In order to guarantee safe smartphone use and foster comprehensive student development, the report ends by promoting organized educational interventions, digital literacy initiatives, and legislative frameworks.

Keywords: *Smartphone usage, Professors' perspective, Academic impact, Artificial Intelligence, College students, Digital dependency.*

Introduction

In today's world, smartphones are essential instruments that are changing social interaction, education, and communication. Smartphones are used as academic aids in higher education, giving students immediate access to digital materials, collaborative platforms, and information. However, there are worries about the behavioral, psychological, and academic effects of excessive smartphone use among college students due to its rising prevalence (Kuss & Griffiths, 2017).

Smartphones have brought about a paradigm shift in the dynamics of teaching and learning, according to academics. Digital distractions, multitasking, and diminishing attention spans have all posed challenges to traditional classroom involvement (Rosen, Lim, Smith, & Smith, 2014). Concurrently, technology innovations including digital learning platforms, educational applications, and artificial intelligence (AI) have improved academic accessibility and efficiency (Chen, Xie, Zou, & Hwang, 2020). In academic settings, the dual nature of smartphone usage offers both benefits and drawbacks.

Through their ongoing interactions with students, professors are able to detect developing digital trends, academic adaptations, and behavioral changes. Their opinions provide important insights into how smartphones affect students' study habits, academic achievement, cognitive engagement, and moral behavior. Additionally, the use of chatbots and AI-powered technologies has transformed academic research and learning procedures, raising new issues with creativity, intellectual engagement, and ethical scholarship (Dwivedi et al., 2023).

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The current study summarizes the body of research on professors' thoughts on the impact of smartphones on academic performance, the influence of AI, and general attitudes toward smartphone use among college-bound students. In order to provide a thorough grasp of the digital transformation of higher education, the review attempts to contextualize these viewpoints within current educational challenges and technological advancements.

Professors' Profile and Academic Context

With their extensive understanding of pedagogical procedures, student learning patterns, and academic outcomes, professors constitute an important stakeholder group in higher education. Because of their professional background, they are able to identify minute shifts in academic discipline, learning motivation, and classroom participation. Research shows that teachers are frequently the first to notice how technology affects students' academic practices (Gikas & Grant, 2013).

With their extensive understanding of pedagogical procedures, student learning patterns, and academic outcomes, professors constitute an important stakeholder group in higher education. Because of their professional background, they are able to identify minute shifts in academic discipline, learning motivation, and classroom participation. Research shows that teachers are frequently the first to notice how technology affects students' academic practices (Gikas & Grant, 2013).

According to research, instructors who have taught for a long time are better aware of how digital integration affects students' learning styles (Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich, 2017). Due to smartphone distractions, senior faculty members often voice concerns about students' diminishing focus, diminished critical thinking, and superficial engagement with academic material. On the other hand, younger academics typically highlight cellphones' educational possibilities, such as digital collaboration, blended learning, and AI-supported academic support (Kukulska-Hulme, 2020).

Due to their professional experience, professors are able to evaluate students' long-term intellectual growth as well as their immediate academic performance. As a result, their perspectives offer insightful empirical and firsthand information about how smartphone use is changing the academic world.

Academic Impact of Smartphone Usage: Professors' Perspectives

1 Positive Academic Contributions

Several studies acknowledge the positive effects of smartphones on education when they are used appropriately. Professors recognize cellphones as powerful teaching tools because they provide access to academic databases, online lectures, digital libraries, and interactive learning platforms (Gikas & Grant, 2013). Mobile-assisted learning enhances flexibility, self-paced study, and tailored instruction, especially in blended and online learning environments (Kukulska-Hulme, 2020).

Smartphones enable collaborative learning through online classrooms, discussion boards, and group communication tools. According to Chen et al. (2020), mobile learning applications promote active engagement, information sharing, and academic collaboration. Instructors cite participation in online academic discussions, real-time feedback techniques, and faster turnaround times for assignments.

Furthermore, students can engage with short educational resources in short bursts thanks to cellphones, which support micro-learning strategies. This approach enhances retention and aligns with contemporary learning preferences when appropriately integrated into instructional procedures (Hwang & Fu, 2019).

2 Negative Academic Consequences

Despite these benefits, instructors focus primarily on the negative effects of excessive smartphone use on academic performance. Digital multitasking dramatically reduces attention, memory retention, and conceptual understanding, according to a number of studies (Rosen et al., 2014). During lectures, professors routinely witness students using social media for gaming, chatting, and browsing, which causes split attention and decreased learning effectiveness.

Excessive smartphone use is negatively correlated with academic achievement, according to research. Higher smartphone dependency is associated with worse grade point averages (GPAs) among college students, according to research by Lepp, Barkley, and Karpinski (2015). These results are corroborated by professors, who point to decreased academic discipline, shallow learning strategies, and decreased classroom involvement.

Furthermore, academic complacency has been encouraged by the use of digital shortcuts, pre-made internet solutions, and AI-generated content. According to Chen et al. (2020), professors are worried that students are becoming less cognitively engaged as a result of prioritizing convenience over conceptual understanding.

3 Impact on Cognitive and Learning Processes

Distractions from smartphones lead to cognitive overload and divided concentration. According to cognitive load theory, too many digital stimuli reduce working memory capacity, which has a detrimental effect on learning outcomes (Sweller, Ayres, & Kalyuga, 2011). Instructors indicate that students are becoming more mentally exhausted, less capable of solving problems, and having diminishing analytical abilities.

Additionally, students' intrinsic drive for in-depth learning is diminished by smartphone dependence. The incentive for independent research, critical thinking, and critical inquiry is diminished by the accessibility of quick access to information (Carr, 2010). This change is seen by academics as harmful to scholarly maturity and intellectual growth.

Artificial Intelligence (AI) Usage and Academic Impact

1 AI Integration in Academic Practices

Higher education has changed as a result of the integration of AI-based solutions, such as chatbots, automated content creators, and intelligent tutoring systems. The promise of AI to improve academic productivity, research efficiency, and tailored learning is acknowledged by professors (Dwivedi et al., 2023).

AI chatbots help students with academic writing support, conceptual clarification, content summaries, and literature searches. Chen et al. (2020) claim that AI-driven educational

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technology support adaptive learning by allowing for tailored training based on each student's unique learning requirements. Academic efficiency, time management, and access to scholarly materials are all enhanced by AI applications, according to professors.

2 Ethical Concerns and Academic Integrity

Professors voice serious worries about ethical issues and academic integrity notwithstanding these benefits. Originality, critical thinking, and scholarly authenticity are threatened by an over-reliance on AI-generated outputs (Dwivedi et al., 2023). According to studies, the reliance on AI is causing an increase in instances of plagiarism, mechanical writing, and shallow academic involvement (Cotton, Cotton, & Shipway, 2023).

Instructors stress the danger of cognitive reliance, which occurs when students rely too much on AI technologies instead of learning how to think critically on their own. This pattern calls into doubt both the integrity of academic assessment systems and the long-term intellectual growth of students.

3 Impact on Research and Knowledge Creation

AI tools speed up data analysis, literature reviews, and manuscript production in research settings. Professors warn against blindly adopting these tools, which compromise methodological rigor and conceptual originality, even when they improve research efficiency (Dwivedi et al., 2023).

The difficulty is striking a balance between academic credibility and technical support. To enable the proper incorporation of AI in academic contexts, professors support institutional rules, digital literacy training, and ethical AI frameworks.

General Perceptions of Professors on Smartphone Usage

The general attitudes of professors on smartphone use are ambivalent. Smartphones represent digital empowerment, intellectual accessibility, and technical advancement. Conversely, they stand for diminishing academic discipline, reliance, and distraction.

According to studies, academics view smartphones as two-edged tools that need to be regulated in an organized way (Gikas & Grant, 2013). Professors emphasize the significance of classroom discipline, digital ethics, and institutional policies while appreciating their educational potential.

Instructors frequently point to behavioral shifts in students, such as decreased perseverance, impatience, and a propensity for rapid reward. These changes have an impact on academic resilience and learning motivation, and they are somewhat linked to smartphone culture (Kuss & Griffiths, 2017).

Professors also notice that the interactions between teachers and students have changed, with less direct interpersonal interaction due to digital mediation. Adaptive instructional approaches that include technology while maintaining mentorship and human engagement are required in light of this shift.

NEP 2020 and UGC Guidelines on Smartphone Usage in Higher Education

Policy Framework: NEP 2020 and Digital Learning in India

The Indian government's National Education Policy (NEP) 2020 offers a thorough framework for incorporating digital technologies into higher education. Digital resources, such as cellphones, are acknowledged by NEP 2020 as crucial tools for improving access, equity, quality, and flexibility in education. To guarantee continuity and diversity in education, the policy places a strong emphasis on the growth of online learning platforms, digital repositories, virtual laboratories, and blended learning models (Ministry of Education [MoE], 2020).

NEP 2020 specifically emphasizes how mobile-based learning systems can support learning at any time and from any location, particularly for students from remote, rural, and socioeconomically disadvantaged areas. The policy encourages the use of MOOCs, virtual labs, DIKSHA, SWAYAM, and the National Digital Library (NDL), all of which are widely accessible through cellphones (MoE, 2020). Students may access e-content, recorded lectures, e-books, scholarly papers, and academic databases because to cellphones' flexibility, which expands learning outside of the traditional classroom.

Additionally, NEP 2020 places a strong emphasis on helping students build their digital literacy, critical thinking skills, ethical technology use, and awareness of cyber safety. It emphasizes the need for higher education institutions to teach students ethical digital behavior, promoting effective academic use while opposing abuse, excessive screen time, and digital addiction (MoE, 2020). The policy promotes moderate and controlled use of digital devices while acknowledging issues with digital addiction, short attention spans, and mental health issues.

Additionally, the policy encourages blended learning, which combines in-person education with online resources. According to MoE (2020), cellphones are seen as important facilitators of research involvement, academic networking, interactive teaching, and collaborative learning. Therefore, NEP 2020 emphasizes ethical use, self-regulation, and institutional monitoring while offering a robust policy mandate for incorporating cellphones into formal higher education.

University Grants Commission (UGC) Guidelines on Digital Learning and Smartphone Usage

As India's top regulatory organization for higher education, the University Grants Commission (UGC) has released a number of recommendations, advises, and regulatory frameworks that encourage the use of digital technologies, online education, and mobile-based learning. In order to improve academic engagement and learning results, UGC actively encourages the use of ICT tools, Learning Management Systems (LMS), virtual classrooms, and mobile learning applications (UGC, 2020; 2021).

According to UGC recommendations, cellphones should be utilized mainly as academic tools, making it easier to access e-resources, research databases, e-journals, digital libraries, and interactive learning platforms (UGC, 2020). In order to enable students to include smartphones into note-taking, research, group discussions, project collaboration, and academic communication, the Commission urges educational institutions to create digital learning environments.

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UGC does, however, also voice concerns about misuse, over-reliance, digital distraction, cyber threats, and false information. Higher education institutions have been recommended by the Commission to implement institution-specific digital usage policies that restrict smartphone use in class while permitting organized academic interaction (UGC, 2021). Establishing frameworks for digital discipline that support responsible use, cyber ethics, online safety, and academic integrity is advocated.

In recognition of their critical role in preserving educational continuity, UGC released special guidelines during the COVID-19 epidemic that encouraged remote learning via smartphones and digital platforms (UGC, 2020). In addition to highlighting the value of cellphones in closing learning gaps, the experience brought to light issues including digital weariness, unequal access, psychological stress, and learning discrepancies.

In order to guarantee that cellphones are used effectively for academic purposes, UGC also recommends student digital orientation programs, staff training, and the creation of digital pedagogies. These policies seek to strike a balance between the advantages of education, mental health, and moral digital participation (UGC, 2021).

Implications for Smartphone Usage among College Students

When combined, NEP 2020 and UGC recommendations offer a structured policy framework that promotes smartphone integration in education while addressing the academic and psychosocial hazards connected to excessive or uncontrolled use. These regulations prioritize:

- Promotion of **academic-focused smartphone usage**
- Integration of **blended and digital learning**
- Development of **digital literacy and ethical responsibility**
- Regulation to prevent **addiction, distraction, and academic misconduct**
- Institutional monitoring and **student counseling mechanisms**

In order to lessen the detrimental effects of excessive smartphone dependence among college students, these policies emphasize the significance of balanced digital engagement, psychosocial well-being, and institutional support systems from the standpoint of social work and educational intervention (MoE, 2020; UGC, 2021).

National Education Policy (NEP) 2020 and Smartphone Usage in Higher Education

Digital technology is acknowledged in the National Education Policy (NEP) 2020 as a revolutionary instrument for improving educational access, equity, quality, and accountability. In order to encourage student-centered learning, blended learning models, and inclusive education, the policy emphasizes the integration of digital platforms, online learning materials, and mobile-based apps (Ministry of Education [MoE], 2020). With the ability to access e-content, virtual classrooms, digital libraries, and learning management systems, smartphones are seen as essential facilitators of flexible learning, especially in higher education.

NEP 2020 places a strong emphasis on encouraging students' digital literacy, responsible digital citizenship, ethical technology use, and critical thinking. In addition to encouraging institutions to implement technology-driven teaching-learning methodologies while addressing issues like digital addiction, cyber safety, and information overload, it suggests developing teachers' competence to successfully incorporate technology into pedagogy (MoE, 2020). Additionally, the policy calls for organized digital well-being initiatives in educational institutions and recognizes the psychological and social ramifications of excessive digital participation.

NEP 2020 emphasizes the necessity of comprehensive student development from a social work and mental health standpoint, incorporating behavioral management, emotional well-being, and responsible digital habits. This is in line with the results of the current study, which show that excessive smartphone use among college students has both academic advantages and psychosocial hazards.

UGC Guidelines on Responsible Use of Smartphones and Digital Devices

The University Grants Commission (UGC) has released a number of rules and advisories to encourage students in higher education to connect with technology in a way that is ethical, balanced, and productive. UGC aggressively supported online education during the COVID-19 epidemic while also warning against excessive screen time, digital tiredness, and psychological stress (UGC, 2020; 2021).

UGC emphasizes:

- Structured online learning schedules
- Screen time moderation
- Mental health support systems
- Promotion of digital well-being
- Ethical and academic use of mobile technologies

Additionally, UGC promotes the creation of student counseling centers, digital detox programs, and awareness campaigns on smartphone addiction, cyber safety, and digital ethics. These suggestions highlight the significance of professional social work involvement and institutional initiatives in addressing students' problematic smartphone usage behaviors (UGC, 2021).

The current study backs up UGC's claims with empirical data from instructors' points of view, emphasizing behavioral reliance, academic disruption, attention impairments, and social disengagement brought on by excessive smartphone use. Consequently, incorporating UGC's frameworks for digital well-being into institutional policy can greatly improve student outcomes.

Discussion

According to the literature, instructors' opinions on college students' smartphone use are complex and varied. With their ability to facilitate knowledge access, collaborative learning, and AI-assisted education, smartphones are essential academic tools. Excessive use also interferes with academic discipline, attentiveness, cognitive engagement, and intellectual integrity.

Institutional frameworks, self-regulation skills, and usage habits all have a significant impact on how smartphones affect academic performance. While uncontrolled use

encourages dependency and distraction, constructive integration encourages innovation in schooling. This relationship is further complicated by the development of AI technologies, which both challenge ethical standards and intellectual validity while providing previously unheard-of academic support.

Teachers promote balanced digital participation, stressing the need for ethical AI frameworks, digital literacy initiatives, and pedagogical reforms. Their own knowledge highlights how vital it is to create institutional regulations that encourage safe technology use while maximizing its educational potential.

Conclusion

The current research emphasizes how important academics' viewpoints are to comprehending how higher education is changing academically and technologically. Although they provide amazing educational potential, smartphones present serious problems when utilized excessively and unethically. These complications are further increased by the incorporation of AI technologies, which calls for organized pedagogical and regulatory interventions.

Cognitive development, ethical AI integration, and balanced digital engagement must be given top priority in future educational systems. Institutions may create comprehensive frameworks that support academic achievement, intellectual integrity, and long-term technological growth by incorporating academics' experiential perspectives.

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I would like to express my sincere gratitude to all those who contributed to the successful completion of this review paper titled **"Professors' Perspectives on the Impact of Smartphone Usage Among College-Going Students: A Review of Academic, Artificial Intelligence and Perceptual Dimensions."**

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Original Article

Disparities In Bioterrorism Preparedness: Examining the Social Justice Implications

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Abstract

Bioterrorism poses a significant and urgent threat to public health, national security, and social stability. However, the ability to effectively respond to such attacks is not equally shared among different populations. This research critically analyzes the differences in bioterrorism preparedness, focusing on how unequal public health systems and systemic marginalization put vulnerable communities—especially those identified by race, socioeconomic status, geography, or immigration status—at greater risk. It examines the link between public health security and social justice, arguing that current bioterrorism preparedness frameworks often reinforce, rather than reduce, existing health and social inequalities.

Using an interdisciplinary approach that includes public health policy analysis, critical race theory, and ethical considerations, the study looks into how government preparedness plans, emergency response strategies, and resource distribution practices fail to sufficiently protect marginalized groups. Historical examples—like the unequal response during the COVID-19 pandemic, the Tuskegee syphilis study, and the neglect of low-income neighbourhoods during Hurricane Katrina—demonstrate that systemic inequalities affect who is most at risk when biosecurity is threatened.

This study further examines national preparedness strategies and the resilience of health systems through the perspective of equity. It points out specific deficiencies in infrastructure, including the absence of bio-surveillance in rural and Indigenous areas, inadequate culturally sensitive healthcare communication, and limited access to vaccines and emergency medical services in underserved urban regions. These deficiencies not only undermine overall national security but also raise significant ethical concerns regarding the prioritization of human life and whose safety is considered most important in policy-making.

Moreover, this research investigates how public trust—crucial for any successful public health response—often diminishes in marginalized communities due to historical trauma, systemic neglect, and discriminatory practices. This lack of trust can impede timely reactions to bioterrorism threats, affecting everything from vaccine acceptance to adherence to quarantine protocols. The study concludes with suggestions for incorporating social justice into bioterrorism preparedness strategies, such as fair resource allocation, inclusive policy-making, and focused investments in at-risk communities.

In the end, this research contends that genuine preparedness against bioterrorism cannot be achieved without a dedication to justice. Therefore, national security frameworks must adapt to emphasize equity, acknowledging that the resilience of the most marginalized individuals is key to the resilience of society as a whole. By tackling these inequalities, governments and health systems can create a more inclusive and effective defence against bioterrorist threats while promoting broader public health objectives.

Keywords *Bioterrorism Preparedness, Social Justice, Public Health Disparities, Marginalized Communities, Health Equity.*

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Introduction

Bioterrorism is the intentional release of biological agents to create illness, death, or fear, and it represents a significant threat to public health and national security. To tackle these threats, public health infrastructure is essential: surveillance systems, laboratory capabilities, emergency response plans, healthcare facilities, trained personnel, communication networks, and supply chains for vaccines and medical countermeasures must all operate effectively. However, these resources are not evenly distributed. Marginalized communities—defined as those with low socioeconomic status, racial or ethnic minorities, rural or remote areas, immigrant groups, Indigenous populations, and others—often live in places where public health infrastructure is lacking. This inequality raises important social justice issues: who receives protection, who is at risk, and what ethical and policy frameworks guide us in addressing these disparities? The necessity to analyze bioterrorism preparedness through a social justice lens is not just theoretical. Recent pandemics, like COVID-19, have highlighted how unequal health infrastructure increases vulnerability. Communities with weak health systems, limited access, and low trust experienced significantly higher rates of illness and death. The same concepts apply—and may be even more critical—in a bioterrorism situation, where the speed of detection, resource distribution, and public adherence can be life-saving. If preparedness is inconsistent, marginalized communities might miss early warnings, timely treatments, or access to countermeasures like vaccines. They may also struggle to implement effective non-pharmaceutical interventions (such as isolation and quarantine) due to financial limitations, overcrowded living conditions, or poor governance. Therefore, the consequences are severe and disproportionately felt.

Current studies on public health readiness typically emphasize national or regional capabilities as a whole, often treating the system as a single entity. Yet, research has started to uncover that rural hospitals, small clinics, and communities far from urban areas encounter distinct challenges. For instance, a study examining the views of rural hospitals revealed that these small and remote facilities find it difficult to follow federal guidelines, keep trained personnel, obtain supplies, and collaborate with higher government levels. These institutions usually function with limited financial resources, less advanced infrastructure, and greater geographic and logistical challenges compared to urban facilities. Such inequalities are worsened by fragmented funding and varying policy demands.[1]

Additionally, beyond physical infrastructure, social elements like public trust are crucial. Trust in health organizations, public authorities, and communication methods is very important, particularly when fear, misinformation, or stigma are present during a biothreat. Marginalized groups often report lower trust levels in public health systems, shaped by historical exclusion, past negative experiences, cultural differences, or feelings of neglect. In India, for instance, research in Bihar indicates that individuals in poorer areas or those with chronic illnesses had notably reduced trust in the public health system, linked to service inadequacies, poor management, and previous negative encounters.[2] In low- and middle-income countries (LMICs) and in situations with weak governance, trust issues create obstacles to adopting preventive measures or following official advice—elements that could significantly impede an effective response to bioterrorism.

Social justice demands more than fairness in rhetoric; it requires structural change. Preparedness frameworks—be they in statutes, regulations, policy plans, or funding allocations—must explicitly consider equity. Key questions arise: are resources distributed in ways that ensure marginalized communities have the minimum effective capacity for detection, response, and recovery? Are preparedness guidelines cognizant of differential capacities (e.g., variations in staffing, distances, infrastructure)? Do communication and community engagement strategies reflect linguistic, cultural, and social diversity? Are emergency plans co-designed with affected communities so that interventions are feasible locally?

Empirical data show significant differences in preparedness across various jurisdictions. In California, a RAND Corporation study revealed that even within a wealthy U.S. state, bioterrorism readiness varies greatly among counties, from excellent to poor.[3] Particularly, smaller and rural areas tend to score lower, often due to unclear roles, limited resources, and inconsistent leadership. These results highlight a critical issue: disparities exist even in relatively well-resourced systems.

Another important aspect is the accessibility of acute care and hospital resources. The closure of rural hospitals in the U.S. South from 2007 to 2018 has increased travel times for many rural areas, particularly those with large Black and Latinx populations.[4] Longer distances to hospitals hinder timely access to emergency care, lab tests, and intensive treatment—key components in responding to a bioterrorism incident.

This study seeks to address a gap in existing research: examining how inequities in public health infrastructure (both physical and institutional) and social factors (trust, geography, socioeconomic status, race/ethnicity) combine to create varying vulnerabilities to bioterrorism among marginalized groups. The main research questions are:

[1] Perspectives of Rural Hospitals on Bioterrorism Preparedness Planning, **J. Rural Health** 272, 274–75 (2000).

[2] A. Kumar et al., What Influences the People's Trust on Public Healthcare System in Bihar, India? A Mixed Methods Study, 13 **BMC Health Servs. Res.** 1, 5–6 (2025).

[3] Nicole Lurie et al., *Gaps in Public Health Preparedness: Lessons Learned in California*, RAND Corp., Research Briefing RB9080 (2004).

[4] Aaron B. Cantu et al., Structural Factors and Racial/Ethnic Inequities in Travel Times to Acute Care Hospitals in the Rural U.S. South, 41 **Health Affs.** 1712, 1715–17 (2023).

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1. What structural aspects of public health infrastructure are most lacking in marginalized communities regarding bioterrorism preparedness?
2. How do trust issues, past experiences, social factors, and governance either worsen or alleviate these infrastructure shortcomings?
3. What policies, ethical considerations, and practical measures could enhance preparedness in ways that foster equity and social justice?

To tackle these questions, the paper uses a mixed-method approach: reviewing existing empirical studies, analyzing case studies (urban, rural, Indigenous), and conducting ethical/policy analysis. The normative framework will reference theories of justice (like Rawls and Daniels) and public health ethics to evaluate if current practices fulfill moral duties regarding equal protection and participatory inclusion.

In conclusion, being prepared for bioterrorism is not just a technical or biomedical issue; it is closely linked to justice. Marginalized communities, which already experience disparities in health outcomes, are likely to suffer the most when preparedness is inadequate. It is crucial to ensure equitable infrastructure, fair distribution of resources, inclusive policy design, and trustworthiness, not only for ethical reasons but also because the overall security of public health relies on the resilience of all communities. The upcoming sections will examine the current state of disparity, outline mechanisms of vulnerability, and suggest reforms to align bioterrorism preparedness with the goals of social justice

Literature Review

Preparing for bioterrorism involves more than just detecting agents or stockpiling countermeasures; it needs a strong public health system that is resilient, fair, and able to serve all parts of society. The research shows there are big differences—geographical, socioeconomic, and institutional—in skills, resources, and readiness. Importantly, many studies indicate that marginalized groups—rural, low-income, racially or ethnically minoritized, or otherwise underserved—face significant challenges. This review brings together findings on (1) structural and infrastructural inequalities, (2) social, professional, and psychological aspects, (3) policy, legal, and ethical issues, and (4) recognized gaps and areas needing more research.

I. Structural and Infrastructural Disparities

A. Rural-Urban Differences

Rural hospitals and healthcare providers are often noted for their lack of preparedness. Schur, Berk, and Mueller state that rural hospitals often find federal guidelines too broad and not suitable for their size or infrastructure; panel participants highlighted that "one-size-fits-all" preparedness models usually do not fit geographically isolated hospitals.[5] The long travel distances, lack of specialized staff, and logistical challenges in these areas exacerbate these issues.[6]

Doctors in rural Florida voiced concerns about their awareness, diagnostic skills, and ability to implement response plans for bioterrorism incidents.[7] Many felt unprepared, particularly in identifying cases, receiving training, and participating in simulation exercises.[8]

Veterinarians in rural North Texas also reported low confidence: despite regular exposure to certain agents, only a small number had previous training; there was a significant need for training, especially in identifying category A agents.[9]

B. Local and State Health Department Capacities

Local Public Health Agencies (LPHAs) often highlight issues with communication tools and indicate poor coordination with state and federal agencies.[10] A NACCHO report after September 11 revealed that many LPHAs did not have comprehensive response plans or enough staff trained for bioterrorism or chemical/radiological threats.[11] The GAO also noted significant differences in disease surveillance, laboratory systems, and compatible communication systems among state and local jurisdictions.[12] Studies on hospital preparedness similarly point out deficiencies in surge capacity, infection control, and the routine diagnosis and management of high-consequence pathogens.[13]

Social, Professional, and Psychological Factors

A. Training, Knowledge, Willingness

The readiness and capability of healthcare providers to respond are greatly influenced by their previous training and how prepared they feel. A study in Florida found that only around one-third of community providers believed they were equipped to handle a bioterrorism incident.[14] Factors like past drills, training, views on the seriousness of the threat, and feelings of institutional support were indicators of their readiness.[15] In Korea, similar research indicates that how well individuals believe they can cope, their perceived preparedness on the front lines, and their prior education

[5] Claudia Schur, Marc Berk & Curt Mueller, *Perspectives of Rural Hospitals on Bioterrorism Preparedness Planning*, Rural Health Rsch. Gateway 1, 2–4 (2004).
[6] *Id.* at 3–5.
[7] Aram Dobalian et al., Preparedness of Rural Physicians for Bioterrorist Events in Florida, 30 **J. Rural Health** 418, 420–22 (2014).
[8] *Id.* at 422–24.
[9] John Roland et al., Assessing Bioterrorism Preparedness and Response of Rural Veterinarians: Experiences and Training Needs, 5 **Prehosp. Disaster Med.** 219, 223–25 (2009).
[10] Nat'l Ass'n of Cnty. & City Health Officials, *Assessment of Local Bioterrorism and Emergency Preparedness: Biological Threats & Terrorism* 12–15 (2002).
[11] *Id.* at 16–18.
[12] U.S. Gov't Accountability Off., *Bioterrorism: Preparedness Varied Across State and Local Jurisdictions*, GAO-03-155 (2003).
[13] Hospital Preparedness to Bioterrorism and Other Infectious Disease Emergencies, 19 **Clin. Infectious Diseases** 1479, 1485–87 (1994).
[14] Aram Dobalian et al., *Bioterrorism Preparedness in Rural and Urban Communities Proposal*, U01-HS014355-02 (grant synopsis).
[15] Assessment of Community Healthcare Providers' Ability and Willingness to Respond to Emergencies Resulting from Bioterrorist Attacks, 70 **Biosecurity & Bioterrorism: Biodefense Strategy, Prac. & Sci.** 413, 417–18 (2012).

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have a significant impact on public readiness for bioterrorism.[16]

B. Mental Health Needs

Bioterrorism has both physical and psychological effects, leading to mental health challenges that last longer than the event itself.

In rural areas, primary care providers frequently do not have access to mental health specialists, which can result in PTSD and physical symptoms being overlooked.[17] Tsao et al. discovered that the mental health systems in rural communities are particularly ill-equipped to handle psychological trauma after such events.[18]

Policy, Legal, and Ethical Dimensions

A. Legal / Regulatory Preparedness

Following the anthrax attacks of 2001, model legislations such as the Model State Emergency Health Powers Act were suggested and adopted to varying extents in different states.[19] These legal reforms were designed to enhance public health laws in order to address bioterrorism threats, which encompass surveillance, quarantine, and health authorities.[20] Nevertheless, the implementation of these reforms has been uneven, with certain states falling behind in terms of legal frameworks or operational preparedness.[21]

B. Ethical Challenges and Justice Framing

Wynia & Gostin examine the ethical obstacles present in health care systems, highlighting that the ability to detect issues is hindered when patients are unable to receive care and when physicians do not have the responsibility or motivation to report atypical diseases.[22] The U.S. Commission on Civil Rights' report titled "Briefing on Bioterrorism and Health Care Disparities" (2002) contends that the current inequalities in healthcare will exacerbate the damage caused by bioterrorism, emphasizing that emergency preparedness must take into account access and equity considerations.[23] Additionally, a related yet separate body of literature concerning pandemic preparedness indicates that pandemic planning frequently focuses on procedural justice (rules, neutrality) instead of substantive justice (outcomes, fairness), thereby neglecting to tackle ongoing health disparities.[24]

Gaps and Emerging Insights

The literature, while rich in case studies and descriptive accounts, reveals several under-explored areas that intersect directly with social justice concerns.

1. Quantitative Outcome Data – There exists a limited number of comprehensive studies that connect disparities in preparedness to actual outcomes (such as morbidity, mortality, response delays, and healthcare expenses) in both real and modelled biothreat scenarios.

2. Global and LMIC Contexts – A significant portion of research originates from the United States, Korea, and other high-income regions. There is a scarcity of knowledge regarding readiness and disparities in low- and middle-income countries or Indigenous/remote areas on a global scale.

3. Community Participation / Local Voice – Although the viewpoints of providers are represented, the communities themselves are infrequently involved in the design or evaluation of preparedness strategies; issues related to trust, cultural alignment, and acceptability are often overlooked.

4. Sustainability of preparedness – Numerous enhancements occur following specific events or surges in funding (for instance, post-9/11). The long-term maintenance of capacity—encompassing resources, training, and infrastructure—remains inadequately researched.

5. Integration of Equity Metrics – Preparedness plans frequently lack clear metrics or benchmarks for equity, complicating the evaluation of whether marginalized groups are being adequately protected.

Literature Summary and Positioning of Current Study

In conclusion, the current body of research provides substantial evidence that disparities in infrastructure, organization, profession, and law hinder preparedness for bioterrorism, frequently exacerbating the vulnerability of marginalized communities. Recurring issues include insufficient training, poor communication, inadequate surveillance, and weak legal frameworks. The literature on social justice indicates that seemingly neutral policies can reinforce inequities when foundational capacities are imbalanced.

This research intends to expand upon these principles by (a) incorporating various aspects of disparity (rural versus urban, legal, infrastructural, socioeconomic), (b) directly applying social justice theory to evaluate not only the existing gaps but also how moral responsibilities and policy possibilities could address them, and (c) pursuing comparative insights that encompass contexts beyond the extensively studied cases in the United States—thereby contributing to the understanding of quantification, sustainable policy development, and community engagement

Disparities in Bioterrorism Preparedness

[16] Jinhee Kim et al., Factors Influencing Preparedness for Bioterrorism Among Koreans, 18 **Int'l J. Envtl. Res. & Pub. Health** 5401, 5405–06 (2021).

[17] Posttraumatic Stress Disorder in Rural Primary Care: Improving Care for Mental Health Following Bioterrorism, 58 **J. Psychosom. Res.** 311, 314–15 (2005).

[18] Jennie C.I. Tsao et al., *Impact of Bioterrorism on Rural Mental Health Needs*, U.S. Rural Health Rsch. Project (2005).

[19] William Martin, *Legal and Public Policy Responses of States to Bioterrorism*, 94 **Am. J. Pub. Health** 1093, 1094–96 (2004).

[20] *Id.* at 1095–96

[21] *Id.* at 1096.

[22] Matthew K. Wynia & Lawrence O. Gostin, *Ethical Challenges in Preparing for Bioterrorism: Barriers Within the Health Care System*, 94 **Am. J. Pub. Health** 1096, 1098–99 (2004).

[23] U.S. Comm'n on C.R., *Briefing on Bioterrorism and Health Care Disparities* (Mar. 8, 2002), https://www.usccr.gov/files/pubs/archives/biotrbrf/main.htm.

[24] Debra DeBruin, Joan Liaschenko & Mary Faith Marshall, *Social Justice in Pandemic Preparedness*, 102 **Am. J. Pub. Health** 586, 587–89 (2012).

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Bioterrorism readiness varies significantly between different areas, organizations, and communities, leading to inequalities that affect both efficiency and fairness. These inequalities appear in how resources are distributed, the ability of institutions, training opportunities, legal systems, geographic accessibility, and social factors. The following sections analyse how these differences occur, what causes them, and their impacts.

1. Resource and Infrastructure Disparities

One of the most obvious sources of inequality is the difference in infrastructure and resources between large, well-funded health systems and small, remote, or under-resourced ones. For instance, rural hospitals often do not have the ability to meet federal or state standards for bioterrorism preparedness due to limitations in physical space, staffing, lab diagnostics, and communication systems.[25] In the report "Perspectives of Rural Hospitals on Bioterrorism Preparedness Planning," hospital representatives mentioned that many federal guidelines do not align well with the scale and capabilities of small rural hospitals.[26] Geographic isolation raises the cost and difficulty of obtaining training, supplies, and technical help.[27] Similarly, a RAND Corporation study in California found that even in a state with relatively high overall resources, there was significant variation among counties in preparedness across all areas—leading jurisdictions performed well, while less advantaged ones fell behind.[28] Local Public Health Agencies (LPHAs) in many regions of the U.S. report deficiencies in disease surveillance, laboratory systems, and communication technologies.[29] A General Accountability Office (GAO) report indicated that many state and local jurisdictions had not yet established compatible communication systems or strong laboratory networks, both essential for detecting and responding to biothreats.[30] In low- and middle-income countries (LMICs), infrastructural gaps are even more evident. For example, a review of influenza pandemic preparedness in India revealed that disparities in health personnel, healthcare facilities, public health spending, transportation networks, and access to care differ significantly between districts, especially disadvantaging remote, poor, or marginalized caste/tribe regions.[31] Surveillance systems, supply chain logistics, and laboratory capacity are often focused in urban areas, leaving large rural populations underserved.[32]

2. Training, Competence, and Professional Disparities

Preparedness is greatly influenced by human capacity, which includes knowledge, training, drills, and experience. Disparities occur when training opportunities are not equal.

A survey conducted among physician assistants (PAs) in northern Texas revealed that over half (58.6%) had not engaged in any bioterrorism preparedness training, a situation that has continued since 9/11, indicating a lack of follow-through in areas with significant needs.[33] A similar survey in Florida involving community health providers (physicians, nurses, pharmacists) indicated that fewer than one-third felt capable and ready to respond to a bioterrorism incident; most had minimal recent training or drills.[34]

Rural physicians face particular challenges: discussions with rural physicians in Florida pointed out obstacles such as limited access to information, distance from training facilities, costs, and competing responsibilities.[35] In the report "Physicians' Preparedness for Bioterrorism and Other Public Health Priorities,"[36] a national survey indicated that emergency physicians were more likely than primary care doctors to report having training and preparedness, yet many still felt unprepared, particularly in identifying and diagnosing bioterrorism agents.[37]

The differences in training and knowledge are worsened by variations in institutional support. Some hospitals or health departments conduct regular drills, while others lack the financial or administrative resources to organize and execute them. In many regions, preparedness for natural disasters or more frequent infectious disease outbreaks receives better support than bioterrorism, which is often viewed as more distant or hypothetical.[38]

3. Geographic and Demographic Disparities

Geography is important: the differences between urban and rural areas, how remote they are, and how accessible they are significantly influencing preparedness.

Remote areas and rural counties frequently do not have easy access to specialized labs, quick diagnostics, emergency supplies, or skilled personnel.[39] For example, in the U.S., counties with populations under 10,000 are far less likely to

[25] *Perspectives of Rural Hospitals on Bioterrorism Preparedness Planning*, 16 **J. Rural Health** 272, 274–75 (2000).
[26] *Id.* at 275–77.
[27] *Preparedness of Rural Physicians for Bioterrorist Events in Florida*, 30 **J. Rural Health** 418, 420–22 (2014).
[28] RAND Corp., *Gaps in Public Health Preparedness: Lessons Learned in California*, Research Briefing RB9080, Findings at 1–2 (2004).
[29] NACCHO, *Assessment of Local Bioterrorism and Emergency Preparedness: Biological Threats & Terrorism*, at 5–7 (2002).
[30] U.S. Gov't Accountability Off., *Bioterrorism: Preparedness Varied Across State and Local Jurisdictions*, GAO-03-155, at 10–12 (2003).
[31] L.K. Clark et al., *Existing Health Inequalities in India: Informing Preparedness Planning for an Influenza Pandemic*, 44 **Soc. Sci. & Med.** 140, 145–48 (2012).
[32] R. Verma et al., *Challenges of Bioterrorism: An Indian Perspective*, 15(2) **Indian J. Pub. Health Rsch. & Dev.** 414, 414–17 (2024).
[33] *Physician Assistants and Bioterrorism Preparedness*, 20 **Prehosp. & Disaster Med.** 271, 272–74 (2005).
[34] *Assessment of Community Health Care Providers' Ability and Willingness to Respond to Emergencies Resulting from Bioterrorist Attacks*, 5 **Biosecurity & Bioterrorism: Biodefense Strategy, Prac. & Sci.** 413, 417–19 (2007).
[35] *Critical Challenges and Impediments Affecting Rural Physicians During a Public Health Emergency*, 106 **S. Med. J.** 21, 22–24 (2013).
[36] *Physicians' Preparedness for Bioterrorism and Other Public Health Priorities*, 292 **JAMA** 217, 218–20 (2004).
[37] *Id.* at 219–21.
[38] *Id.* at 219–21.
[39] U.S. Comm'n on C.R., *Bioterrorism and Health Care Disparities*, at 12–14 (2002).

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have thorough plans for dealing with terrorist or bioterrorist threats compared to larger counties.[40]

Demographic elements—like race/ethnicity, socioeconomic status, caste/tribe identity, and education—affect both the risk of exposure and the ability to respond. In India, a study during the H1N1 pandemic revealed that lower caste, indigenous populations, poorer families, and regions with fewer healthcare workers faced significantly worse access to treatment, higher exposure risks, and poorer health outcomes.[41]

Likewise, regions with lower healthcare funding and inadequate transportation systems experience delays in detection, treatment, or vaccine distribution.[42] Particularly in low- and middle-income countries (LMICs), rural and marginalized groups are more affected by both direct infrastructure shortcomings and indirect social factors like poverty, lower education levels, and limited political influence, which reduce their access to preparedness resources.[43]

4. Legal, Policy, and Coordination Disparities

Having legal authority, policy frameworks, and coordination mechanisms is crucial for implementing measures like quarantine, surveillance, and countermeasure distribution, as well as defining roles during emergencies. Differences occur in how various jurisdictions apply or enforce these frameworks.[44]

In the U.S., following the anthrax attacks and post-9/11, several federal laws and acts (such as the Public Health Security and Bioterrorism Preparedness and Response Act of 2002) were introduced to create a standard for bioterrorism preparedness; however, the execution has been inconsistent. Some local jurisdictions do not have updated laws or have failed to modify regulations to address new threats or modern detection methods. Policy fragmentation is a common concern: local, state, and federal agencies may have conflicting roles, poor communication, or vague resource responsibilities.[45]

Low- and middle-income countries (LMICs) often operate under outdated legal frameworks or those intended for infectious disease outbreaks, rather than specifically for bioterrorism. Research indicates that many nations lack clear legal requirements for biothreats or do not have the financial and institutional resources to enforce them properly. For instance, studies on outbreak preparedness in India show that while disease surveillance programs are in place, the laws addressing intentional biological threats are relatively weak or not well developed.[46]

5. Social Determinants, Public Trust and Equity

Even when infrastructure and legal capacity are present, social factors such as poverty, education, trust in public institutions, culture, and language influence how well communities can access preparedness interventions.

Public trust is crucial for following non-pharmaceutical interventions, participating in drills, getting vaccinations, and adhering to public health guidelines. Communities that have been historically overlooked or discriminated against often have a distrust of authorities, which results in less cooperation or delayed symptom reporting. While there is more literature on pandemics (like COVID-19) than on bioterrorism specifically, the trends are likely similar. For instance, studies on pandemic responses in India indicate that lower education levels, caste or tribal identity, poverty, and gender impact how health messages are perceived, trust in public health officials, and access to healthcare.

Language, cultural relevance, and local beliefs influence how risks are understood and acted upon. In diverse communities, generic communication may not be effective. Preparedness plans frequently lack culturally sensitive risk communication. Training programs and drills might not include marginalized groups or take into account their unique challenges (such as overcrowded living conditions, lack of transportation, or the necessity to work instead of quarantine).

6. Consequences of Disparities

The differences mentioned have several harmful effects.

- Delayed detection and response: Limited monitoring and diagnostic abilities in under-resourced areas can let bioterror agents remain unnoticed or misdiagnosed for extended periods.
- Inequitable health outcomes: Marginalized groups may experience higher illness and death rates due to late or insufficient access to treatment or preventive care.
- Reduced overall resilience: Weaknesses in one part of the system lower the system's overall capacity; an outbreak or biothreat in a distant area can spread or create ripple effects.
- Erosion of trust and social cohesion: If marginalized communities feel ignored, it undermines trust in public health initiatives more broadly, even during non-bioterror emergencies.
- Ethical and justice implications: These disparities breach principles of distributive justice (fair risk and protection allocation), procedural justice (involvement in decision-making), and substantive justice (equal results).

7. Summary

In conclusion, the research indicates that disparities in bioterrorism preparedness are genuine, complex, and closely linked to wider social inequalities. Infrastructure shortcomings, uneven training, geographic isolation, legal and policy fragmentation, and social factors all work together to disadvantage marginalized communities. Although significant progress has been made in high-income areas, many gaps still exist—particularly concerning empirical outcome data, participatory policy design, and comparative studies in low- and middle-income countries (LMICs). Recognizing these disparities is crucial not only for justice but also for the effectiveness of national and global health security.

Ethical And Social Justice Considerations

[40] *Id.* at 13.
[41] Clark et al., *supra* note 7, at 146–48.
[42] *Id.* at 147–49.
[43] Verma et al., *supra* note 8, at 414–15.
[44] *Public Health Security and Bioterrorism Preparedness and Response Act of 2002*, Pub. L. No. 107-188, § 101, 116 Stat. 594 (2002).
[45] GAO-03-155, *supra* note 6, at 8–11.
[46] *Ready or Not — Preparedness for Bioterrorism*, 345 **New Eng. J. Med.** 1041, 1041–44 (2001).

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Preparing for bioterrorism is crucial for the safety of society, but it brings up complicated ethical and social justice concerns. The actions taken to prevent or deal with intentional biological threats often create conflicts between different values: personal freedoms against community safety; effectiveness against fairness; immediate security against lasting trust. To ensure that preparedness is both efficient and fair, ethical guidelines should direct policies and practices, and social justice should be a core focus, not an afterthought. Here are important factors, their conflicts, and recommended norms based on existing literature.

I. Core Ethical Principles in Bioterrorism Preparedness

1. Human rights and civil liberties must be respected. States are responsible for protecting their populations from threats, but this does not allow for widespread violations of individual rights.[47] Measures like quarantine, mandatory vaccination, surveillance, or movement restrictions should be reasonable, clear, and based on law to prevent misuse. Henry Annas states that compromising fundamental human rights during responses to bioterrorism erodes public trust and ultimately harms public health initiatives.[48]

2. Obligation to care, warn, and report. Healthcare workers and institutions have ethical responsibilities in identifying, containing, and treating issues. Wynia & Gostin suggest that problems can arise when patients cannot access care (duty to care), when doctors are hesitant or untrained to report suspicious cases (duty to report), or when containment efforts are neglected due to an overly narrow focus on individual patient needs instead of the greater good.[49]

3. Justice — both in distribution and process. Distributive justice requires that the burdens and benefits of bioterror preparedness be shared equitably. Often, marginalized groups face greater risks and have fewer resources. Procedural justice demands fair involvement: communities affected should have a say in decisions regarding policies that impact them (such as vaccine distribution and quarantine regulations).[50]

4. Openness and trust. Bioterrorism incidents create fear, uncertainty, and the risk of misuse or overreach, making trust essential. Open decision-making, effective communication, and accountability are vital for maintaining the credibility of public health authorities. Without these, compliance may decline, particularly in marginalized communities with histories of neglect or mistreatment.[51]

5. Minimal infringement / proportionality. Actions that restrict freedoms (like movement, assembly, and privacy) should be the least invasive necessary to achieve valid public health objectives. Overly harsh or permanent restrictions are both unethical and ineffective.[52]

6.Solidarity and reciprocity. Solidarity requires that communities cooperate and share burdens during emergencies. Reciprocity refers to ensuring that those who assume greater risks (e.g., healthcare workers) are protected and supported.[53]

Social Justice Issues: Marginalization, Inequity, and Vulnerability

1. Unequal access to healthcare. Numerous marginalized groups (due to factors such as socioeconomic status, race/ethnicity, geographic location, and immigration status) experience a lack of consistent access to health services. In the event of a bioterror attack, these disparities result in delayed detection, postponed treatment, and increased mortality rates. Ethical frameworks contend that universal access to a basic level of health services is not merely a policy issue but a moral obligation.[54]

2. Allocation and prioritization of resources. The determination of who receives limited resources (such as vaccines, antivirals, and ventilators) first raises questions of justice. The prioritization of frontline workers is frequently justified; however, decisions regarding whether to favor the affluent, urban populations, well-connected individuals, or the elderly present complex equity challenges. Those who are already disadvantaged should not face further barriers in accessing lifesaving resources.[55]

3. Trust, stigma, and discrimination. Marginalized communities often harbor distrust towards health institutions due to historical injustices or neglect. They may be apprehensive about facing discrimination in areas such as surveillance, testing, or treatment. The risk of stigmatization is also present, particularly if certain groups are linked (whether accurately or inaccurately) to the origin or transmission of a biological agent. These elements affect the effectiveness of health interventions; neglecting them can exacerbate harm.[56]

4. Involvement and inclusion in policy formulation. Ethical justice necessitates that the perspectives of marginalized communities be incorporated into planning and decision-making processes: this ensures that policies are culturally relevant and that their needs and limitations are acknowledged. Exclusion can lead to the development of policies that are either impractical or unjust, thereby exacerbating inequalities.[57]

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[47] George J. Annas, *Bioterrorism, Public Health, and Human Rights*, **Health Aff.** 94, 95–96 (2002).

[48] *Id.* at 95–97.

[49] Matthew K. Wynia & Lawrence O. Gostin, *Ethical Challenges in Preparing for Bioterrorism: Barriers Within the Health Care System*, 94 **Am. J. Pub. Health** 1096, 1097–99 (2004).

[50] *Id.* at 1098.

[51] Cheryl Erwin & Sheryl Dacso, *Ethical and Legal Issues in Bioterrorism Events*, 9 **J. Biosecurity, Biosafety & Biodef. L.** 1, 5–7 (2018).

[52] *Id.* at 8.

[53] Gregory A. Poland, Robert M. Jacobson, Jon C. Tilburt & Kristin L. Nichol, *The Social, Political, Ethical, and Economic Aspects of Biodefense Vaccines*, **Vaccine** Suppl. 4, D23–27 (2009).

[54] Matthew Wynia & Lawrence Gostin, *The Public Health Value of Health Professionals*, 93 **Am. J. Pub. Health** 1098, 1098–1100 (2003).

[55] *Id.* at 1097–98.

[56] George J. Annas, *Reforming Informed Consent*, 36 **Health Aff.** 96, 96–97 (2017); Wynia & Gostin, supra note 8, at 1098.

[57] atricia J. Erwin & Clifford Dacso, *Health Equity and Social Justice*, **De Gruyter Brill** 3, 3–5 (2021).

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5. Sustainability and systemic change. Preparedness initiatives often garner significant attention and funding in the aftermath of crises, but there is typically a lack of sustained follow-up. Social justice demands that investments be enduring, fostering resilient public health infrastructure, particularly in underserved regions, rather than relying on temporary emergency solutions.[58]

III. Tensions and Trade-Offs

- **The distinction between individual and collective good.** Initiatives that serve the community, such as quarantine, may encroach upon personal freedoms. Achieving a balance is an ethically sensitive matter. The existing literature emphasizes that collective actions ought to be legally regulated, proportionate, and subject to oversight.[59]
- **The conflict between speed and due process.** In the face of urgent biothreats, swift measures may be necessary; however, expedient actions must not compromise fairness or individual rights. For instance, immediate quarantine mandates or compulsory vaccinations require procedural safeguards (such as notice and the right to appeal) even in times of urgency.[60]
- **The tension between security and transparency.** Certain biodefense information is classified. Nonetheless, a lack of transparency can erode public trust. Ethical guidelines recommend that, whenever feasible, authorities should disclose information regarding risks, uncertainties, and the reasoning behind their decisions.[61]
- **The issue of allocation biases.** Resources often gravitate towards more prominent or affluent areas (urban centers, wealthy regions), neglecting marginalized communities. To ensure fair distribution, proactive policies are necessary rather than mere dependence on market dynamics or political influence.[62]
- **Concerns regarding data, surveillance, and privacy.** While surveillance is essential for detection, it raises significant issues related to privacy, potential misuse, and targeting. It is ethically imperative to implement effective oversight, protect data, and restrict data usage to essential purposes.[63]

IV. Legal and Normative Frameworks

There is substantial literature on how laws and regulations have attempted to codify ethical constraints in biodefense and public health emergencies.

- The Model State Emergency Health Powers Act and similar legislation grant states enhanced authorities (such as quarantine, isolation, and vaccination), yet they have faced criticism for being excessively broad and lacking adequate safeguards or accountability.[64]
- International legal standards (for example, human rights law and treaties) also set boundaries on the lawful actions of governments, even in times of threat. For example, treaties ensure the rights to health, life, and non-discrimination, which limit the scope of bioterrorism preparedness policies.[65]
- Ethical guidelines, such as the WHO's recommendations on the emergency use of unregistered interventions (MEURI), illustrate the ethical application of experimental treatments during emergencies. While this is more frequently utilized in naturally occurring outbreaks (such as Ebola), the underlying principles are relevant to bioterrorism when countermeasures involve experimental approaches.[66]

V. Prescriptions and Best Practices

Drawing on the ethical and justice considerations, the literature suggests a number of best practices:

1. Incorporating equity into all preparedness strategies. Policies must feature clear equity metrics: for instance, basic standards for every region, resources allocated for underprivileged communities, and requirements for access irrespective of income, race, or location.

2. Legal protections and oversight. Powers given during emergencies require checks and balances: judicial review, legislative oversight, sunset provisions, and defined criteria.

3. Involving the community and participatory planning. Involve marginalized groups in the planning process: recognizing local vulnerabilities, acceptable solutions, and preferred communication methods. This fosters trust and helps prevent one-size-fits-all errors.

4. Clear communication. Risk communication must be transparent about uncertainties, possible trade-offs, and should be culturally and linguistically appropriate for various groups.

5. Support for the healthcare workforce. Those on the front lines must be ethically protected: access to PPE, vaccines, mental health resources, and fair compensation. Failing to support them weakens the entire system.

6. Long-term investment. Instead of temporary funding, create resilient systems in underserved regions: laboratories, surveillance, vaccine distribution capabilities, and trained personnel.

. Connection to Infrastructure Disparities and Marginalized Communities

- When ethical and social justice factors are overlooked, infrastructure disparities worsen the impact on marginalized groups:

[58] *Id.* at 6–7.
[59] Matthew Wynia & Lawrence Gostin, *The Public Health Value of Health Professionals*, 93 **Am. J. Pub. Health** 1098, 1096–97 (2003).
[60] George J. Annas, *Reforming Informed Consent*, 36 **Health Aff.** 96, 97 (2017).
[61] Patricia J. Erwin & Clifford Dacso, *Health Equity and Social Justice*, **De Gruyter Brill** 3, 2–3 (2021).
[62] Gregory A. Poland et al., *The Re-emergence of Vaccine-Preventable Diseases*, 90 **Mayo Clin. Pr Wynia & Gostin, supra note 13, at 1099.oc.** 1501, D24–25 (2015).
[63]
[64] George J. Annas, *Reforming Informed Consent*, 36 **Health Aff.** 96, 95–98 (2017).
[65] **Ethical and Legal Considerations in Mitigating Pandemic Disease: Workshop Summary, Inst. of Med. (U.S.) Forum on Microbial Threats** (2007), https://www.ncbi.nlm.nih.gov/books/NBK54163/.
[66] World Health Org., *Guidance for Managing Ethical Issues in Infectious Disease Outbreaks* 39–41 (2016), https://www.who.int/publications/i/item/9789241549837.

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- Lacking access to care leads to missed detections. Without equitable communication, public health messages may not reach or be trusted. Failing to prioritize underserved communities in vaccine or treatment distribution continues the cycle of inequality.
- The ethical responsibilities of duty to care, solidarity, and fairness suggest that national preparedness is only as robust as its weakest link. Marginalized communities with infrastructure deficits represent that weak link.
- Ensuring justice is not only a moral issue but also a practical one: outbreaks in marginalized areas can spread; distrust in any community can hinder compliance and detection.

Policy Analysis and Case Studies

When looking at how policy frameworks have tried to tackle bioterrorism preparedness, it's helpful to examine specific legal tools, funding initiatives, and case studies. This reveals where there are still gaps—in policy design, execution, fairness, and effectiveness—and offers insights on how to better connect preparedness with social justice goals.

I. Key Policies and Legislation

1. **Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (U.S.)** Following the 2001 anthrax attacks, this Act (P.L. 107-188) was introduced to enhance the U.S. capability to prevent, prepare for, and respond to bioterrorism and other public health crises. Important features included the regulation of "select agents and toxins," improved surveillance, increased laboratory capacity, and better coordination among federal, state, and local authorities.[67] However, assessments indicate that the implementation has been inconsistent: there is significant variation among state and local jurisdictions in the capacity they have developed, with many rural or under-resourced local public health agencies still struggling with staffing, laboratory capabilities, or communication systems.[68]
2. **Model State Emergency Health Powers Act (MSEHPA)** Introduced in the US after 2001, MSEHPA aimed to update state laws to empower public health officials with sufficient authority for quarantine, surveillance, and mandatory reporting.[69] Some states implemented sections of the proposed legislation, while others altered or dismissed it due to worries about civil rights, expenses, and administrative challenges.[70] This variation in adoption has resulted in a fragmented legal framework, with some states possessing strong powers to address biological threats, while others are unclear or lack the necessary resources.[71]
3. **Pandemic and All-Hazards Preparedness Reauthorization Act (PAHPRA), 2013** Although the name implies a concentration on pandemics and natural disasters, PAHPRA also clearly includes biological threats (even those that are intentional), the development of medical countermeasures, and enhances government authority in public health emergencies.[6] One policy analysis suggests that while the Act has enhanced certain capabilities (such as stockpiling, coordination, and clarity), it has not completely resolved structural inequalities—for instance, smaller local health departments continue to face challenges in obtaining adequate funding and qualified staff.[7]

Case Studies

A. United States – Smallpox Vaccination Program (2003)

The U.S. started a national smallpox vaccination campaign after 2001 to protect against the risk of intentional smallpox release.[72] The plan was to vaccinate response team members, healthcare workers, and others. However, the program faced pushback: many hospitals declined to join, citing concerns about adverse events; there was public doubt regarding the chances and seriousness of a smallpox attack; worries about costs and liability; and uncertainties in scientific risk evaluations.[73] Only a small number of target civilians received vaccinations before the program was limited.[74]

From a social justice viewpoint, several problems emerged: hospitals with fewer resources (often rural or small) had less ability or willingness to take part; communication about the risks and benefits of the vaccine was inconsistent; liability and safety worries were more pronounced for smaller institutions lacking strong insurance or legal backing. This situation highlights that even with solid federal policy support, local capacity, trust, and institutional backing are essential for fair implementation.

B. Local Health Departments & Federal Funding in U.S.

Another situation concerns the link between federal funding for bioterrorism readiness and the actions of local health departments (LHDs). A study on LHDs revealed that receiving federal funds (like those from the CDC) was strongly linked to increased preparedness efforts—especially in hiring emergency preparedness coordinators. However, many LHDs still lacked essential capabilities without such funding.[75] Additionally, leadership and

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[67] **Public Health Security and Bioterrorism Preparedness and Response Act of 2002**, Pub. L. No. 107-188, 116 Stat. 594

[68] Kewal Krishan, B. Kaur & A. Sharma, *India's Preparedness Against Bioterrorism: Biodefence Strategies and Policy Measures*, 113 **Curr. Sci.** 1675, 1675–82 (2017).

[69] **Model State Emergency Health Powers Act**, Nat'l Conf. of Comm'rs on Unif. State Laws (2001).

[70] *Legal and Public Policy Responses of States to Bioterrorism: Model State Emergency Health Powers Act as Catalyst*, 94 **Am. J. Pub. Health** 1093, 1094–96 (2004).

[71] *Id.* at 1095–96.

[72] Matthew K. Wynia & Lawrence O. Gostin, *A Look Behind the Scenes: Bioterrorism, Smallpox, and Public Health Policy*, 288 **JAMA** 1058, 1059–60 (2002).

[73] *d.* at 1060–61.

[74] **2003 United States Smallpox Vaccination Campaign: Overview & Outcomes**, Ctrs. for Disease Control & Prevention (CDC), https://www.cdc.gov/smallpox/bioterrorism-response-planning/public-health/vaccination-campaign.html (last visited Sept. 23, 2025).

[75] Id.

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previous crisis experience are important factors.[76] Yet, there are disparities: smaller, less affluent LHDs, or those located in rural regions, often receive less funding and have lower baseline capacities, which restricts their capabilities—even with federal assistance.[77] This situation illustrates how policy (federal grants) can help lessen some disparities, but unless allocation formulas, eligibility criteria, reporting requirements, and technical support are tailored to consider local differences (in resources, infrastructure, and geography), inequalities will continue.

C. India – "India's Preparedness Against Bioterrorism: Biodefence Strategies and Policy Measures" (2017) & "Challenges of Bioterrorism: An Indian Perspective"

These two studies review India's legal, policy and infrastructural preparedness. The 2017 article assesses India's existing laws and biodefence strategies, noting that while India has several laws (for example, pertaining to hazardous substances and health emergencies), there is weak implementation, insufficient laboratory networks, surveillance that is more robust in urban centers than rural, and limited public awareness or institutional capacity particularly in remote districts.[78] The "Challenges" piece emphasizes demographic diversity, high population density, linguistic and cultural diversity, significant rural population, and uneven health infrastructure as major obstacles to effective bioterrorism preparedness.[79]

These case studies highlight classic social justice issues: remote and marginalized populations are less covered; policy may exist, but implementation is uneven; and resource constraints intersect with geography, literacy, and governance challenges. They also suggest India needs stronger integration between policies and local capacities, more clarity in role definitions, and more robust capacity building in under-served regions.

Analysis of Policy Effectiveness & Disparities

From the cases and policies above, several analytic observations emerge regarding disparities in preparedness.

1. **Variation in Implementation vs. Policy on Paper** Many policies are strong in intention but weak in implementation. Whether it's the U.S. smallpox vaccination campaign or India's biodefense strategies, the gap between legislation, federal guidelines, and what is practically available at the local/community level is large. Marginalized communities often suffer most from this gap.
2. **Role of Funding, Staffing, and Institutional Capacity** Policies that depend heavily on federal or central funding sometimes undermine equity if funding flows disproportionately to already well-resourced areas. The case of U.S. LHDs shows that smaller or poorer departments often lack staff or technical resources to use grants effectively, or to apply for them. Similarly, in India, well-connected urban institutions are more likely to have strong labs, trained personnel, and surveillance networks than rural or remote areas.
3. **Legal Authority and Legislative Variability** Where legal frameworks differ across states or regions (as in U.S. states adopting or modifying MSEHPA differently), the capacity to enact measures (quarantine, surveillance, mandatory reporting) varies sharply. Regions with weaker or unclear legal authority are often less prepared to act decisively in emergencies.
4. **Public Trust, Engagement, and Communication** The smallpox campaign's mixed reception underscores that public acceptance matters. Policies that do not engage communities, clearly communicate trade-offs (e.g., vaccine risks, benefits), or provide transparency often face resistance. In India, where linguistic, cultural, and socio-economic diversity is high, one-size-fits-all messaging or top-down implementation exacerbate disparities.
5. **Geographic and Demographic Inequities** Both in U.S. and India, rural, remote, poorer, or marginalized population groups lag behind in preparedness. Whether due to underinvestment, logistical barriers (transport of sample, supply of countermeasures), or inadequate surveillance infrastructure, these inequities are persistent.

Lessons and Policy Recommendations

Based on policy analyses and case studies, several reforms emerge that align preparedness with social justice:

- **Equitable funding formulas:** Ensure that funding policies allocate more weight to underserved areas—rural, remote, or low-income—to enable base capacity building, not just "top-ups".
- **Legal standardization with flexibility:** Use model legislations or guidelines, but allow adaptation so that states/districts can adjust to local capacities, while insisting on minimal legal authority standards for public health response.
- **Mandatory minimum infrastructure standards:** Policies should require baseline capacities (lab, surveillance, communication, emergency coordination) in all jurisdictions, tied to accountability or performance metrics.
- **Community involvement and participatory planning:** Involve local communities in designing preparedness plans, risk communication strategies, vaccination or countermeasure deployment, taking into account local culture, language, trust, and constraints.
- **Transparent communication and managing risk perception:** Ensure policy designs include strategies to communicate clearly about benefits and risks, particularly for interventions with potential adverse effects or trade-offs.
- **Sustainable capacity building:** Policy should not only be reactive after crises but establish ongoing training, infrastructure maintenance, stock-pile management, and workforce development, especially in under-resourced areas.

[76] *Id.* at 1061–62.
[77] *Impact of Federal Funding on Local Health Department Preparedness*, supra note 7, at 81–83.
[78] Ruchi Verma et al., *Challenges of Bioterrorism: An Indian Perspective*, **Indian J. Pub. Health Rsch. & Dev.**, Vol. 15, No. 2, at 1–5 (2024).
[79] *Id.* at 4–5.

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Recommendations For Equitable Bioterrorism Preparedness

To guarantee that bioterrorism preparedness is both technically proficient and socially equitable, national, regional, and local health authorities, along with community stakeholders, should implement the following recommendations. These recommendations are categorized into structural reforms, policy and regulatory measures, community engagement and communication, capacity building, and monitoring and accountability.

1. Structural Reforms & Resource Allocation

a. Equitable Funding & Resource Distribution

● Formulate funding models that clearly consider baseline vulnerabilities such as rurality, poverty, demographic marginalization, and current infrastructural shortcomings. These models should incorporate weighted distributions for facilities located in remote or disadvantaged areas to ensure that even the most basic standards are achieved.

● Establish specific grants aimed at underserved regions to enhance core capacities, including laboratories, cold chain systems for vaccines and medical countermeasures, emergency stockpiles, and rapid transport and logistics infrastructures.

b. Strengthening Health Infrastructure in Marginalized Areas

● Guarantee that health care facilities (clinics, community health centers, local hospitals) possess fundamental structural resilience: dependable power, water, sanitation, secure building structures, and logistical support for supply chains.

● Create mobile or decentralized laboratory units that can conduct disease surveillance and provide rapid diagnostic responses, ensuring that remote regions are not reliant on far-off central laboratories.

2. Policy, Regulation & Legal Frameworks

a. Regulatory Frameworks for Biosafety and Biosecurity

- Implement the WHO's Stepwise Approach to Regulatory Requirements for Biosafety and Biosecurity in Biomedical Laboratories. National regulatory bodies should evaluate current regulations, pinpoint deficiencies, and progressively enhance oversight, licensing, institutional biosafety committees, and accountability systems.[80]
- Enforce the WHO Laboratory Biosecurity Guidance, which encompasses risk-based strategies, supervision, and secure methods across the entire pathogen lifecycle.[81]

b. Laws that Ensure Equity in Emergency Powers

● Revise or implement laws that explicitly outline the powers and responsibilities in the event of biothreat emergencies—this includes quarantine, surveillance, and mandatory notifications—while incorporating safeguards for civil liberties and anti-discrimination.

● Guarantee that legislation requires preparedness objectives (such as minimum time/distance for access to marginalized regions, e.g., maximum travel time to diagnostic centres, and the percentage of the population included in emergency plans).

c. Coordinated Multi-Level Governance

● Enhance collaboration among national, regional, and local authorities, guaranteeing that local health departments possess the necessary resources and legal authority to function effectively.

● Create oversight bodies or commissions that incorporate community representatives to ensure that policy development aligns with local conditions.

3. Community Engagement, Communication & Trust

a. Risk Communication Tailored to Diverse Populations

● Create communication strategies in various languages and formats (written, audio, visual) that are culturally sensitive, utilizing trusted local leaders and mediators.

● Implement participatory risk mapping to allow communities to voice their concerns, knowledge deficiencies, and logistical challenges, enabling the adaptation of communication and interventions.

b. Inclusion of Marginalized Communities in Planning & Design

● Make certain that communities from rural, Indigenous, minority, and migrant backgrounds are represented in preparedness planning groups, scenario exercises, and policy feedback systems. This fosters procedural justice and improves feasibility and compliance.

● Create platforms (such as town halls, advisory boards, and community liaisons) to ensure their voices are considered prior to the implementation of policies.

c. Building & Maintaining Trust

● Recognize historical injustices: acknowledge the harm, abuse, or neglect experienced by marginalized groups within health systems, and foster transparency regarding preparedness initiatives.

● Promote accountability and transparency in decision-making processes (clarifying why specific areas are prioritized and what trade-offs are involved), which includes publicly reporting adverse events during emergency responses.

4. Training, Capacity Building & Preparedness Exercises

a. Workforce Training & Retention

● Allocate resources for training initiatives aimed at healthcare professionals, laboratory technicians, and public health officials, especially those from underprivileged areas, to identify biothreat agents, implement countermeasures, and coordinate emergency responses.

● Offer incentives such as scholarships, retention bonuses, and career advancement opportunities for individuals serving in underserved or isolated regions.

b. Simulation Exercises & Drills Inclusive of Marginalized Areas

● Emergency preparedness drills should consistently encompass rural, remote, and marginalized regions; the design of scenarios must take into account local

[80] **World Health Organization**, *Guidance on Implementing Regulatory Requirements for Biosafety and Biosecurity in Biomedical Laboratories: A Stepwise Approach* 1–5 (2020).

[81] **World Health Organization**, *Laboratory Biosecurity Guidance*, at Key Elements & Best Practices (2024).

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infrastructure limitations (such as restricted road access, power supply, etc.).

● After-action reviews need to assess equity concerns: Were marginalized areas left unprepared? Were communication efforts successful? What obstacles were faced?

c. Laboratory Capacity & Biosecurity Training

● Leverage WHO recommendations to enhance biosafety committees, promote dual-use awareness, ensure secure management of pathogens, and establish laboratory regulations.[82]

● Allocate resources and technical assistance for biosafety education, implement cybersecurity measures for laboratories managing sensitive data, and provide oversight that aligns with associated risks.[83]

5. Monitoring, Evaluation & Accountability

a. Equity Metrics & Indicators

● Establish quantifiable metrics of readiness that reflect social justice: access durations, per capita laboratory capacity, demographic distributions of vulnerability, communication outreach, levels of trust, etc.

● Mandate the public reporting of these metrics; utilize them to inform future resource distribution and policy modifications.

b. Audits & Independent Reviews

● Conduct independent evaluations of preparedness strategies, particularly in marginalized areas, to determine if these plans are implemented in reality (not merely documented), if resources are accessible, if training has occurred, and so forth.

c. Sustainability & Long-Term Investment

● Prevent funding cycles characterized by instability during crises; create consistent funding sources (such as national budgets and international assistance) that sustain essential capabilities at all times.

● Guarantee the upkeep of infrastructure, restocking of supplies, continuous training, and system enhancements instead of permitting deterioration.

6. Integration with Broader Social Determinants of Health

● Acknowledge that the readiness for bioterrorism is not an isolated endeavor; vulnerabilities frequently stem from factors such as poverty, inadequate housing, insufficient education, and poor transportation, among others. Strategies for preparedness should be integrated with initiatives that tackle social determinants.

● Include access to clean water, nutrition, and primary health care as essential components of resilience development in underserved communities.

7. Technological and Innovation-Based Supports

● Employ digital resources (for instance, Geographic Information Systems, artificial intelligence, mobile applications) to identify at-risk communities, monitor disease surveillance, and coordinate response logistics.

● Guarantee that technology is within reach: take into account digital literacy, internet availability, and language obstacles; implement low-tech solutions when necessary.

● Adhere to the World Health Organization's revised biosecurity recommendations, taking into account new technologies like artificial intelligence, genetic modification, and cyber threats in laboratories.[84]

Examples & Contextual Adaptation

When implementing these recommendations, it is essential to consider the context. Solutions that are effective in urban high-income areas may not be suitable for rural, resource-limited, or culturally varied environments. Therefore:

● Tailor guidelines to fit local geography, available resources, cultural practices, and social frameworks.

● For instance, in India, facilities located in tribal or remote areas might require mobile laboratories and incentives for staff; training in the languages spoken by local communities; and legal authority for districts to operate independently without awaiting state or national approval.

● Global collaboration can be beneficial: exchanging best practices, establishing cross-border laboratories in regions with porous borders, and coordinating the procurement of countermeasures for economically disadvantaged areas.

Conclusion

Examining disparities in bioterrorism preparedness from a social justice perspective uncovers a complicated relationship among public health systems, social inequalities, and ethical responsibilities.

Bioterrorism represents a distinct and significant danger that requires a thoroughly coordinated, adequately funded, and fair public health response.

Nevertheless, as this research indicates, marginalized groups—defined by race, ethnicity, socioeconomic status, geography, or other criteria—are consistently less equipped to handle bioterrorism threats due to ongoing structural disparities in public health systems, policy formulation, and resource distribution.

Unequal Preparedness Reflects Broader Social Inequities

At the heart of these inequalities is a larger truth: public health preparedness is not isolated. It is deeply intertwined with social determinants of health, including poverty, educational access, housing, transportation, and healthcare availability. Marginalized groups often encounter compounded vulnerabilities that weaken their capacity to endure bioterrorism incidents. A lack of healthcare facilities, insufficient laboratory capabilities, ineffective emergency communication systems, and underfunded public health agencies create an environment where the swift detection and response to biological threats are significantly obstructed.

These inequalities are not mere coincidences; they stem from a history of neglect, discriminatory practices, and systemic underfunding. The years of the pandemic have

[82] **World Health Organization**, *WHO Updates Laboratory Biosecurity Guidance* (July 4, 2024), **World Health Organization News Release**.

[83] Richard Haigh et al., *Epidemic and Pandemic Preparedness and Response in a Multi-Hazard Context: COVID-19 Pandemic as a Point of Reference*, 21 **Int'l J. Envtl. Res. & Pub. Health** art. 1238 (2024).

[84] Sandra C. Melvin et al., *The Role of Public Health in COVID-19 Emergency Response Efforts From a Rural Health Perspective*, 17 **Prev. Chronic Dis.** 200256 (2020).

revealed and intensified these flaws, highlighting that preparedness initiatives predominantly Favor wealthy, urban, and well-resourced communities. Conversely, rural, Indigenous, immigrant, and economically disadvantaged populations often find themselves sidelined in national emergency preparedness efforts.

Ethical and Social Justice Implications

From an ethical standpoint, the unequal distribution of preparedness resources and capabilities represents a breach of fundamental principles of justice, equity, and human dignity.

Public health ethics requires that every individual, irrespective of their background, should have fair access to protection against preventable harm—including bioterrorism.

Marginalized communities should not be seen merely as passive recipients of assistance but as active collaborators in the development and execution of preparedness strategies.

Social justice necessitates a deliberate shift in bioterrorism preparedness to focus on those who are most vulnerable and historically neglected.

This involves recognizing the structural factors that contribute to vulnerability, tackling systemic racism and exclusion, and empowering marginalized populations through inclusive policy-making initiatives.

Equitable preparedness is not just a moral obligation but also a practical necessity: ignoring certain communities creates pockets of risk that threaten the safety of the entire population.

Importance of Structural Reform and Policy Innovation

This study emphasizes that a significant reduction in disparities necessitates structural reforms across various levels. Firstly, funding models for public health preparedness should explicitly consider inequities in foundational infrastructure and social vulnerability. It is crucial to allocate resources equitably, targeting areas that are under-resourced to develop sustainable capacity. Funding should not be limited to short-term emergency cycles but must also ensure the maintenance and enhancement of essential facilities, laboratories, and stockpiles.

Secondly, policy frameworks need to be updated to incorporate equity as a core principle. Regulations related to biosafety, emergency powers, surveillance, and response must include clear provisions to protect marginalized groups, uphold civil liberties, and empower local agencies to respond promptly. Legal safeguards against discrimination during emergencies should be reinforced.

Lastly, governance models must transition towards participatory and inclusive frameworks. Engaging communities is no longer optional; it is essential. Policies created without the genuine involvement of marginalized communities are likely to be ineffective or even detrimental. Empowering local leaders and organizations not only enhances the quality of preparedness but also fosters the trust and social cohesion necessary for compliance and resilience in times of crisis.

Community Engagement and Trust-Building

The literature and case studies reviewed highlight the critical significance of communication, transparency, and trust-building within marginalized communities.

Risk communication needs to be culturally aware, multilingual, and conveyed by reliable local figures. Unidirectional, top-down messaging has shown to be inadequate; rather, engaging in two-way dialogues that honour community insights and directly address concerns is essential.

Furthermore, trust can only be established by addressing historical injustices and showing accountability during emergency responses. Governments and health organizations must emphasize transparency, share data openly, and recognize their errors. Fostering ongoing relationships with marginalized groups beyond times of crisis will help ensure that bioterrorism preparedness does not turn into another instance of exclusion or fear.

Capacity Building and Workforce Development

The study also highlights human resources as a significant deficiency. Marginalized regions frequently do not have trained healthcare professionals and public health workers who can identify, diagnose, and manage bioterrorism threats. Investing in local workforce development, which encompasses training, career incentives, and retention strategies, is essential.

Simulation exercises and emergency drills that involve marginalized communities enhance practical readiness and uncover context-specific obstacles. These exercises should mirror real-world situations, including infrastructural limitations such as transportation or communication outages. Ongoing learning and adaptation informed by after-action reviews guarantee that preparedness progresses alongside evolving social and epidemiological conditions.

Monitoring, Evaluation, and Accountability

A strong system for monitoring and evaluation that incorporates an equity perspective is crucial for addressing preparedness deficiencies.

Creating indicators that assess both technical capabilities and social justice results—like fair access to diagnostic services or the extent of communication outreach—enhances transparency and directs enhancements.

Independent audits and public reporting systems bolster accountability. They guarantee that equity commitments are substantive rather than merely symbolic, leading to real improvements. Additionally, ongoing investment and the institutionalization of preparedness roles prevent the drawbacks associated with temporary emergency funding, fostering long-term resilience.

Integrating Social Determinants and Technological Innovation

Ultimately, this study emphasizes the importance of incorporating bioterrorism preparedness within the wider framework of social determinants of health. Tackling issues like poverty, education, housing, and infrastructure is essential for developing effective preparedness systems. A comprehensive strategy that links emergency readiness with overall health equity will foster stronger, more resilient communities.

Technological innovations such as digital mapping, AI-driven surveillance, and mobile diagnostic platforms present valuable resources, but their implementation must be approached cautiously to prevent worsening existing inequities. It is crucial to prioritize accessibility, digital literacy, and privacy safeguards.

Moving Forward: A Call to Action

In summary, tackling the inequalities in bioterrorism preparedness necessitates a comprehensive, equity-focused strategy. This entails breaking down structural obstacles, reforming existing policies, fostering inclusive governance, investing in underrepresented communities, and upholding transparent accountability systems. Only through these unified efforts can public health systems guarantee that no community is overlooked when confronted with bioterrorism threats.

The stakes are significant. Bioterrorism incidents have the capacity to result in devastating loss of life and societal upheaval. At-risk populations are disproportionately vulnerable to danger, yet frequently omitted from preparedness initiatives. Ethical obligations and practical requirements align in asserting that future preparedness plans must be grounded in social justice.

By acknowledging and addressing these disparities, public health can achieve its core mission: to safeguard the health and dignity of all individuals, particularly those who are most vulnerable. This dedication will not only preserve lives but also enhance the social cohesion and resilience of communities in the face of biological threats and beyond.

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Original Article

Biodegradable Plastic Production from Agricultural Waste and Biopolymers (PLA-PCL)

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Abstract

Growing environmental concern over non-degradable plastic waste has driven global demand for sustainable alternatives. The study focuses on developing biodegradable plastic films from natural starch sources such as potato, sugarcane waste, and maize, blended with biodegradable polymers like Poly Lactic Acid (PLA) and Polycaprolactone (PCL). After production, these film rolls were printed with custom branding and marketed to local restaurants and small businesses as an eco-friendly packaging solution. This approach not only utilizes agricultural residues, such as sugarcane bagasse and maize waste, to add value to agro-industrial by-products but also provides an environmentally safe alternative to single-use plastics. The combination of natural starch-based polymers with biodegradable synthetic components is a practical method for creating sustainable packaging materials. Starch-PLA-PCL blends have the potential to reduce plastic pollution, promote economic practices, and support a green, biodegradable, sustainable future.

Keywords: *PLA, PCL, Biodegradable waste.*

Introduction

Plastics are harmful in today's environment because they are lightweight, versatile, chemically inert, and have good electrical and thermal qualities. These properties make plastics indispensable in a variety of industrial applications, including domestic equipment, fittings, furniture, appliances, electrical components, medical devices, and packaging. By 2024, worldwide plastic output had topped 450 million tons per year and is anticipated to double by 2040 [Sarah P et al.,2024; Association ISW 2024], with single-use plastics accounting for more than 95% [Environment U. et al.,2018]. Notably, plastic accounts for more than 90% of all raw materials utilized in the packaging business. The synthesis of plastics, a twentieth-century breakthrough [Bordes P et al., 2009], transformed industrial manufacturing. Plastic polymers, a by-product of the petroleum industry, were inexpensive to produce and rapidly gained the reputation of being 'the magic substance'. Plastic manufacturing was controllable from 1950 to 1970; however, production increased dramatically during the next two decades, posing unexpected waste management issues. Plastic garbage is frequently disposed of straight into the environment due to its non-biodegradability, resulting in huge landfills. In 2015, global plastic garbage creation was around 6300 Mt [Babayemi JO et al., 2019], with approximately 79% ending up in landfills or spreading in the environment.

If current trends continue, plastic trash output is expected to nearly double to around 12,000 Mt by 2050. Landfilling is the most common waste management strategy in Europe, with EU landfills burying 7.2 million tonnes of plastic trash in 2018 [Mossman S et al., 2020]. Under typical environmental conditions, these waste plastics will degrade into microplastics owing to weathering, exposure to sunlight, and combustion. Microplastics pose serious risks to both the ecosystem and wildlife by altering food chains [Wabnitz C et al., 2010]. Furthermore, burning plastic garbage emits dangerous chemicals into the atmosphere, including dioxins, furans, and polychlorinated biphenyls. These toxic gases are carcinogens, mutagens, or damaging to the central nervous system, causing malignancies, heart disease, respiratory issues, neurological damage, and even altering reproduction [Verma R et al., 2016].

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As a result, proper plastic waste management is critical to maintaining a healthy ecosystem. Strategies such as the 3R idea have been created to solve this issue, yet there are still issues associated with traditional plastic trash management. Consequently, research and development in renewables and biodegradable polymers are garnering widespread notice. Biodegradable materials can gradually dissolve without affecting the environment, providing a viable answer to the problems caused by non-biodegradable plastics. These bio-degradable polymers (BDP) have a diverse spectrum of characteristics, allowing them to compete with non-biodegradable thermoplastics in a variety of applications. Polylactic acid (PLA) and polyhydroxyalkanoate (PHA), both generated from biopolymers, are among the most widely used biodegradable plastics [Avérous L et al., 2008]. This research investigates the synthesis and applications of biodegradable plastics as a potential solution to environmental pollution produced by non-biodegradable polymers.

Pollution of the Environment with Non-Degradable Plastic

Many non-biodegradable plastics are being discharged into the environment over the course of their life cycle due to the rapid increase in plastic production worldwide. Global plastic output increased from 1.5 million tons in the 1950s to 450 million tons by 2024 and is predicted to double by 2040. 79% of single-use plastic products are poorly managed and ultimately wind up in large landfills, according to UN worldwide environmental reports [Nations U et al., 2019]. There are numerous environmental problems associated with landfills. "Leachate," or the liquid that seeps through the landfill, frequently contains dangerous materials like viruses, organic contaminants, and heavy metals that, if left unchecked, can contaminate the adjacent groundwater and seep into the surrounding soil [Zhou Y et al.,2020]. Local water supplies may be seriously endangered by this leachate.

Furthermore, landfills take up a lot of space, destroying habitat and reducing biodiversity in the surrounding areas. Furthermore, plastic trash in landfills contributes to long-term pollution since the plastics do not disintegrate for hundreds of years before breaking down into microplastics that are carried. Plastics can degrade into microscopic particles via photodegradation, thermal oxidation, or hydrolysis mechanisms [Li P, Wang X et al., 2021]. In the early 1970s, researchers discovered microplastic particles in coastal water [Carpenter EJ et al.,1972]. Later, Thompson RC and colleagues created the term'microplastic' for plastic particles smaller than 5 mm [Thompson RC et al., 2004]. The majority of microplastics are produced by the partial degradation of PE, PP, PVC, PET, and PS, which are very difficult to decompose and persist in the environment for long periods. Plastics' extremely high molecular weights, resistance to mid-chain attack, relative water resistance, and low surface area to volume ratio are the main reasons for their low rate of deterioration [Huang JC et al., 1990]. Do Sul et al. claim that plastics are found in terrestrial, aquatic, and atmospheric systems [do Sul JAI, et al., 2014]. They enter these environments by a variety of routes, including being carried from land to rivers and ultimately arriving in the ocean [Jambeck JR et al., 2015]. Coastal nations dump over eight million tons of non-biodegradable plastics into the ocean annually, which is enough to cover every foot of the planet's shoreline with five trash bags. Every year, millions of creatures, including fish, birds, and other marine life, perish as a result of this non-biodegradable plastic garbage. Plastics are known to affect about 700 species, some of which are endangered. Land animals are now at risk from plastics, and when they ingest them, they suffer agonizing deaths. This degradation of the environment is mostly caused by plastic bottles. Local communities frequently use burning discarded plastics as a waste reduction strategy since it lessens the substantial amount of trash that ends up in landfills. By using the heat generated by burning to generate electricity [Al-Salem S et al.,2019] or to heat buildings as an alternative energy source [Fahim I et al.,2021], waste plastic incineration may offer energy recovery possibilities. Waste made from polyolefin-based polymers, such as PE and PP, can be burned to provide energy [Gupta A et al., 2008; Bora RR et al., 2020; Kannan P et al.,2013].

Introducing Biodegradable Plastics as an Alternative to Non-Biodegradable Plastics

Researchers have started looking into biodegradable plastics as a way to address the environmental issues raised by petroleum-based plastics. According to their developmental stage, there are now three different kinds of biodegradable plastics. The first kind entails mixing additives that are broken down by microbes with polymers [Joseph TM et al.,2023].

Non-degradable polymers are combined with particular additives or plasticizers to enable partial or full biodegradation in these blended biodegradable plastics. Although these polymers have additives that encourage biodegradation through microbial activity, they are not naturally biodegradable. Certain environmental conditions are necessary for the microbial metabolism of these polymers. However, the kind of additives, air exposure, moisture content, and microbial activity all affect how quickly blended polymers degrade. Synthetic polymer materials with grafted groups that experience hydrolysis due to microbial attack comprise the second category. Biodegradable segments are chemically grafted onto the polymer chain of synthetic polymers. The grafted segments allow the plastic to degrade hydrolytically and enzymatically. The third and most effective technique uses fermentation to create polymers from naturally occurring ingredients, including the well-known poly (lactic acid) (PLA), poly(hydroxybutyrate) (PHB), and poly(hydroxyalkanoate) (PHA). The majority of these are made from renewable resources. Under composting conditions, these plastics break down into carbon dioxide, water, and biomass.

Biodegradable Plastics

PLA (Poly lactic acid) Synthesis, Properties, and Uses

One popular substitute for non-biodegradable plastics is poly (lactic acid). Because it can be derived from non-toxic, renewable feedstocks, namely sugar and starch, PLA is one of the most significant biopolymers [Singhvi M

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et al.,2019]. Because PLA has characteristics that allow it to be used in the human body, its uses were mainly restricted to the biomedical industry until the early 2010s [Datta R et al.,2006]. Because PLA has crucial qualities, including biodegradability, mechanical strength, and processability, it was introduced to the packaging sector as a biodegradable packaging material in the late 2010s [Godavitarne C et al.,2017]. The fermentation of sugars from natural sources, including corn, sugarcane, and other food components, is the first step in the creation of polylactic acid (PLA). Lactic acid (2-hydroxypropanoic acid), the most common hydroxycarboxylic acid discovered by a Swedish scientist in 1970, is the first step in the manufacture of PLA. In addition to being a naturally occurring component of many foods and a byproduct of in situ microbial fermentation, lactic acid (LA) can be produced chemically or via fermentation. Examples of fermented products include yogurt, buttermilk, sauerkraut, sourdough bread, and many more. From anaerobic prokaryotes to humans, LA is an essential metabolic intermediary in the majority of living things. LA has long been utilized in the food industry to preserve, taste, pH buffer, and suppress bacterial decomposition in a variety of processed foods [Schreurs VV et al., 2010].

Technical-grade lactic acid was also used in leather manufacture. LA's two functional groups facilitate a variety of chemical reactions. These reactions fall into four categories: condensation, esterification, reduction, and alcohol substitution. LA can be employed in such reactions to create materials with potential for widespread usage in industrial and consumer products [Holten CH et al.,1971]. The primary results of these chemical processes are polymers for producing plastic and plastic-based textiles. PLA's hydroxyl and carboxyl functional groups allow it to create linear polyesters via intramolecular or self-esterification. PLA has a variety of mechanical and physical qualities that are crucial to its uses. PLA's density is 1.21-1.25 g/cm3, making it ideal for lightweight applications [Hiroi R et al.,2004]. PLA can exist in both amorphous and semi-crystalline forms, which affect its strength and melting point. The semi-crystalline PLA offers increased rigidity and a higher melting point. PLA has a glass transition temperature (Tg) of 50 °C to 80 °C and a melting temperature of 150 °C to 180 °C [Lim L-T et al.,2008], which directly affects its thermal stability. PLA's versatility makes it suitable for a variety of sectors. PLA's biocompatibility has led to its use in biomedical applications such as targeted drug delivery systems, drug encapsulation, and tissue engineering. A significant improvement is in PLA stereo-complexes (sc-PLA) created by mixing poly l-lactic acid and poly d-lactic acid [Balla E et al., 2021; Mathew AP et al.,2006], which improve thermal stability and make PLA ideal for heat-resistant applications. Recent research on the inclusion of microfillers, nanofillers, and elastomers into PLA aims to increase its elasticity, rigidity, thermal stability, flame retardancy, and customized electrical properties, thereby increasing PLA's utility in electronic applications. Furthermore, the creation of PLA/natural fiber composites provides a superior alternative to synthetic fibers. Furthermore, PLA is commonly employed in the packaging business [Beltrán FR et al.,2021; Subramaniam S et al.,2019; Tirado-Garcia I et al., 2021; Spiridon I et al., 2016].

PCL(Polycaprolactone)Synthesis, Properties, and Uses:

First produced in the early 1930s, polycaprolactone (PCL) is a polymer whose biodegradable qualities led to its commercial availability [Finch C et al.,1985]. Ring-opening polymerization is one of the ways that can be used to prepare it. PCL is a semi-crystalline, hydrophobic polymer with a low melting point and strong solubility. During the resorbable polymer boom of the 1970s and 1980s, it attracted interest in the biomedical industry [Nair LS et al.,2007] due to its favorable qualities [Woodruff MA et al.,2013], including controlled drug administration, mechanical properties, and customizable degradation kinetics. However, alternative resorbable polymers with quicker breakdown rates eclipsed PCL.

PCL's exceptional rheological and viscoelastic qualities, which make it appropriate for scaffold building, have sparked renewed interest in tissue engineering [Luciani A et al., 2008]. PCL's low melting point (59-64 °C) and Tg of −60 °C make it suitable for polymer processing, including extrusion, injection molding, and foaming [Wu C-S et al.,2003].

Its crystallinity is around 67%, and the crystallization rate can be increased by using starch as a nucleating agent for PCL. Crystallinity is frequently evaluated by comparing the melting enthalpy of PCL to that of pure, 100% crystalline PCL (139.5 J/g). To increase its mechanical strength, PCL can be reinforced with fibers or combined with polymers like PLA or starch. For instance, adding starch improves damping qualities and increases stiffness by increasing the storage modulus, which makes it helpful in biomedical applications that call for energy dissipation [Asadpour S et al.,2018; Wan Y et al.,2009]. Because of the hydrolyzable ester connections in its structure, PCL is biodegradable at different rates depending on its molecular weight, crystallinity, and environmental circumstances. It breaks down bacterial and fungal enzymes but not human ones. Additionally, PCL's degradation rate can be adjusted by blending it with other polymers, such as starch. Tissue engineering is one of the most prominent applications of PCL because of its biodegradable properties. Tissue replacement and implementation methodology distinguish some of the most recent advances in tissue engineering. The services provided in the fields of biomaterials, stem cells, growth factors, and biomimetic substrates have greatly improved. These advancements have created new potential for designing laboratory-grown tissues with the extracellular matrix, modified cells, and bioactive chemicals. Although PCL's slow rate of degradation is advantageous for long-term implants, it poses a problem for applications that need quick disintegration, like disposable packaging. By altering its composition, molecular weight, or crystallinity, or by mixing it with other polymers, PCL's degradation profile can be customized. Additionally, this polymer is not as economically appealing as conventional plastics due to its high production cost, especially as cost-cutting measures like blending with starch can change the material's characteristics. PCL's weak gas and water barrier qualities restrict its usage in packaging, but carbon nanotubes as

Nano fillers can somewhat mitigate this effect at a higher cost and complexity.

Conclusion

The pollution caused by non-biodegradable plastics can be mitigated by the development and application of biodegradable plastics. This study unequivocally demonstrates that biodegradable plastics made from renewable resources, like PLA and PCL, present a viable substitute for conventional petroleum-based plastics.

They aid in addressing the global problem of plastic pollution in addition to lowering the consumption of fossil fuels. Although they are mostly utilized in packaging, biodegradable plastics have a number of qualities that make them suitable for application in a variety of industries. They help ecosystems that are harmed by traditional plastics since they biodegrade in natural environments.

Additionally, attempts to enhance the synthesis of biodegradable polymers to create new composites and blends have enhanced their mechanical and thermal properties to resemble those of non-biodegradable plastics. One of the biggest obstacles facing biodegradable plastics today is the high cost of production when compared to non-biodegradable plastics. Additionally, biodegradable materials enable composting or recycling activities that would unlock the potential consequences of the materials, notably on the environment. The current waste management framework needs to be updated.

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Original Article

Factor Influencing the Adoption of Electric Two Wheelers in Tier-2 City.

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Abstract

This study examines how consumers in Gaya Ji, a tier 2 city in Bihar State, feel about electric two-wheelers. Consumer preferences for buying two-wheeler electric vehicles (EVs) are investigated in this study. Understanding the variables influencing customer choices is the main goal, with an emphasis on infrastructure, age, affordability, and environmental concerns. The study will use both primary and secondary data and a quantitative research methodology. A modest market survey and a structured questionnaire will be used to get the data.

Keywords: *Consumer buying behaviour, Electric two-wheeler vehicles, Consumer perception.*

Introduction

India ranks second globally in terms of two-wheeler manufacturing and production. In terms of domestic sales and the quantity of two-wheelers produced, it is ranked second only to China and Japan. In recent years, the Indian two-wheeler industry has experienced remarkable growth. The quick rise of electric two wheelers (EVs) is causing a radical change in the Indian auto industry. Among these, consumers looking for affordable, environmentally responsible, and technologically sophisticated substitutes which move to adopt electric vehicles.

In the past ten years, India's two-wheeler market has grown significantly. Demand has been shown to be rising mostly in rural and urban areas. Some of the key elements propelling the expansion of the Indian industry include very low competitive pricing and upkeep.

Top EV Two-Wheeler Sales in India – Full Year 2025

Rank	Brand	Units Sold	Notes
1	TVS Motor	2,95,315	#1 in 2025
2	Bajaj Auto	2,66,919	Strong growth
3	Ather Energy	1,97,596	Surpassed Ola
4	Ola Electric	1,96,767	Decline vs 2024

Source: Autovolte

According to the most recent data published by the Federation of Automobile Dealers Associations (FADA), India's retail sales of electric two-wheelers (e-2W) increased by 11.36 percent year-over-year (YoY) in 2025 thanks to consistent demand for well-known brands, increased model availability, and the introduction of new models into the market.

Retail sales of electric two-wheelers totaled 1,279,951 units in 2025, up from 1,149,416 units the year before. However, the two-wheeler segment's electric penetration increased slightly from 6.1% in 2024 to 6.3% in 2025 (FADA).

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Two-Wheeler OEM	CY25	CY'24	YoY%
TVS MOTOR COMPANY LTD	2,98,881	2,20,819	35.35%
BAJAJ AUTO LTD	2,69,847	1,93,663	39.34%
ATHER ENERGY LTD	2,00,797	1,26,357	58.91%
OLA ELECTRIC TECHNOLOGIES PVT LTD	1,99,318	4,07,700	-51.11%
HERO MOTOCORP LTD	1,09,168	43,712	149.74%

Source: Auto.economictimes

Literature Review

Dr. Vinitha T R and Lethy L B (2025) their purpose of the study is to gather opinions, feelings, and perceptions on awareness of and propensity to buy e-vehicles in order to protect environmental sustainability in Thiruvananthapuram city. The primary goal of this study is to learn about consumers' perceptions of electronic vehicles and their expectations for them in the near future.

Dr. Suraj Kamble, Saurabh Bodkhe, and Manoj Patil (2025) emphasize the necessity for public and private entities to concentrate on developing a strong infrastructure for charging, providing better financing choices, and increasing awareness through well-planned marketing and educational initiatives.

Dr. Laxmikant B. Deshmukh and Ku. Shivani Gautam Damodar (2023) create an adoption intention model for behavioral electric two-wheelers. The goal of the current study was to determine the variables influencing Vidarbha region customers' intentions to switch to electric two-wheelers. The empirical findings show that customer attitudes about electric two-wheelers are greatly influenced by social influence, perceived economic gain, environmental concern, and charging infrastructure.

Manoj V N and Dr. K. Jayaprakash (2023) focuses on how satisfied customers are with electric two-wheelers in Kerala's Kasaragod District. It concludes that the brand name, motor power, and alertness are the elements that influence customer satisfaction.

Prof. Jayprakash Lamoria and Nidhi Singh (2023) intend to poll consumers in Vadodara city about their perceptions of several characteristics, including age, gender, monthly income, and understanding of electric automobiles.

Dr. M. Geeta, P. Charan Sai, and C. Rakesh Goud (2022) investigated the five influencing elements in order to investigate consumers' intents to buy electric two-wheelers. We looked into environmental concern, perceived economic benefits, societal influence, charging infrastructure, and attitude based on the literature review.

Goutham. K and Dr. M.P. Kumaran (2021) their paper examines consumer satisfaction with electric bikes, specifically focusing on Coimbatore.

Sarthak Das (2020) study examines how prospective buyers in Pune city perceive and are aware of electric two-wheelers. Additionally, they have doubts regarding the product's lifespan and performance.

A. Anandalakshmy and Dr. K. Brindha (2017) their study's goal is to establish women's preferences for two-wheelers, as well as the many factors that influence their purchasing behavior and expectations. The study's sample size was carried out in Coimbatore.

Objectives Of the Study

1. To find out the awareness of consumer about the electric bike in Gaya Ji city.
2. To find out the factor influencing the sales of electric bike.
3. To find out the market share of different manufacturing companies dealing in electric bike.
4. To suggest measures to increase sales of electric bikes.

Research Methodology

This study is descriptive in nature and uses both primary and secondary data. Primary data was gathered in Gaya Ji using a standardized questionnaire and in-person interviews. Respondents have been chosen using a convenient sampling technique. 80 respondents make up the sample size for this study. The necessary secondary data has been gathered from sources such as books, journals, papers, websites, and other publications.

Data Analysis and Interpretation

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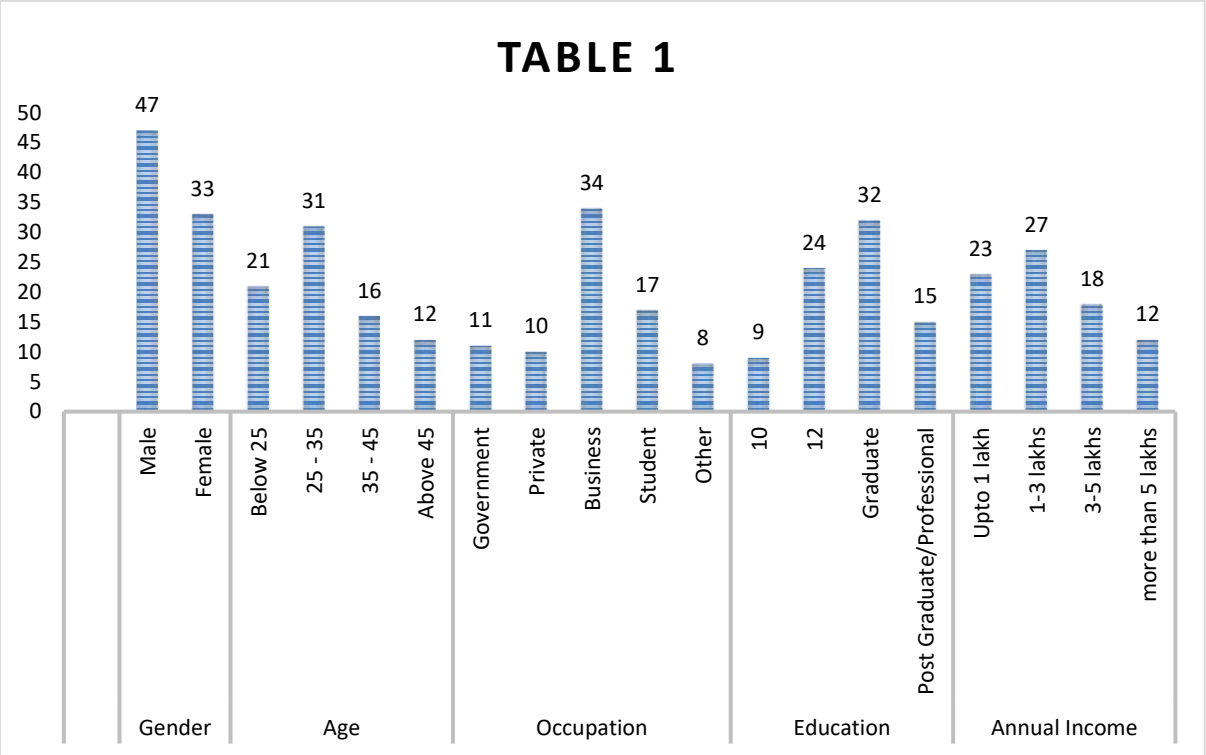
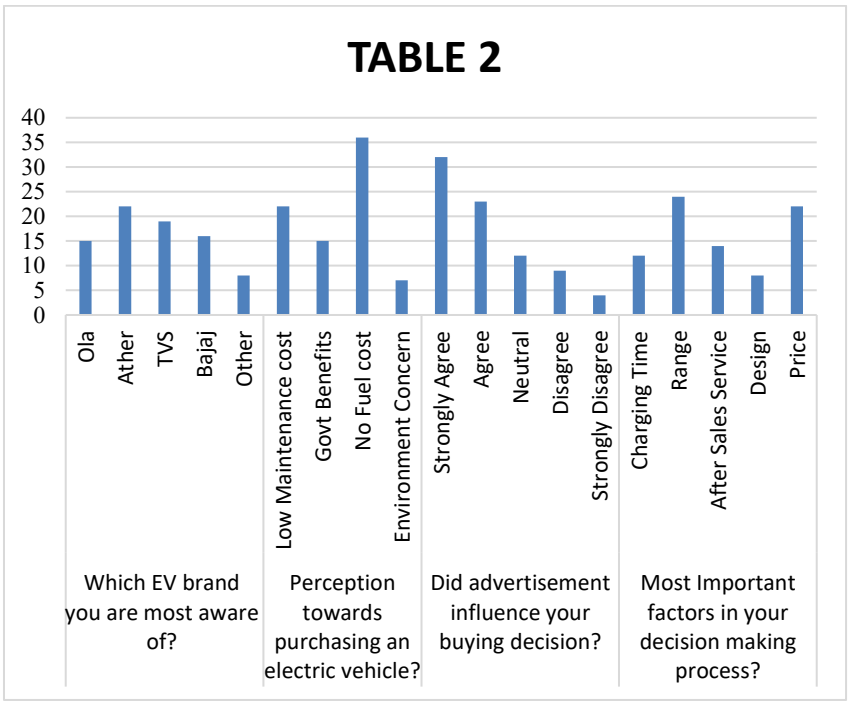


From the above table 1, it is clear that male respondents (60%) are higher as compared to female respondents. Age wise data stratification signifies that almost half of the population (65 %) belongs to the age group below 35 years category. This indicates that electric-2 wheeler is more popular among younger generations. Education wise data stratification illustrates that 80 % population having graduated and above qualification or professionals. Annual income data signifies around 85% population is having less than 5 lakhs income who usage electric-2 wheeler.



From Table 2, shows that Ather brand is most popular brand in Gaya Ji city. It is clear that most of customers having perception towards purchasing an electric two-wheeler are no fuel cost. This indicates that advertisement

plays a vital role in buying decision. The study finds that price, range and after sales services are the most important factors in decision making process.

Scope And Limitation Of the Study

1. The present study focuses on customer perception towards Electric Two-Wheelers in Gaya Ji city. It helps to identify the awareness level of customers about electric two-wheeler and also helps to find out the customer perception towards electric two-wheelers.
2. The main scope of the study is to analyze the customer satisfaction towards electric two wheelers with respect to Gaya Ji city, Bihar.
3. The study also aims at analyzing the level of challenges faced by customer towards electric two-wheelers.
4. The study was restricted to 80 respondents in Gaya Ji city.
5. The data was obtained through questionnaire and it has its own limitations.
6. The result would be varying according to the individuals as well as time.

Finding And Conclusion

The purpose of this study was to investigate consumers' intentions to buy electric two-wheelers. We looked into environmental concern, perceived economic benefits, societal influence and charging infrastructure based on the literature review. The study's conclusions indicate that price, charging infrastructure, battery technology, and range (distance traveled in a single charge) are the key factors influencing Indian consumers' adoption of electric two-wheeler.

This study makes it evident that, when compared to traditional two-wheelers, electric two-wheelers are falling behind in terms of dependability, acceleration, and after sales service. It is a significant obstacle to the market expansion of electric two-wheelers. Customers find it difficult to trust the durability and after-sales service. The most crucial elements influencing the purchase decision are range, price, and charging time.

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I would like to express my sincere gratitude to everyone who contributed to the successful completion of this review paper titled "Factors Influencing the Adoption of Electric Two-Wheelers in Tier-2 Cities."

I am deeply thankful to my guide/supervisor for their invaluable guidance, constructive suggestions, and continuous encouragement throughout the preparation of this manuscript. Their expertise and support were instrumental in shaping this study.

I also extend my heartfelt appreciation to the faculty members and my institution for providing the academic resources, encouragement, and conducive environment necessary for carrying out this research.

I gratefully acknowledge the authors, researchers, government agencies, and industry experts whose published articles, reports, books, and policy documents on electric mobility, consumer behavior, sustainable transportation, and environmental sustainability formed the foundation of this review. Their scholarly contributions have significantly enhanced the quality and depth of this work.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Women Employment and Economic Empowerment through Beedi Household Industry in Solapur

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Abstract

One of the main cottage businesses in Solapur is the beedi home sector, which gives many women—especially those from lower socioeconomic groups—jobs. The beedi industry's contribution to women's employment and economic empowerment is examined in this study. Because beedi rolling is a home-based activity, women can make money while taking care of the home. Women's involvement in this sector raises living conditions, increases family income, and strengthens their position in home decision-making. The survey also emphasizes the social and economic advantages that female employees receive, including more self-confidence and financial independence.Their well-being is nevertheless impacted by issues including low pay, unfavorable working conditions, health risks, a lack of social security, and few alternatives for alternative jobs. The study comes to the conclusion that, although the beedi household industry has contributed significantly to women's empowerment in Solapur, sustained economic and social empowerment of women workers will require supportive policies, improved working conditions, skill development initiatives, and social welfare programs.

Introduction

Women are vital to society's socioeconomic advancement. In addition to enhancing home welfare, their involvement in revenue-generating activities promotes general economic expansion. Many women in India work in household and cottage industries, which offer flexible work schedules. Among these sectors, the beedi business has become one of the most important sources of income for women, particularly in rural and semi-urban areas. One of the main hubs of the beedi industry is the Maharashtra district of Solapur. Beedi rolling is a domestic vocation for thousands of women who labor in this mostly home-based industry. District-level reports state that some 70,000 women worked in Solapur's beedi sector.

Women have the chance to manage household duties and earn money in the beedi household industry. Their financial commitment to the family is increased, their ability to make decisions is strengthened, and economic independence is encouraged by this economic involvement. Beedi rolling is the main source of income and household survival for many women from economically disadvantaged backgrounds. According to studies, women favor this line of work because it can be done from home in addition to family chores. Despite its significance, women who work in the beedi business confront a number of difficulties, including low pay, a lack of social security, health risks, and little chances to advance their skills. Women employees are frequently economically insecure due to the industry's informal and home-based nature. However, their participation in the beedi sector has greatly.The purpose of this study is to investigate how the beedi home business helps women in Solapur find work and to assess how it affects their socioeconomic position, living standards, and economic empowerment.

Meaning Role of Women Employment and Economic Empowerment through Beedi Household Industry in Solapur

In Solapur, women's employment and economic empowerment through the beedi household industry refers to their involvement in home-based beedi production operations that give them options for livelihood and revenue. For thousands of women, especially those from lower socioeconomic groups, the beedi sector has grown to be a significant source of employment. Women can raise their level of living, contribute to their family's finances, and become more financially independent by earning money through beedi rolling.

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They can support their children's education, take part in household decision-making, and provide for everyday family needs thanks to this job. Due to the flexibility of home-based work, women are able to combine income-generating activities with household duties. Therefore, the beedi household business contributes significantly to the socioeconomic development of families in Solapur, the reduction of poverty, and the advancement of women's economic empowerment.In Solapur, the beedi household business is essential to the employment and economic empowerment of women. Thousands of women are given possibilities for employment, their financial contribution to the family is increased, and their social and economic standing is strengthened. For many households in Solapur, the sector continues to be a significant source of revenue despite obstacles like poor salaries and health dangers.

Objectives:

1.To examine the employment opportunities provided to women through the beedi household industry in Solapur.
2.To assess the economic contribution of women beedi workers to their household income and family welfare.
3.To analyze the impact of beedi employment on women's economic empowerment, including financial independence and decision-making power.
4.To identify the socio-economic conditions of women engaged in the beedi household industry.
5.To study the challenges and problems faced by women beedi workers in their workplace and daily lives.
6.To evaluate the role of the beedi industry in improving the living standards of women and their families.

Impacts of Women Employment and Economic Empowerment through Beedi Household Industry in Solapur

1. Employment Generation:

The beedi household industry provides large-scale employment opportunities to women, especially in rural and low-income families.

2. Income Enhancement:

Women earn a regular income through beedi rolling, which helps improve household financial stability.

3. Economic Independence:

Earning their own income increases women's financial independence and decision-making power within the family.

4. Poverty Reduction:

The industry serves as an important source of livelihood, helping families reduce poverty and meet basic needs.

5. Work-from-Home Opportunity:

Women can work from their homes while managing household responsibilities, making it suitable for married women and mothers.

6. Improved Living Standards:

Additional income contributes to better education, healthcare, nutrition, and housing for family members.

7. Women's Empowerment:

Economic participation enhances women's confidence, self-esteem, and social status in the community.

8. Skill Development:

Women gain specialized skills in beedi rolling, packaging, and related activities.

9. Support for Rural Economy:

The beedi industry contributes significantly to the local economy of Solapur by creating employment and generating income.

10. Increased Savings and Financial Inclusion:

Regular earnings encourage women to save money and participate in self-help groups and banking activities.

11. Social Participation:

Financial empowerment enables women to take part in community activities and local decision-making processes.

12. Challenges and Health Issues:

Despite economic benefits, women often face low wages, job insecurity, and health problems due to prolonged exposure to tobacco dust.

Table 1:

Year-wise Units and Employment (2015–2025)

Year	Total Units	Change from Previous Year	% Growth	Employment	Change	% Growth
2016	**1350**	—	—	**70000**	—	—
2017	**1330**	-20	**-1.48%**	**69500**	**. -500**	**-0.71%**
2018	**1310**	-20	**-1.50%**	**69000**	**-500**	**-0.72%**
2019	**1290**	**-20**	**-1.53%**	**68000**	**-1000**	**-1.45%**
2020	**1269**	-30	**-2.33%**	**66500**	**-1500**	**-2.21%**
2021	**1230**	**-30**	**-2.38%**	**. 65500**	**-1000**	**-1.50%**
2022	**1200**	-30	**-2.44%**	**65000**	**-500**	**-076%**
2023	**1170**	-30	**-2.50%**	**64000**	**-1000**	**-1.54%**
2024	**1135**	-35	**-2.99%**	**63000**	**-1000**	**-1.56%**
2025	**1100**	-35	**-3.08%**	**62000**	**-1000**	**-1.59%**

In 2016, the Beedi Household Industry in Solapur consisted of 1,350 units and provided employment to 70,000 women workers. This year serves as the base year for the study. The industry played a significant role in generating employment and supporting the economic well-being of women from low-income households.

2017

In 2017, the number of units declined to 1,330, showing a decrease of 20 units (-1.48%) compared to the previous year. Women employment also fell slightly to 69,500 workers, a decline of 500 workers (-0.71%). Despite the decrease, the industry remained an important source of income for women 2018.

During 2018, the number of units further decreased to 1,310, reflecting a decline of 20 units (-1.50%). Employment also reduced to 69,000 women workers, a decrease of 500 workers (-0.72%). The data indicates a gradual downward trend in both industrial units and employment opportunities.

2019

In 2019, the number of units dropped to 1,290, showing a decline of 20 units (-1.53%). Women employment

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decreased more noticeably to 68,000 workers, representing a reduction of 1,000 workers (-1.45%). The decline suggests growing challenges within the beedi industry.

2020

The year 2020 recorded the most significant decline during the study period. The number of units fell to 1,260, a decrease of 30 units (-2.33%). Women employment declined sharply to 66,500 workers, resulting in a loss of 1,500 jobs (-2.21%). This year marked the highest reduction in employment and industrial activity.

2021

In 2021, the number of units further reduced to 1,230, indicating a decrease of 30 units (-2.38%). Employment declined to 65,500 workers, with a reduction of 1,000 workers (-1.50%). Although the decline continued, the rate of employment loss was lower than in 2020.

2022

During 2022, the total number of units decreased to 1,200, a decline of 30 units (-2.44%). Employment stood at 65,000 women workers, showing a reduction of 500 workers (-0.76%). Compared to previous years, the employment decline was relatively moderate.

2023

In 2023, the number of units dropped to 1,170, reflecting a decrease of 30 units (-2.50%). Women employment declined to 64,000 workers, a loss of 1,000 workers (-1.54%). The continuing negative growth indicates persistent structural challenges in the industry.

2024

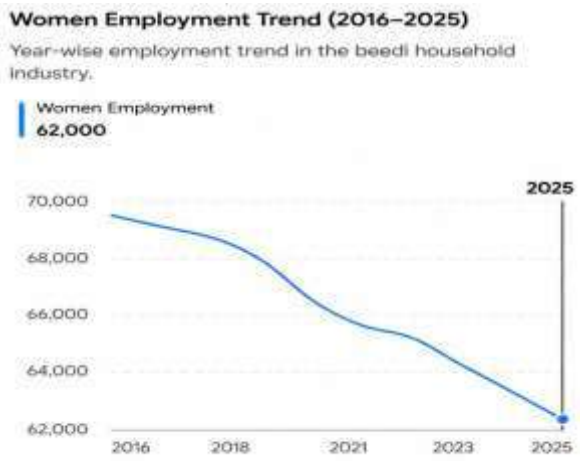
The year 2024 witnessed a sharper decline in industrial units, which fell to 1,135, a reduction of 35 units (-2.99%). Employment decreased to 63,000 women workers, representing a decline of 1,000 workers (-1.56%). The industry continued to shrink in terms of both production units and workforce.

2025

In 2025, the number of beedi household units further declined to 1,100, showing a decrease of 35 units (-3.08%). Women employment fell to 62,000 workers, a reduction of 1,000 workers (-1.59%). Although employment opportunities decreased over the years, the industry remained an important source of livelihood and economic support for thousands of women in Solapur.

Overall Analysis

The table clearly shows a continuous decline in both the number of beedi household units and women employment from 2016 to 2025. Total units decreased from 1,350 to 1,100, while employment fell from 70,000 to 62,000 workers. The most significant decline occurred in 2020, whereas the overall trend remained negative throughout the study period. Nevertheless, the beedi industry continued to contribute to women's employment and economic empowerment by providing income and supporting household welfare



Graph Analysis

The graph shows that women employment in the Beedi Household Industry of Solapur declined steadily from 70,000 workers in 2016 to 62,000 workers in 2025. The highest decline occurred in 2020, when employment fell to 66,500 workers. After 2020, employment continued to decrease gradually each year.

Conclusion

The graph indicates a negative growth trend in women employment during the study period. Although employment opportunities declined, the beedi household industry continued to provide livelihood support and economic empowerment to thousands of women in Solapur.

Advantages:

1. Provides employment opportunities to a large number of women.
2. Generates additional income for poor and low-income families.
3. Promotes financial independence among women.
4. Allows women to work from home.
5. Offers flexible working hours.
6. Helps women contribute to household decision-making.
7. Improves the standard of living of families.
8. Requires low educational qualifications and skills.
9. Encourages women's participation in economic activities.
10. Reduces unemployment among rural and urban women.
11. Supports children's education through increased family income.

Disadvantages:

1. Exposure to tobacco dust causes respiratory diseases.
2. Long working hours may lead to physical fatigue.
3. Low wages and piece-rate payment system.
4. Lack of job security and stable income.

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5. Limited access to social security benefits.
6. Poor working conditions at home.
7. Risk of eye strain, headaches, and skin allergies.
8. Dependence on middlemen and contractors.
9. Limited opportunities for skill development and career growth.
10. Possibility of child labour involvement in family work.
11. Irregular supply of raw materials can affect earnings.

finding:

1. The beedi household industry is a major source of employment for women in Solapur.
2. Most women workers belong to economically weaker and low-income families.
3. Beedi rolling is preferred because it can be performed from home.
4. Women's earnings contribute significantly to household income and family welfare.
5. Employment in the beedi industry has increased women's financial independence.
6. Women workers participate more actively in household decision-making due to their economic contribution.
7. The industry provides employment opportunities to women with low educational qualifications.
8. Most women workers are paid on a piece-rate basis and receive relatively low wages.
9. Health problems such as respiratory disorders, headaches, eye irritation, and allergies are common among beedi workers due to tobacco exposure.
10. Many women workers lack adequate social security benefits, including health insurance and pension facilities.
11. Despite economic empowerment, women continue to face job insecurity and irregular income.
12. The beedi industry plays an important role in poverty reduction and livelihood generation in Solapur.

Women workers have limited opportunities for skill development and alternative employment.

The economic contribution of women beedi workers has improved their social status within the family and community.

Suggestions:

1. Increase minimum wages for women beedi workers to ensure fair income.
2. Provide social security benefits such as health insurance, pension, and maternity benefits.
3. Organize skill development and training programs to improve women's productivity and alternative employment opportunities.
4. Improve working conditions by ensuring proper ventilation, lighting, and hygiene in workspaces.
5. Promote financial literacy among women workers to enhance savings and investment habits.
6. Facilitate access to microfinance and self-help groups (SHGs) for economic independence.
7. Strengthen implementation of labor laws to protect women workers' rights.
8. Encourage education and vocational training for workers' children to break the cycle of poverty.
9. Develop alternative livelihood opportunities to reduce dependence on the beedi industry.
10. Increase awareness about government welfare schemes available for women workers.

Conclusion:

The beedi household industry plays a significant role in providing employment opportunities to women in Solapur, especially those from economically weaker and rural backgrounds. It enables women to contribute to household income while balancing domestic responsibilities. The industry has helped improve women's economic participation, financial independence, and social status to some extent.

However, women workers continue to face several challenges, including low wages, irregular employment, poor working conditions, health problems, lack of social security benefits, and limited opportunities for skill development. These issues restrict the full realization of economic empowerment.

For sustainable empowerment, coordinated efforts from the government, industry owners, non-governmental organizations, and society are essential. Measures such as fair wages, better working conditions, health and welfare facilities, education, skill development, and access to financial services can significantly improve the lives of women beedi workers.

In conclusion, while the beedi household industry has contributed positively to women's employment and economic empowerment in Solapur, further policy support and developmental initiatives are necessary to ensure their long-term socio-economic well-being and empowerment

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I would like to express my sincere gratitude to everyone who contributed to the successful completion of this review paper titled **"Women Employment and Economic Empowerment through Beedi Household Industry in Solapur."**

I am deeply thankful to my guide/supervisor for their invaluable guidance, continuous encouragement, and constructive suggestions throughout the preparation of this manuscript. Their expertise and support have been instrumental in completing this work successfully.

I also extend my heartfelt appreciation to the faculty members and my institution for providing the necessary academic resources and a supportive environment for conducting this study.

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Conflicts of interest

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Original Article

A Constitutional Analysis of The Inter-Relationship Between Ecosystem and Health

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Abstract

The Indian Constitution is amongst the few constitutions in the world that mention provisions related to environment protection. The object of this research paper is to interpret the role of the judiciary. Though confined to limitations, it has evolved in ensuring the protection of the environment. The paper discusses the landmark judgements and how the Supreme Court with the aid of Article 21 of the Constitution of India has guaranteed right to health.

Keywords- *Environment, Protection, right to health Article 21, Right to life, Judiciary, Personal liberty*

Introduction

"We won't have a society if we destroy the environment"

~ By Margaret Mead

Human interaction with the environment aids in accessing food, water and other necessities but one of the important factors responsible for environmental degradation is advancement in Science and Technology Since environment directly affects the health quality and plays a crucial role in the quality of life, it is our responsibility to ensure environmental awareness and provide insights about environmental preservation. Taking into account the severity of human intervention leading to environmental deterioration and since human existence depends on the balance between the ecosystem and environment it is crucial to ensure sustainable development for a healthy and productive life which is in harmony with nature.

Genesis of the Study

Environment plays a vital role in people's physical, mental and social well-being. It has been observed for decades that destructive consequences of environmental pollution on human beings and their quality of life has increased considerably. The problem of environmental pollution can be traced back to the rapid industrialization in Japan during the 19th century of the Meiji period. The pollution problem in the 1970s reached high levels around all the major cities making it hazardous to human life. Unfortunately, the successive governments displayed ignorance to air and waste pollution and focused on the needs of businesses. In 1968, for the first time the Basic Law for Environment Pollution Control was partly enacted because of pollution-related diseases which included deadly Minamata disease and Yokkaichi asthma across the nation. Gradually the international scenario emphasized more on the protection of environment in order to ensure good health to its citizens and this was initiated by the Stockholm Conference by increasing awareness about the environmental crisis and prompting the Indian Government to amend its constitution and add Article 49-A and Article 51-A (g) in its 42nd Amendment in 1976. Article 49-A imposed an obligation on the state that "The State shall endeavor to protect and improve the environment and safeguard the forests and wildlife and imposed a responsibility under Article 51-A(g) on every citizen in the form of Fundamental Duty which states that "It shall be the duty of every citizen of India to protect and improve the natural environment Including forests, lakes, rivers and wildlife and to have compassion for living creatures."

International Provisions

Within twenty years from the Stockholm Declaration 1972 the UN Conference on Environment and Development (*UNCED*) 1992, ascertained that global environmental issues were of utmost importance, and therefore it has not only contributed in creating awareness about the environmental hazards due to human intervention but also in adding a number of international legal instruments to combat environmental challenges. Marine pollution results in damage to the environment and to the health of all the organisms in order to protect the sea , an international agreement 'The United Nations Convention on the Law of the Sea (UNCLOS) 1994'was established which states guidelines for protection against sea pollution.

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Constitutional Provisions

The preamble of the Indian constitution mentions a socialist pattern in a society which is on the lines that priority must not be to make private profits but ensure social gains and dignity of life which is inherent in a decent standard of living and pollution free environment. The Environment (Protection) Act, 1986 defines the environment as environment includes water, air and land and the interrelationship which exists among and between air, water, land, human beings and other living creatures namely plants, micro-organism and property. In 1950 when the constitution was framed it did not include any provision for protection of the environment because they did not anticipate any environmental related problems but later realized its importance and incorporated provisions in the 42nd amendment to the constitution.

Right to life and Environment Protection (Article 21):

Article 21 of the Indian Constitution guarantees Right to life as a fundamental right. It states that "No person shall be deprived of his right to life or personal liberty except in accordance with procedures established by law". Right to life not only includes the right to have a dignified life but also right to food, shelter, pollution-free water and clothing where they can live safely without any threat to their lives.

Judicial Interpretation

The apex court has played a significant role in ensuring healthy environment to all its citizens either Suo motto or public interest or through public interest litigations and has attempted to use two methods to interpret Article 21 firstly to strengthen Article 21 and secondly to interpret rights which are not enumerated under Art 21.It requires all the laws affecting personal Liberty to pass the test of Art 14 and Art 19 of the constitution thereby ensuring that the procedure depriving a person of his personal Liberty is fair and just. Through this method the court recognized several rights that were implied by Art 21. It is by this method the SC recognized the right to life and personal Liberty to include the right to a wholesome environment and other rights.

Right to healthy environment has been incorporated directly or indirectly into the judgments by the Indian courts in the following cases: -

1) Charan Lal Sahu v. Union of India[1]

In this case the court enforced **"Right to a wholesome environment"**

2) Subhash Kumar v. State of Bihar [2]

The court held that Article 21 includes Right to life and enjoyment of pollution-free water and air for full enjoyment of life.

3)Vellore Citizens Welfare Forum v. Union of India[3]

Pollution was caused by discharge of untreated effluents by tanneries and other industries into the agricultural fields, road side waterways open lands and into the river which were a source of water supply to the residents of that area.

The Court ordered for the constitution of Green Benches in India for managing matters identifying with environment protection and furthermore for quick and speedy removal of environmental cases.

4) Ratlam Municipality v. Vardicha [4]

Ecology and public health were to be prioritized under Art.21 in the case of

It was held by the Supreme Court that the pollution-free environment is a part of Art. 21.

5) Murli S. Deora v. Union of India[5]

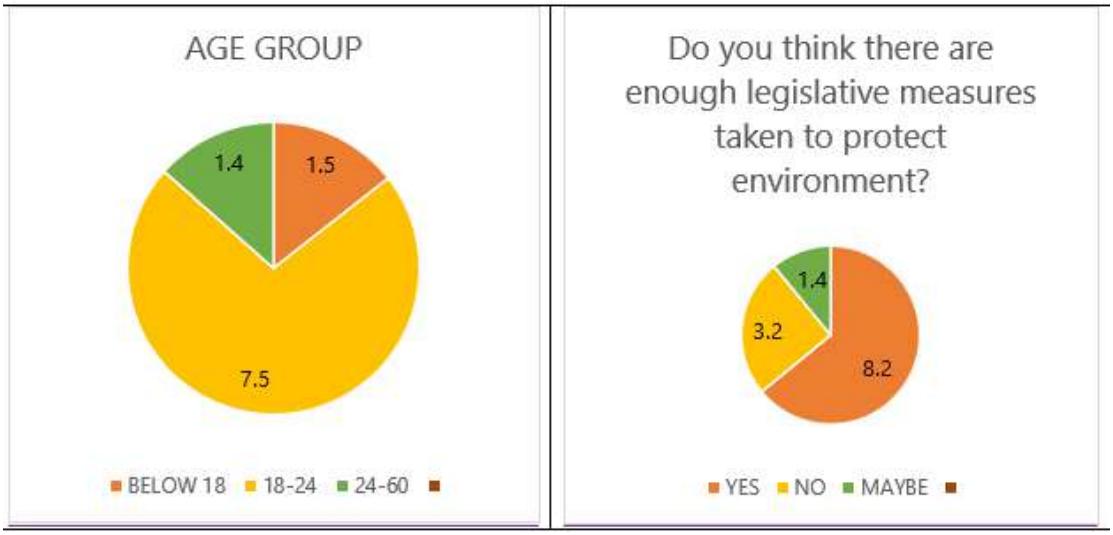
In this case the contention was raised that smoking is injurious to health and may affect the health of smokers but there is no reason that the health of passive smokers should also be injuriously affected. Since Art. 21 guarantees that no one shall be deprived of their life, it was held that it would be in the interest of the citizens to prohibit smoking in public places and the person not indulging in smoking cannot be compelled

to passive smoking on account of the acts of the smokers.

6)M.C.Mehtav.Union of India[6] **(Ganga Pollution case)**

This landmark case also supported the view that the right to a healthy environment is part of life under Article 21 of the Constitution the Court held that 'the polluting tanneries have to be closed down even though it would bring unemployment, loss of revenue because the preservation of life, health and ecology are more important than anything else'. It's not just about the life of the people who get affected, also the animals who drink this water.

Graphical Representation:



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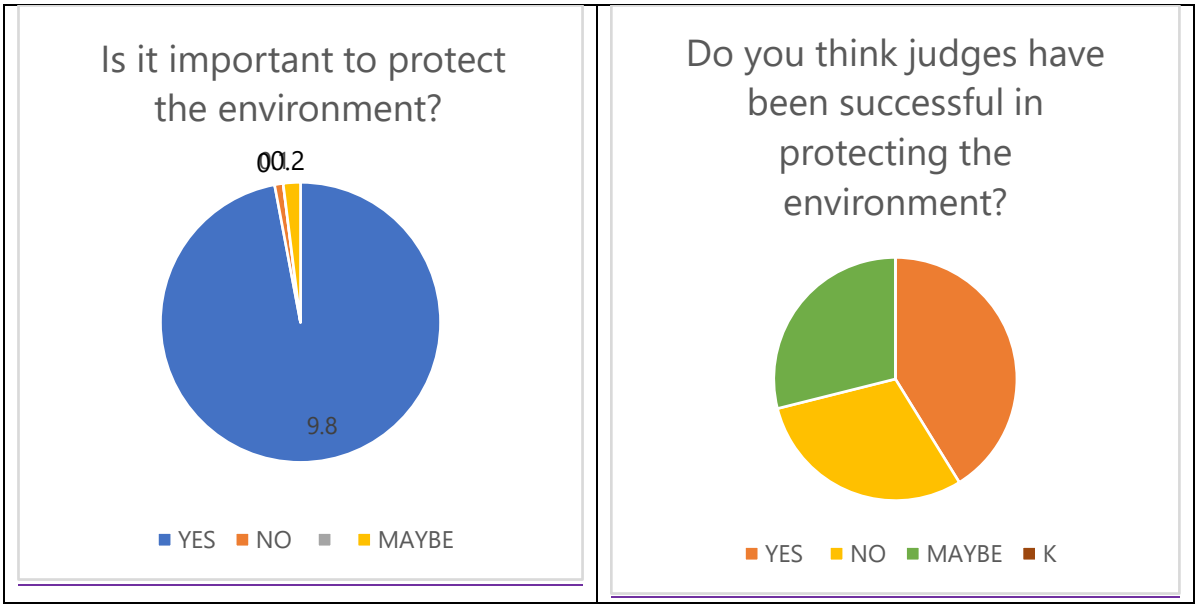

Conclusion:

From the broad interpretations of Article 21, it is evident that the Supreme Court over the years has become the foundation of environment jurisprudence, and has contributed immensely in ensuring environmental protection. The consequence to the foundation of environment jurisprudence has led to the introduction of a number of environmental laws. It has been observed by people that the constitution poses many challenges and fails to clearly provide for the citizen's right to a clean and safe environment. A number of amendments have been proposed to the Constitution, to ensure environment preservation and protection and in order to achieve the objective it is important to recognize and incorporate environmental rights as fundamental Rights in the Constitution of India which emerge from the Supreme Court's interpretation to the term 'Right to Life'. It is also the responsibility of the panchayats and municipalities to give weightage to ecological aspects and to protect the environment. Thus, a progressive analysis of environmental pursuit of the courts has been undertaken in order to develop the ideology of environment as being a part of right to life. Therefore, it is conspicuous that Article 21 is a mandate for environment protection.

Recommendations:

The research paper discusses the survey conducted to reduce environmental degradation and recommends the following steps to be undertaken

(i)Creating awareness amongst masses about the relevance and synthesis of Article 21 with regards to environment protection.

(ii)Adoption of measures to prioritize preservation of environment

(iii)Urbanization has posed several threats to the environment and so it becomes extremely important to take efforts which aid in preservation of resources for future generations.

(iv)Citizens should be proactive and work towards establishing a pollution free environment.

(v)Government must ensure inclusion of environmental protection in education

(vi)The Constitution of India must expressly include environment under Article 21.

(vii)Display of negligent behaviour causing tremendous harm to the environment must attract stringent penalty

(viii)To ensure every citizen abides by his duty to respect the environment, and enhance the quality of life.

Acknowledgment

I would like to express my sincere gratitude to everyone who contributed to the successful completion of this review paper titled "A Constitutional Analysis of the Inter-Relationship Between Ecosystem and Health."

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I also extend my heartfelt thanks to the faculty members and my institution for providing the necessary academic resources, encouragement, and a conducive environment for carrying out this study.

I gratefully acknowledge the contributions of researchers, legal scholars, environmental experts, constitutional authorities, and public health professionals whose books, research articles, reports, constitutional provisions, judicial decisions, and policy documents formed the foundation of this review. Their scholarly work has significantly enriched my understanding of the relationship between environmental protection, constitutional law, and public health.

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Conflicts of interest

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3) 1996 5 SCR 241
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A Study of Ethical Challenges and Responsible Practices in Artificial Intelligence

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Abstract

Artificial Intelligence (AI) and automated systems have advanced rapidly in recent years, *offering significant benefits by performing routine and even safety-critical tasks, often more efficiently than humans. However, this progress also raises serious ethical, legal, and safety concerns, including issues related to privacy, bias, and decision-making in systems like autonomous vehicles. Prominent figures and researchers emphasize the urgent need for strong ethical frameworks and regulatory governance to ensure AI is used responsibly, particularly in critical infrastructures.*

Artificial intelligence has become a transformative force across multiple sectors, offering significant benefits such as improved efficiency, enhanced decision-making, innovation, and increased safety. It enables automation, supports data-driven insights, and contributes to advancements in fields like healthcare, finance, and technology. However, AI also presents notable challenges, including job displacement, high implementation costs, ethical concerns, privacy issues, and limitations in understanding human emotions. These challenges highlight the need for careful management, regulation, and human oversight. Therefore, balancing the advantages and disadvantages of AI is essential to ensure its responsible development and use. As AI continues to evolve, addressing these concerns will be critical to maximizing its positive impact on society while minimizing potential risks.

Keywords: *Artificial Intelligence, Office of Responsible AI, Emotional Intelligence*

Introduction

"Greater responsibility brings Greater power". Artificial intelligence (AI) has granted humanity immense power, but if it is not used responsibly and cautiously, it could ultimately turn against us.

Responsible AI refers to the ethical and fair development and use of artificial intelligence. It emphasizes transparency, accountability, fairness, and the well-being of both individuals and society. The aim of responsible AI is to minimize risks and biases while ensuring strong privacy protections, so that it benefits humanity rather than exposing it to harm or misleading outcomes.

For example, to enable a machine to recognize human faces, it must be trained on a large and diverse set of facial images. If the training data includes only faces of a particular skin tone, the AI may fail to accurately identify faces with other skin tones. Therefore, in responsible AI, diverse datasets representing all skin tones are used to ensure fairness, avoid bias, and promote equitable treatment for everyone.

Ethical Considerations in Responsible AI

Ethical considerations in responsible AI aim to align AI technologies with moral principles, respect human values, and address relevant legal aspects, thereby supporting positive societal development. Key aspects include bias, fairness, transparency, inclusivity, security, human autonomy, and societal impact.

Human autonomy—ensuring that AI systems respect, preserve, and enhance human decision-making rather than replace or unduly influence it—deserves particular emphasis. Recent trends show that AI's influence on decision-making, especially among youth, has increased significantly. This may lead to negative consequences, such as a reduced ability to make independent decisions. Moreover, many reports suggest that AI is poised to dominate the world, making it essential to preserve human autonomy through ethical considerations in responsible AI.

For example, in a study by Jonathan Downie, it is stated that "the rapid development of artificial intelligence (AI) and its application in interpreting have raised concerns that human interpreters may become unnecessary. In particular, the promotion of AI interpreting systems and their use at some high-level international conferences have created the impression that machines may soon replace humans" (Jonathan Downie, 2020).

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Principles and Practices in Responsible AI

To ensure that the AI technologies we develop and use are responsible, we must follow certain key principles and practices. Professionals consistently emphasize the importance of adhering to these principles, which include fairness, transparency, empathy, robustness, and accountability. Let us briefly examine each of them for a better understanding.

Fig:1 Principles of responsible AI

Fairness: Fairness involves ensuring impartial treatment of all individuals and groups by AI systems. This can be achieved by consistently evaluating and addressing potential biases in algorithms to prevent discriminatory outcomes.

Transparency: Transparency is fundamental to building trust in Artificial Intelligence systems. Through transparency, we aim for openness and clarity in the development and deployment of AI systems. Most importantly, it involves providing stakeholders—including users, developers, and the public—with a clear understanding of how AI algorithms function and make decisions. In practice, this is achieved by clearly explaining how AI systems work, including their decision-making processes, to build trust and understanding.

Empathy: The principle of empathy in responsible AI highlights the importance of understanding the emotional and practical needs of individuals affected by AI systems. It promotes a human-centered design approach that recognizes the diverse perspectives, experiences, and concerns of users. In practice, this involves engaging a wide range of stakeholders—including end-users—in the design process to better understand their needs and address their concerns in ways that benefit society as a whole.

Robustness: Robustness refers to the ability of an AI system to remain resilient, reliable, and stable over time, even in adverse conditions. A robust AI system can maintain its functionality and accuracy while minimizing the risk of errors or disruptions. This is achieved by designing algorithms that perform consistently and efficiently, even when faced with unexpected inputs or uncertainties.

Accountability: Organizational culture plays a crucial role in fostering accountability in AI, where individuals across departments and functions collectively uphold high standards of responsibility for both themselves and the AI technologies they use. It promotes a strong sense of ethics and responsibility in how AI systems are developed, managed, and used, ensuring their impact on people is carefully considered.

Practical Approaches to Implementing Responsible AI

Merely understanding the need, consequences, and principles of responsible AI is not enough to drive meaningful change. It is the practical implementation of these principles that leads to tangible outcomes and a better future. Therefore, execution is just as important as development and strategic planning.

One of the most effective approaches is to adopt a human-centered design methodology. Human-Centered Design (HCD) in responsible AI prioritizes the needs, experiences, and well-being of people throughout the design and development of AI systems. It emphasizes understanding the perspectives of end-users and incorporating their feedback to create ethical, user-friendly technologies that align with human values.

Another approach to implementing responsible AI is to continuously examine data and identify the limitations of datasets. AI outputs reflect the data on which they are trained; therefore, it is essential to review data regularly while respecting privacy and confidentiality. This helps identify and mitigate potential biases, inaccuracies, and ethical concerns within the data. Additionally, recognizing dataset limitations ensures that AI models are trained on representative, diverse, and fair data, leading to more reliable and unbiased outcomes.

Finally, for effective implementation, AI systems must be tested and updated even after deployment. Continuous monitoring and timely updates are essential to ensure their responsible and appropriate use. Various testing practices and quality control measures should be applied to ensure that the AI operates in a responsible and reliable manner.

Following the completion of testing, if any anomalies are detected, the system should undergo upgrades, and essential modifications need to be incorporated which would help in attaining the goal of making the artificial intelligence responsible as well as flawless for the beneficial use of stakeholders and for a better tomorrow.

Key Challenges and Risks in Responsible AI

Challenges are inevitable in any domain, including responsible AI. While we have discussed the principles, implementation, and ethical use of AI, consistently adhering to these standards remains a significant challenge in practice.

"Success is not the end, failure is not fatal: what matters most is the courage to persist and move forward." This principle is essential to keep in mind throughout the challenging journey of responsible AI and beyond.

One of the most prominent challenges is ensuring privacy protection and security. In an era of widespread data sharing, maintaining confidentiality is increasingly difficult. Upholding this responsibility and assuring users of the safety of their data remains a critical challenge, requiring strong commitment and trustworthy practices.

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Another significant issue is bias, a concern highlighted from the beginning of this discussion. As humans, we strongly oppose bias and discrimination, as they are inherently unjust and unacceptable. Therefore, if an AI system produces biased outcomes, it is likely to be perceived as untrustworthy and unreliable. To ensure the effectiveness and positive impact of AI technologies and to achieve their broader goals, it is essential to minimize bias to the greatest extent possible.

Establishing clear, robust, and effective rules and policies is essential for responsible AI. Without such frameworks, it is difficult to ensure that AI systems operate ethically and within appropriate boundaries. Addressing this challenge requires engaging experts, conducting thorough analysis, and making informed decisions to guide the responsible development and use of AI.

Pros and Cons of AI

Advantages of AI

1. Efficiency and Productivity

Artificial intelligence enhances efficiency and accuracy by automating routine and repetitive tasks, allowing systems to operate continuously without breaks or fatigue. It reduces human effort, saves time, and ensures consistent and reliable performance. AI can process vast amounts of data quickly, enabling faster analysis and better decision-making. As a result, businesses experience increased productivity and reduced operational costs, making AI a powerful tool for improving overall performance across various industries.

2. Enhanced Decision Making

Artificial intelligence can analyze large datasets to uncover hidden patterns and trends that may not be easily recognized by humans. This ability supports better decision-making across fields like finance, healthcare, and marketing. By providing data-driven insights and using predictive analytics, AI improves the accuracy of forecasting and helps organizations make more informed decisions.

3. Personalization and Customer Experience

Artificial intelligence helps businesses deliver personalized experiences by analyzing customer behavior and preferences through machine learning. This enables personalized marketing strategies, improves customer support with tools like chatbots and virtual assistants, and provides customized product recommendations, leading to greater customer satisfaction and engagement.

4. Innovation and Development

Artificial intelligence drives innovation by enabling the creation of new products, services, and solutions across various industries. It plays a key role in advancing fields such as robotics, autonomous technology, and healthcare. AI contributes to breakthroughs in medical research and treatment, supports the development of self-driving systems, and encourages innovative applications that transform how industries operate and evolve.

5. Risk Reduction

Artificial intelligence enhances safety by performing tasks in hazardous environments, reducing the need for human involvement in dangerous situations. It is especially valuable in industries like mining, construction, and space exploration, where risks are high. By handling dangerous tasks, minimizing human exposure to harm, and improving overall workplace safety, AI helps protect workers while maintaining efficiency.

Disadvantages of AI

1. Job Displacement

The automation of tasks through artificial intelligence can lead to job displacement in certain sectors, as machines take over routine and manual work. While AI also creates new opportunities, some roles become obsolete, causing workforce disruption. This increases the need for retraining and skill development, and may contribute to higher unemployment if the transition is not managed effectively.

2. High Implementation Costs

Developing and implementing artificial intelligence systems requires substantial investment, which can be a challenge for many organizations. The costs of hardware, software, and hiring skilled professionals are often high, making it difficult for smaller businesses to adopt AI. In addition to the initial expense, ongoing maintenance and updates further increase costs, leading to accessibility issues for small enterprises.

3. Ethical and Privacy Concerns

Artificial intelligence systems raise important ethical and privacy concerns, particularly regarding how data is collected, stored, and used. Issues such as data privacy and security, increased surveillance, and the ethical use of AI technologies are significant challenges. Additionally, biases in AI algorithms can lead to unfair or discriminatory outcomes, making it essential to ensure fairness, transparency, and responsible use of AI systems.

4. Dependency and Reliability

Over-reliance on artificial intelligence can create risks if systems fail or produce incorrect results, potentially leading to serious consequences. Ensuring the accuracy and reliability of AI outputs is essential, as errors can affect decision-making. Therefore, maintaining proper checks and balances and involving human oversight is important to monitor AI systems and prevent misuse or critical failures.

5. Lack of Emotional Intelligence

Artificial intelligence has limitations in understanding and responding to human emotions, which affects its performance in emotionally sensitive situations. It struggles to interpret feelings accurately and may not handle complex human interactions effectively. This can impact areas such as customer service and relationship management, where emotional intelligence is important for building trust and providing appropriate support.

Benefits and Real-life Examples

Across all groups—users, employees, stakeholders, and governments—there is a clear and growing demand for responsible AI, underscoring its essential value. A company's success largely depends on its capacity for innovation and competitiveness. In this context, responsible AI serves as a key enabler by fostering meaningful innovation and promoting high-quality competition. This, in turn, supports the development of unique, reliable, and ethically sound services that meet the evolving demands of today's society.

Similarly, as noted earlier, addressing ethical and legal challenges in AI is essential. Implementing responsible AI enables organizations to minimize potential risks by

establishing clear policies, governance structures, and a culture that aligns AI systems with organizational values. A well-executed responsible AI program helps proactively identify and address issues before deployment, reducing the likelihood of failures. Even when failures occur, it ensures their impact is minimized, thereby limiting harm to individuals and society.

Moreover, aligning AI initiatives across all aspects of an organization—from its mission to its ethical values—makes it easier to achieve goals in a more efficient, accurate, and timely manner. To better understand the importance of responsible AI, it is useful to examine its real-world impact. For instance, Microsoft has established a comprehensive responsible AI governance framework in collaboration with its AI, Ethics, and Effects in Engineering and Research (AETHER) Committee and the Office of Responsible AI (ORA). These groups work together to promote and enforce responsible AI principles across the organization. This approach has fostered committed and innovative leadership, enabled the development of inclusive governance models, and empowered employees through strategic investment and support.

Another notable example of the successful application of responsible AI can be seen in the healthcare sector, particularly in cancer detection and treatment. IBM's Watson for Oncology, a cognitive computing system, has been used to support oncologists by analyzing vast amounts of medical literature, clinical trial data, and patient records. It assists in identifying potential treatment options by providing evidence-based insights. The impact of this technology includes the development of personalized treatment plans, enhanced clinical decision support, a more patient-centric approach, and improved consistency and accuracy—ultimately contributing to significant global advancements in healthcare.

Conclusion

Artificial intelligence presents both remarkable opportunities and important challenges. It enhances efficiency, decision-making, innovation, and safety, making it a powerful tool for progress across various sectors. However, issues such as job displacement, high costs, ethical concerns, and bias highlight the need for careful consideration. This makes responsible AI essential, as it ensures ethical development, reduces risks, improves transparency, and builds trust. Ultimately, balancing the benefits and drawbacks of AI is crucial for its sustainable and fair use. Embracing responsible AI practices ensures that technological advancement aligns with human values and contributes positively to society.

Acknowledgment

I would like to express my sincere gratitude to everyone who contributed to the successful completion of this review paper titled "A Study of Ethical Challenges and Responsible Practices in Artificial Intelligence."

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I gratefully acknowledge the contributions of researchers, scholars, technology experts, and organizations whose books, research articles, reports, ethical guidelines, and policy documents on artificial intelligence, responsible AI, data privacy, algorithmic fairness, transparency, and governance served as the foundation of this review. Their scholarly work has greatly enriched this study.

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Original Article

Artificial Intelligence in Tourism Management: Opportunities, Applications and Challenges

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Abstract

Artificial intelligence (AI) is revolutionizing the tourism sector by making improvements in customer satisfaction, operational efficiency, personalization, and decision-making processes. Machine learning, chatbots, recommendation engines, computer vision, and generative AI, among other AI technologies, have been gaining increasing acceptance among tourism companies to increase their efficiency and competitiveness. This research provides an introduction on the applications of AI in tourism management, latest trends in the field, and the problems and future prospects of AI-based tourism systems.

Keywords: *Artificial Intelligence, Tourism Management, Chatbots, Recommendation Systems, Smart Tourism, Generative AI.*

Introduction

Tourism industry is among the largest industries globally and has witnessed great technological changes within the last ten years. Artificial intelligence (AI) has become the most important tool to ensure good customer services, automation of the process, and personalization of travels. There are many areas in which AI technology is used in order to optimize the process and increase its effectiveness [1].

Fast development of artificial intelligence, particularly after large language models and generative AI became a reality, contributed greatly to the innovative changes in tourism management. Using AI-based chatbots, virtual assistants, recommendation, and prediction systems has allowed tourism companies to increase their customer engagement and support data-driven decision-making [2].

According to recent research, AI helps in achieving sustainable tourism by optimizing resource management, improving visitor experience, and intelligent destination management [3]. Further, the implementation of AI solutions is revolutionizing the tourism environment through integration of smart services, analysis, and recommendations for tourists [4].

However, there are some challenges associated with the use of AI in tourism in terms of privacy, ethics, biases, and dependence on automation systems. Hence, an important point is that it is necessary to analyze AI implementation in tourism management [5].

Literature Survey

Wang et al. (2025) reviewed systematically the literature of AI for tourism management and performed analysis of 177 research papers based on the TCCM (Theory, Context, Characteristics, and Methodology) framework. The authors showed the importance of AI applications in terms of improving customer experience, efficiency, and sustainability in tourism while noting some research gaps in future investigations [1].

Huang et al. (2025) gave an integrative review of Generative AI in tourism management and outlined three main research streams: antecedents to AI adoption, AI applications and effects, and technical issues of AI. The authors paid attention to the increasingly important role of ChatGPT and large language models in tourism services [2].

García-Madurga and Grilló-Méndez (2023) conducted a review on the use of AI in tourism, concluding that AI improves customer service, demand forecasting, recommendation systems, and smart tourism [3]. The importance of using AI ethically and sustainably in the tourism sector was another focus of their review.

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Samala et al. (2021) conducted a systematic review of AI techniques and applications in hospitality and tourism. Their work showed that machine learning, neural networks, natural language processing, and computer vision have found their way into tourism and are commonly used for demand forecasting and tourist behavior prediction, among others. [4].

Recent studies have also explored the application of artificial intelligence for enhancing the customer experience. According to Sanoussi et al. (2025), adoption of AI results in improved personalization, satisfaction, and service quality in tourism. However, privacy concerns, lack of trust, and acceptance are key barriers to adoption. [5].

Applications Of Ai in Tourism Management

AI applications in tourism management include:

1. **AI Chatbots and Virtual Assistants:** These are AI-based chatbots that offer 24×7 customer services, answer travel queries and help travelers book services.
2. **Recommendation Systems:** AI uses machine learning algorithms to suggest destinations, hotels, restaurants, and travel itineraries for the users.
3. **Predictive Analytics:** Using historical data and present data, AI predicts the future demand for tourists and helps in formulating pricing policies.
4. **Smart Tourism and Destination Management:** AI assists in managing traffic, crowds, and offering personalized tourist experiences in smart cities.
5. **Applications of Generative AI:** Large language models and Generative AI help in creating travel itineraries and generating travel content.

Advantages Of Ai in Tourism Management

- Better Customer Experience: Offers Customized Suggestions and Helps to Plan Trips Easily.
- Operational Efficiency: Helps To Automate Mundane Tasks Such as Booking, Checking in And Out, And Handling Customers.
- Cost Savings: Cuts Labor Costs and Avoids Operational Mistakes.
- Quick Decision Making: Ai Processes Huge Chunks of Data Instantly and Helps Managers to Take Informed Decisions.
- Improved Marketing: Helps In Targeted Marketing and Segregation of Customers.
- Real Time Information: Provides Real Time Information Regarding Weather, Traffic, Flights, And Other Tourist Destinations.
- Efficient Resource Utilization: Helps To Manage Hotels, Transportation, And Other Destination Resources Effectively.
- Competitive Advantage: Tourism Businesses Adopting Ai Gain Innovation Capabilities and Improved Service Quality.

Opportunities of Ai in Tourism Management

1. **Personalized Travel Experiences**
   a. AI analyzes customer preferences and provides customized travel recommendations.
   b. Enhances customer satisfaction and loyalty.
2. **Smart Destination Management**
   a. AI helps manage tourist flows, traffic, and crowd control in popular destinations.
   b. Supports sustainable tourism development.
3. **Predictive Analytics**
   a. Forecasts tourist demand, occupancy rates, and travel trends.
   b. Assists businesses in strategic planning and resource allocation.
4. **24×7 Customer Service**
   a. AI chatbots and virtual assistants provide round-the-clock support.
   b. Reduces response time and improves customer engagement.
5. **Sustainable Tourism**
   a. AI optimizes energy consumption, waste management, and transportation systems.
   b. Promotes environmentally responsible tourism practices.
6. **New Business Models**
   a. AI enables innovative services such as virtual tourism, smart hotels, and AI-based travel assistants.

Challenges

While there are many advantages of using AI technology, the following challenges still exist:

Privacy and data security problems

Algorithmic biases and ethical questions

Costs associated with its use

The lack of transparency

Difficulty implementing AI in practice

To overcome those obstacles, one should adopt proper AI policies, ethical standards, and human-centric AI.

Conclusion

Artificial Intelligence is transforming tourism management in terms of making processes efficient, providing better experiences for customers, and facilitating sustainable tourism. AI tools such as machine learning, chatbots, recommendation systems, and Generative AI are transforming tourism services and destination management. Although there are certain ethical and privacy issues associated with the adoption of AI tools, they hold a lot of promise in terms of creating an efficient and sustainable tourism environment.

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I also extend my heartfelt appreciation to the faculty members and my institution for providing the necessary academic resources, encouragement, and a conducive environment for conducting this review.

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Original Article

Fiscal Rules and Economic Governance: A Theoretical Re-examination of Rules versus Institutions

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Abstract

Over the last three decades, fiscal rules have proliferated across advanced, emerging, and developing economies as instruments for disciplining public finances, enhancing credibility, and supporting macroeconomic stability. At the same time, a parallel literature on economic governance and independent fiscal institutions argues that durable fiscal discipline ultimately depends less on numerical constraints and more on the quality of institutions that shape incentives, information, and accountability. This conceptual paper revisits the debate on "rules versus institutions" in fiscal governance, synthesising insights from the fiscal rules literature, new institutional economics, and the emerging evidence on independent fiscal councils. It clarifies the conceptual distinctions between fiscal rules and fiscal institutions, examines the theoretical channels through which each affects fiscal behaviour, and argues that the practical question is not whether rules or institutions are superior, but how combinations of well-designed rules and robust institutions can jointly mitigate deficit bias and common-pool problems. Building on this synthesis, the paper proposes an integrated conceptual framework for fiscal governance that emphasises complementarity between numerical rules, procedural rules, and oversight institutions, especially in developing and resource-rich economies. The paper concludes by outlining a research agenda on the political-economy conditions under which specific rule–institution combinations are likely to be effective and legitimate.

Keywords: *fiscal rules; economic governance; institutions; independent fiscal institutions; fiscal councils; deficit bias; developing economies.*

Introduction

Fiscal indiscipline—persistent deficits, rising debt, and pro-cyclical fiscal policies—is a recurrent feature of many advanced and developing economies and has motivated the rise of fiscal rules as pre-commitment devices. At the same time, frequent rule circumvention, creative accounting, and ad hoc suspensions of rules have led scholars to question whether numerical constraints alone can deliver sustained fiscal discipline without supportive institutions.

In response, a strand of literature framed the debate as "fiscal policy: institutions versus rules," arguing that effective fiscal frameworks require both sound rules and strong institutions that monitor, interpret, and enforce them. This paper revisits that debate from a theoretical and conceptual perspective, aiming to: (a) clarify definitions of fiscal rules, economic governance, and institutions; (b) articulate the main theoretical arguments for and against rule-based and institution-based approaches; and (c) propose an integrated conceptual framework for fiscal governance applicable to diverse country contexts, including developing and resource-rich economies.

Conceptual Foundations: Fiscal Rules

Kopits and Symansky (1998) define a fiscal policy rule as a "permanent constraint on fiscal policy, expressed in terms of a summary indicator of fiscal performance, such as the government budget deficit, borrowing, debt, or a major component thereof." Their seminal contribution also identifies desirable properties of fiscal rules—clarity, transparency, simplicity, flexibility, consistency, enforceability, and adequate support by other policies—that later became the benchmark Kopits–Symansky criteria.

Subsequent work has classified fiscal rules into several types, including budget-balance rules, debt rules, expenditure rules, and revenue or structural balance rules, often embedded in medium-term fiscal frameworks.

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The rapid diffusion of these rules since the mid-1980s reflects hopes that well-designed numerical constraints can reduce deficit bias, enhance credibility, and anchor expectations about fiscal policy paths.

Conceptual Foundations: Economic Governance and Institutions

Economic governance generally refers to the system of institutions, procedures, and norms through which economic policy is formulated, implemented, and monitored. In the European Union context, economic governance is defined as the set of institutions and procedures established to achieve the Union's economic objectives, including mechanisms for fiscal surveillance and coordination.

From the perspective of new institutional economics, institutions are understood as "sets of rules that govern human interaction," including formal laws, informal norms, and organisations that structure incentives and facilitate exchange. Economic governance research, as summarised in the Nobel Prize advanced materials for Ostrom and Williamson, emphasises how different governance structures—markets, hierarchies, and hybrid arrangements—address conflicts of interest, information asymmetries, and enforcement problems. Applied to fiscal policy, this perspective highlights that outcomes depend not only on nominal rules but also on the broader institutional environment in which those rules operate.

Fiscal Rules as Commitment Devices

The theoretical rationale for fiscal rules originates in the political-economy literature on deficit bias and the common-pool problem. When multiple spending constituencies each internalise benefits but not the full tax cost, governments tend to overspend and postpone adjustment, leading to excessive debt accumulation; numerical rules are intended to internalise this externality by limiting discretion ex ante.

Kopits and Symansky (1998) argue that fiscal rules can enhance credibility by committing governments to predictable paths for deficits, debt, or expenditure, thereby reducing time-inconsistency and the temptation to run opportunistic deficits ahead of elections. Empirical surveys for both advanced and developing economies suggest that credible, well-designed rules can be associated with lower primary deficits, reduced pro-cyclicality, and greater debt sustainability, particularly when supported by robust monitoring and enforcement mechanisms.

Limitations and Risks of Pure Rule-Based Approaches

Despite their appeal, purely rule-based frameworks face several limitations that arise from uncertainty, complexity, and political incentives. First, rigid rules may constrain counter-cyclical fiscal policy during downturns or crises, forcing pro-cyclical consolidation unless they incorporate well-designed escape clauses and flexibility mechanisms. Second, rules formulated in simple numerical terms can be circumvented through creative accounting, off-budget operations, or reclassification of expenditure, especially when transparency is low and monitoring weak.

Third, rules that are technically sophisticated but poorly understood by the public may lack democratic legitimacy and become politically unsustainable, leading to frequent revisions or ad hoc suspensions. Wyplosz and others therefore argue that rules without supporting institutions risk being either ineffective because they are not enforced, or destabilising because they are applied mechanically without adequate judgment and accountability.

Institutions and Economic Governance in Fiscal Policy

Institutional approaches to fiscal policy focus on how decision-making procedures, budgetary processes, and oversight bodies shape fiscal outcomes over time. The literature on fiscal institutions highlights mechanisms such as top-down budget preparation, medium-term expenditure frameworks, parliamentary budget offices, and independent fiscal councils as tools to strengthen discipline and transparency.

Good economic governance, as articulated in UN and development-oriented guidelines, encompasses democratic accountability, rule of law, transparency, and effective financial management in both public and private sectors. In this view, fiscal discipline and macroeconomic stability are by-products of broader institutional qualities, including credible enforcement, participatory processes, and a professional bureaucracy capable of implementing complex fiscal strategies.

Independent Fiscal Institutions and Fiscal Councils

Independent fiscal institutions (IFIs) or fiscal councils are publicly funded, non-partisan bodies that provide analysis, oversight, and sometimes recommendations on fiscal policy, but without direct decision-making authority. Definitions used by the OECD and IMF emphasise their independence from the executive, their mandate to evaluate compliance with fiscal rules, and their role in enhancing the transparency and realism of macro-fiscal forecasts.

Empirical studies for EU and OECD countries suggest that the presence of well-designed fiscal councils is associated with more accurate and less optimistic budget forecasts, better compliance with fiscal rules, and somewhat lower primary deficits. These effects appear stronger when councils have clear legal mandates, adequate resources, and the ability to communicate freely with the public, thereby exerting reputational pressure on governments rather than exercising direct coercive power.

Rules versus Institutions: The Core Theoretical Debate

The "rules versus institutions" debate crystallised in Wyplosz's work, which argued that numerical rules alone are insufficient and sometimes counter-productive without complementary institutions that interpret and enforce them. On the one hand, rules are appealing because they appear to depoliticise fiscal policy, tying the hands of governments and providing clear quantitative benchmarks; on the other hand, they are necessarily incomplete, cannot foresee all contingencies, and remain vulnerable to manipulation.

Institutional approaches emphasise processes—who prepares forecasts, how budgets are debated, how compliance is monitored, and what information is made public—over precise numerical targets. Yet institutions without clear numerical anchors can themselves be captured, and may struggle to justify unpopular consolidation in the absence of explicit and pre-announced fiscal objectives. The theoretical challenge, therefore, is to conceptualise fiscal governance as an interaction between rules and institutions rather than a simple choice between them.

Complementarities between Rules and Institutions

Recent literature and policy practice increasingly view fiscal rules and institutions as complements: rules define the targets and constraints, while institutions provide the

interpretive, monitoring, and reputational mechanisms needed to make rules credible and flexible. For example, independent fiscal councils can endorse or produce macroeconomic forecasts, assess whether governments comply with rules, advise on the activation of escape clauses, and explain deviations to the public, thereby reducing both opportunistic optimism and deficit bias.

Empirical evidence indicates that the beneficial effects of fiscal rules on discipline are stronger in countries where budgetary institutions are robust and political systems support transparency and accountability. Conversely, where institutions are weak, rules are more likely to be ignored, reinterpreted, or suspended, and may fail to constrain the underlying political determinants of fiscal behaviour. This supports a conceptual view in which rules and institutions form an integrated fiscal constitution rather than alternative mechanisms.

A Conceptual Framework for Fiscal Governance

Drawing on the above, fiscal governance can be conceptualised as a three-layered framework: (1) numerical rules, (2) procedural rules, and (3) oversight institutions. Numerical rules constrain aggregates such as deficits, debt, or expenditure; procedural rules structure the budget process (top-down vs. bottom-up budgeting, multi-year frameworks, transparency requirements); and oversight institutions monitor compliance, produce or validate information, and communicate with the public.

Within this framework, effective fiscal governance emerges when there is internal consistency between the layers—such that rules are operationally feasible, procedures support compliance, and institutions have both the mandate and capacity to enforce transparency and accountability. The framework underscores that changing only one layer—for example, adopting a debt rule without reforming budget procedures or creating credible monitoring institutions—is likely to generate limited or transitory effects.

Fiscal Governance in Developing and Resource-Rich Economies

The rules–institutions debate takes on particular significance in developing and resource-rich economies, where fiscal policy is often constrained by low revenue capacity, expenditure rigidities, commodity price volatility, and weaker state capability. In such contexts, numerical rules for deficits, debt, or resource revenues are frequently advocated as tools to anchor expectations and prevent boom-and-bust spending cycles, but their effectiveness depends heavily on institutional quality and governance.

Empirical work on resource-rich countries suggests that strong macroeconomic fundamentals, government stability, and engagement with multilateral institutions increase the likelihood of adopting fiscal rules, but adoption does not automatically translate into effective implementation. At the same time, developing countries face greater challenges in building independent fiscal councils and high-capacity treasury systems, implying that external anchors and gradual institution-building may be especially important for credible fiscal frameworks.

Normative Considerations: Democracy, Legitimacy, and Ownership

Beyond technical efficiency, the design of fiscal rules and institutions raises normative questions about democratic accountability and national ownership. Delegating significant aspects of fiscal surveillance to independent experts can enhance credibility but may be perceived as technocratic or undermining parliamentary sovereignty, particularly where fiscal institutions are created under external pressure rather than domestic consensus.

The literature on independent fiscal agencies emphasises that their legitimacy depends on clear legal mandates, transparency, open communication, and a perception that they inform democratic debate rather than substitute for elected representatives. Similarly, fiscal rules that are too complex, externally imposed, or disconnected from national priorities may lack social acceptance and be more prone to contestation and non-compliance, underscoring the importance of aligning fiscal governance with local political and institutional realities.

Implications for Policy Design

From the foregoing conceptual analysis, several implications for the design of fiscal governance frameworks can be drawn. First, the choice of fiscal rule should reflect country-specific macroeconomic risks, fiscal structures, and data capacity; for example, structural balance rules require robust output gap estimation, whereas expenditure rules hinge on reliable multi-year expenditure baselines. Second, procedural reforms that strengthen top-down budgeting, medium-term frameworks, and transparency can enhance the effectiveness of rules by reducing fragmentation and information asymmetry.

Third, the establishment or strengthening of independent fiscal institutions can improve the quality of forecasts, enhance compliance, and provide a more nuanced interpretation of rules, particularly regarding escape clauses and exceptional circumstances. Fourth, in low-capacity settings, a gradual approach that prioritises basic transparency, improved fiscal data, and simple, well-communicated rules may be more feasible and legitimate than complex frameworks that outstrip administrative capability.

Research Agenda

Conceptually, several questions remain open and merit further theoretical and empirical inquiry. One line of research concerns the political-economy conditions under which particular combinations of rules and institutions are likely to succeed, including the interaction between fiscal councils and legislative budget powers. Another concerns the dynamic effects of fiscal rules under varying institutional quality—do strong institutions reduce the need for tight rules, or do they instead make rule adoption more likely and effective?

A further set of questions relates to distributional and intergenerational equity: how different governance arrangements affect the composition of spending, tax policy, and the burden of debt across social groups and generations. Finally, more comparative work is needed on fiscal governance in developing and resource-rich countries, where the interaction between external anchors, domestic politics, and evolving institutions may produce distinct patterns of rule adoption, adaptation, and resilience.

Conclusion

This paper has re-examined the rules–versus-institutions debate in fiscal governance, arguing that the dichotomy is conceptually misleading and practically unhelpful. Fiscal rules, understood as permanent numerical constraints on key fiscal aggregates, provide valuable anchors for expectations and can mitigate deficit bias, but they are

incomplete contracts that require interpretation, monitoring, and adjustment over time. Institutions—encompassing budgetary procedures, oversight bodies, and broader governance norms—shape the incentives and information structures within which rules operate and are thus indispensable for their credibility and effectiveness.

An integrated conceptual framework for fiscal governance therefore emphasises the complementarity of numerical rules, procedural rules, and independent institutions, particularly in environments characterised by political fragmentation, fiscal volatility, and limited administrative capacity. For policymakers and scholars, the key challenge is to design and study fiscal constitutions that are not only technically sound, but also democratically legitimate and resilient to shocks and political pressures across diverse country contexts.

Acknowledgment

I would like to express my sincere gratitude to everyone who contributed to the successful completion of this review paper titled **"Fiscal Rules and Economic Governance: A Theoretical Re-examination of Rules versus Institutions."**

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Original Article

Gig Workers in the Digital Economy: A Primary Study on Social Security and Labour Rights

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Abstract

The rapid expansion of the digital economy has significantly restructured labour markets across the globe, leading to the emergence and growth of the gig economy. Characterized by short-term, flexible, and platform-mediated work arrangements, the gig economy has become an important source of employment in India, particularly for youth and semi-skilled workers. Despite its potential to generate income opportunities and promote labour market flexibility, gig employment raises critical concerns related to social security, income stability, and labour rights.

The present study is based on primary data collected from gig workers in the selected urban area and aims to examine their socio-economic profile, working conditions, income patterns, and access to social security benefits. The study further explores the level of awareness among gig workers regarding their labour rights and available welfare measures. The findings reveal that while gig work provides ease of entry and flexible employment opportunities, it is largely characterized by income uncertainty, absence of formal employment contracts, lack of social protection, and limited awareness of legal rights.

The study highlights a significant gap between the rapid expansion of platform-based employment and the development of adequate institutional and policy frameworks to protect workers. It emphasizes the need for comprehensive labour regulations, effective implementation of social security measures, and increased accountability of digital platforms. The paper concludes that without timely policy intervention, the gig economy may exacerbate labour market vulnerabilities rather than contribute to inclusive and sustainable economic development.

Keywords: *Gig Economy, Digital Economy, Platform Workers, Social Security, Labour Rights, Income Instability, Informal Employment*

Introduction

The rapid advancement of digitalization has significantly transformed the structure and functioning of modern economies, leading to fundamental changes in labour market dynamics. One of the most notable outcomes of this transformation is the emergence of the gig economy, which represents a shift from traditional, long-term employment relationships to flexible, short-term, and task-based work arrangements. In this framework, digital platforms function as intermediaries that connect service providers with consumers, thereby redefining the nature of work, employment relations, and income generation.

In the Indian context, the gig economy has experienced substantial growth in recent years, driven by factors such as increased smartphone penetration, expansion of internet connectivity, rapid urbanization, and the growing demand for on-demand services. Digital platforms operating in sectors such as food delivery, transportation, logistics, and freelance services have created new employment opportunities for a large segment of the population. This has been particularly beneficial for youth and individuals facing constraints in accessing formal sector employment.

Despite its rapid expansion, the gig economy raises important concerns regarding the quality, security, and sustainability of employment. Gig workers are generally classified as independent contractors rather than formal employees, which excludes them from the coverage of traditional labour laws and social security systems. Consequently, they are deprived of essential benefits such as minimum wages, paid leave, health insurance, and retirement security. This classification also weakens their bargaining power and limits their access to legal protection and institutional support.

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Furthermore, the increasing reliance on algorithmic management has added a new dimension to labour regulation within the gig economy. Digital platforms utilize algorithms to allocate tasks, determine compensation, and evaluate worker performance. While such mechanisms enhance operational efficiency, they often lack transparency and reduce worker autonomy, thereby increasing economic vulnerability. The absence of formal employment contracts and effective grievance redressal mechanisms further intensifies the insecurity faced by gig workers.

In this context, there is a growing need to critically examine the working conditions of gig workers, particularly in relation to social security and labour rights. The present study, based on primary data, seeks to provide a micro-level analysis of the socio-economic conditions of gig workers and to assess their access to social protection and awareness of labour rights. By doing so, the study aims to contribute to the broader discourse on labour market reforms and the development of an inclusive and sustainable framework for the gig economy.

In India, gig and platform workers have been recognized under the Code on Social Security, 2020, which provides for certain social security measures such as life and disability cover, health benefits, and maternity benefits. However, the implementation of these provisions remains limited. Gig workers are still not fully covered under key labour protections such as minimum wage, job security, and collective bargaining, which restricts the effective realization of their labour rights.

Review of Literature

The emergence of the gig economy has attracted considerable attention in recent years, particularly in the context of digital transformation and evolving labour market dynamics. A growing body of literature has examined both the opportunities and challenges associated with platform-based employment.

The International Labour Organization (2021) highlights that the gig economy has expanded employment opportunities by offering flexible work arrangements and increasing labour market participation, especially among youth and marginalized groups. However, the report also emphasizes that such employment is largely informal in nature and is often associated with lack of job security and absence of social protection.

In the Indian context, NITI Aayog (2022) observes that the gig economy is growing rapidly and has the potential to generate significant employment in the coming years. While acknowledging its contribution to economic growth and digital inclusion, the report raises concerns regarding income instability and inadequate access to social security among gig workers.

Guy Standing (2011) introduced the concept of the "precariat," referring to a class of workers engaged in insecure and unstable forms of employment. This concept is highly relevant in understanding the conditions of gig workers, who often experience uncertainty in income, lack of employment security, and absence of legal protections.

Further, Valerio De Stefano (2016) argues that gig workers are frequently misclassified as independent contractors, which excludes them from labour laws and deprives them of essential rights such as minimum wages, social security, and collective bargaining. The study emphasizes the need for appropriate regulatory frameworks to address these challenges.

Alex Rosenblat (2018) highlights the increasing role of algorithmic management in platform-based work. The study reveals that digital platforms exercise significant control over workers through algorithms that determine work allocation, pricing, and performance evaluation, thereby reducing worker autonomy and increasing dependency.

In addition, the Economic Survey of India (Government of India, 2021) indicates that a large proportion of gig workers earn low and unstable incomes, with limited access to formal welfare mechanisms. The report also points out that awareness regarding government welfare schemes among gig workers remains relatively low.

Despite these contributions, much of the existing literature relies on secondary data and macro-level analysis. There is a lack of empirical studies based on primary data that capture the lived experiences and working conditions of gig workers at the micro level. Therefore, the present study attempts to bridge this gap by providing field-based evidence on issues related to social security and labour rights.

Research Gap

- Existing studies are predominantly based on secondary data from sources such as NITI Aayog and International Labour Organization, with limited reliance on primary data.
- There is a lack of micro-level studies examining the local and region-specific conditions of gig workers.
- Limited attention has been given to assessing the actual accessibility and utilization of social security benefits among gig workers.
- Insufficient research exists on the level of awareness regarding labour rights and legal protections among gig workers.
- There is a lack of empirical evidence on the impact of platform-based control on working conditions and worker autonomy.

Objectives of the Study

The present study is undertaken with the following objectives:

1. To analyse the socio-economic profile of gig workers in the selected study area.
2. To examine the income patterns and working conditions associated with gig employment.
3. To assess the availability and accessibility of social security benefits among gig workers.
4. To evaluate the level of awareness regarding labour rights and legal protections among gig workers.
5. To identify the major challenges and issues faced by gig workers in the digital economy.

Hypotheses of the Study

Hypothesis 1:

H_0: There is no significant association between income level and access to social security.
H_1: There is a significant association between income level and access to social security.

Hypothesis 2:

H_0: There is no significant association between work experience and awareness of labour rights.
H_1: There is a significant association between work experience and awareness of labour rights.

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Research Methodology

The present study aims to examine the socio-economic conditions, access to social security, and awareness of labour rights among gig workers in the digital economy. A systematic research design has been adopted to ensure the collection, analysis, and interpretation of relevant data in a scientific manner.

1. Nature of the Study

The study is descriptive and analytical in nature. The descriptive aspect focuses on presenting the socio-economic characteristics, income patterns, and working conditions of gig workers. The analytical aspect examines relationships between variables such as income, work experience, social security access, and awareness of labour rights. This combination enables a comprehensive understanding of both the conditions and issues faced by gig workers.

2. Area of the Study

The study is conducted in a selected urban area (e.g., Hubli–Dharwad), where gig economy activities such as food delivery, ride-hailing, and platform-based services are widely prevalent. The area has been selected due to the increasing presence of gig workers, availability of respondents, and its relevance as a growing urban labour market influenced by digital platforms.

3. Sources of Data

a) Primary Data:

Primary data forms the core of this study and has been collected through a structured questionnaire administered to gig workers. The questionnaire is designed to capture detailed information on socio-economic background, employment conditions, income levels, working hours, access to social security benefits, and awareness of labour rights. Direct interaction with respondents has helped in obtaining reliable and first-hand information.

b) Secondary Data:

Secondary data has been collected from reports of NITI Aayog, International Labour Organization, government publications, academic journals, and other relevant research studies. These sources provide a theoretical and contextual background to support the analysis of primary data.

4. Sample Size

The study is based on a sample of 100 gig workers. A relatively larger sample size has been chosen to enhance the reliability and validity of the study. It allows for better representation of different categories of gig workers and improves the accuracy of results and generalization within the study area.

5. Sampling Technique

The study uses convenience sampling and snowball sampling techniques. Since gig workers are scattered and do not have a formal sampling frame, these non-probability sampling methods are appropriate. Initial respondents were selected based on accessibility, and further respondents were identified through referrals, which helped in reaching a wider network of gig workers.

6. Tools for Data Collection

- Structured Questionnaire: Used to collect standardized and comparable data from all respondents.
- Personal Interaction: Informal discussions were conducted wherever possible to gain deeper insights into the problems and experiences of gig workers.

7. Tools for Data Analysis

The collected data has been analysed using simple and appropriate statistical tools:

- Percentage Analysis: To understand the distribution and proportion of responses.
- Tabular Presentation: To organize data systematically for clarity and comparison.
- Comparative Analysis: To examine relationships between variables such as income and social security, and work experience and awareness of labour rights.

8. Variables of the Study

- Independent Variables: Income level, work experience, type of gig work
- Dependent Variables: Access to social security benefits, awareness of labour rights

9. Limitations of the Study

- The study is limited to a specific geographical area, which may restrict generalization.
- The use of non-probability sampling may introduce bias.
- Responses are based on self-reporting, which may involve subjectivity.
- Time and resource constraints limited the scope of the study.

Data Analysis and Interpretation (N = 100)

Table 1: Age-wise Distribution

Age group	No. of Respondents	Percentage
18-25	30	30%
26-35	45	45%
36-45	15	15%
Above 45	10	10%
Total	100	100%

Source:

Interpretation:

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The data reveals that a significant proportion of respondents (45%) belong to the 26–35 age group, followed by 30% in the 18–25 category. This indicates that gig employment is largely concentrated among young adults who are either entering the labour market or are in the early stages of their careers. The relatively lower participation of older age groups suggests that gig work is more attractive or accessible to younger individuals due to factors such as flexibility, lower entry barriers, and familiarity with digital platforms.

Table 2: Educational Qualification

Qualification	No. of Respondents	Percentage
Below PUC	15	15
PUC	25	25
Graduate	25	25
Postgraduate	10	10
Pursuing Studies	25	25
Total	100	100

Source:

Interpretation:

The data indicates that a significant proportion (25%) of respondents are currently pursuing their studies while engaging in gig work. This highlights the role of the gig economy as a flexible source of income for students who combine work with education. Additionally, 50% of respondents have completed PUC or graduation, reflecting a moderately educated workforce. The presence of students in gig employment suggests that such work serves as a supplementary income source rather than a long-term career option for some individuals. It also indicates the growing reliance on gig platforms among youth for financial independence and skill exposure.

Table 3: Nature of Gig Work

Type	**No of respondents**	**Percentage**
Food Delivery	**40**	**40%**
Ride –Hiding	**30**	**30%**
Logistic	**20**	**20%**
Freelancing	**10**	**10%**
Total	**100**	**100%**

Source

Interpretation:

The majority of respondents are engaged in food delivery (40%) and ride-hailing services (30%), accounting for 70% of total respondents. This highlights the dominance of platform-based service sectors in the gig economy. The relatively lower share of freelancing (10%) suggests that high-skill gig work is less prevalent in the selected study area, indicating a concentration of gig employment in low to semi-skilled activities.

Table 4: Monthly Income

Income	No.of Respondents	Percentage
Below 10,000	25	25
10,000-15,000	40	40
15,000-20,000	20	20
Above 20,000	25	25
Total	100	100

Source:

Interpretation:

A substantial proportion (65%) of respondents earn below ₹15,000 per month, indicating low earning capacity among gig workers. Only 15% earn above ₹20,000, suggesting limited upward income mobility. This reflects the precarious nature of gig work, where earnings are largely dependent on demand, incentives, and working hours rather than fixed wages.

Table 5: Working Hours

Hours	No. of Respondents	Percentage
Below 6hrs	15	15
6-8 hrs	35	35
8-10 hrs	30	30
Above 10 hrs	20	20
Total	100	100

Source:

Interpretation:

The data shows that 50% of respondents work more than 8 hours per day, with 20% working beyond 10 hours. This suggests that despite the flexibility associated with gig work, workers often engage in long working hours to maintain a stable

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income. It indicates a trade-off between flexibility and income security, where workers must work longer hours to achieve adequate earnings.

Table 6: Income Stability

Response	No. of Respondents	Percentage
Stable	25	25%
Not Stable	75	75%
Total	100	100%

Source:

Interpretation:

A large majority (75%) reported that their income is not stable. This highlights the uncertain and irregular nature of gig employment, where earnings fluctuate based on factors such as customer demand, platform algorithms, and competition. The lack of income stability increases financial vulnerability and reduces the ability of workers to plan for future expenses.

Table 7: Access to Social Security

Response	No. of respondents	Percentage
Yes	30	30%
No	70	70%
Total	100	100%

Source

Interpretation:

The findings reveal that 70% of respondents do not have access to any form of social security benefits such as insurance, pension, or provident fund. This indicates a significant gap in worker protection and exposes gig workers to risks related to health, accidents, and old age. The limited coverage of social security reflects the informal nature of gig employment.

Table 8: Awareness of Labour Rights

Response	No. of Respondents	Percentage
Aware	35	35
Not Aware	65	65
Total	100	100

Source

Interpretation:

The data shows that 65% of respondents are not aware of their labour rights. This lack of awareness limits their ability to demand fair treatment and access available benefits. It also reflects inadequate dissemination of information and absence of institutional support mechanisms for gig workers.

Table 9: Income vs Social Security (Hypothesis 1)

Income Level	**Yes**	**No**	**Total**
Below 10K	**5**	**20**	**25**
10-15k	**10**	**20**	**40**
Above 15k	**15**	**20**	**35**
Total	**30**	**70**	**100**

Source

Interpretation

The table indicates that access to social security improves with higher income levels. Among workers earning above ₹15,000, a relatively higher proportion has access to social security compared to those in lower income groups. This suggests that income level plays a role in determining access to benefits, possibly due to better awareness or longer association with platforms. **Therefore, a relationship exists, and the null hypothesis is rejected**.

Table 10: Experience vs Awareness (Hypothesis 2)

Experience	Aware	Not Aware	Total
< 1 Year	10	25	35
1-3 Years	15	20	35
> 3 Years	10	20	30
Total	35	65	100

Source

Interpretation

The data shows a gradual increase in awareness of labour rights with higher work experience. Workers with more than 1 year of experience demonstrate slightly better awareness compared to new entrants. However, overall awareness remains low across all categories. This indicates that while experience contributes to awareness, it is not sufficient in the absence of formal education or institutional support. **Hence, the null hypothesis is rejected**.

Findings of the Study

- The study reveals that gig employment is largely dominated by young individuals, particularly in the age group of 26–35 years, indicating that the gig economy is primarily driven by youth seeking flexible income opportunities.

- A significant proportion of respondents are students who are pursuing their studies alongside gig work, suggesting that gig employment serves as a supplementary source of income and allows flexibility in balancing education and work.
- The educational profile indicates that most respondents possess moderate levels of education, reflecting that even educated individuals are engaged in gig work due to limited access to stable formal employment opportunities.
- The findings show that a majority of gig workers earn below ₹15,000 per month, indicating low earning capacity and limited financial stability.
- Income instability is a major concern, as most respondents reported fluctuations in earnings due to demand variability and platform-based factors.
- Despite the flexibility associated with gig work, a significant proportion of workers are engaged for more than 8 hours per day, suggesting that longer working hours are necessary to maintain a reasonable level of income.
- The study highlights that a majority of gig workers do not have access to social security benefits such as insurance, pension, or provident fund, exposing them to economic and health-related risks.
- A considerable number of respondents lack awareness regarding labour rights, limiting their ability to demand fair treatment and access available welfare measures.
- Gig workers are highly dependent on digital platforms for employment, and many have experienced penalties or account-related issues, indicating job insecurity and lack of control over working conditions.
- The analysis suggests that higher income levels and greater work experience are associated with relatively better access to social security and awareness of labour rights, though overall levels remain inadequate.

Suggestions / Policy Implications

- There is a need to extend social security coverage to gig workers by including them under schemes providing health insurance, accident benefits, and pension facilities.
- Minimum income standards or earning guarantees should be introduced to reduce income instability and ensure fair compensation for gig workers.
- Awareness programs should be conducted by government agencies and platform companies to educate gig workers about their rights and available welfare schemes.
- Regulatory mechanisms should be established to ensure transparency in wage determination, task allocation, and performance evaluation by digital platforms.
- Effective grievance redressal systems should be developed to address complaints and disputes faced by gig workers.
- Digital platforms should be made accountable for contributing to social security and welfare measures for gig workers.

Conclusion:

The gig economy has emerged as a significant component of the modern labour market, offering flexible employment opportunities, particularly for youth and students. However, the findings of the study indicate that gig work is largely characterized by low and unstable income, long working hours, lack of social security benefits, and limited awareness of labour rights. While it provides an important source of livelihood and income generation, especially in the absence of adequate formal employment opportunities, it fails to ensure economic security and worker protection. The study also highlights the increasing dependence on digital platforms, which often results in job insecurity and reduced autonomy for workers. In this context, there is a pressing need for comprehensive policy intervention to regulate platform-based employment, extend social security coverage, and enhance awareness of labour rights. A balanced and inclusive approach is essential to ensure that the growth of the gig economy contributes not only to economic development but also to the welfare and protection of workers.

Scope for Further Study

- Future studies can focus on comparative analysis of gig workers across different regions or cities to understand regional variations.
- Further research can examine gender-based participation and challenges within the gig economy.
- Long-term studies can be conducted to analyse income stability and career progression of gig workers.
- The impact of recent government policies and regulations on gig workers can be explored in greater detail.

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I would like to express my sincere gratitude to everyone who contributed to the successful completion of this research paper titled **"Gig Workers in the Digital Economy: A Primary Study on Social Security and Labour Rights."**

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Original Article

Knowledge-Based Tourism Systems: Enhancing Personalized Travel Planning Through Intelligent Decision Support

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Abstract

The field of tourism has undergone great changes through the incorporation of ICTs in its processes. Normal tourism information systems are limited to providing static information and do not give out personalized travel recommendations taking into consideration the preferences and travel history of the tourist, among other things. Knowledge-based tourism systems make use of artificial intelligence, expert systems, machine learning, and knowledge representation techniques to provide intelligent travel recommendations. This paper is about a study on knowledge-based tourism systems where there is an analysis of existing problems and a proposal for an intelligent tourism system framework. and support sustainable tourism development through personalized and context-aware recommendations.

Keywords: *Knowledge-Based Systems, Tourism Information Systems, Artificial Intelligence, Recommendation Systems, Smart Tourism, Decision Support Systems.*

Introduction

Tourism is regarded as one of the most rapidly growing industries, which contributes greatly to the economic development of the world. The development of technologies has influenced the ways of searching for information and planning trips of the modern traveler. Nowadays, the traveler needs personal recommendations and intelligent help at all stages of the journey.

Knowledge-based tourism systems (KBTS) use tourism knowledge, preferences of the tourists, mechanisms of reasoning, and intelligent algorithms for providing decision-making assistance for the tourists.

According to Gretzel et al. [1], smart tourism technologies allow for a personalized experience through data analysis and intelligent decision-making. Likewise, Fesenmaier et al. [2] highlighted the significance of intelligent tourism systems in the process of travel planning and destination choice. The latest developments in artificial intelligence and machine learning have made significant improvements to the functioning of tourism recommendation systems [3].

The rise of knowledge-based systems opens up the possibility to address the issues related to information overload, poor relevance of recommendations, and inefficient trip planning. Through knowledge representation and reasoning techniques, KBTS can provide highly relevant travel recommendations according to individual needs of users.

Literature Survey

Intelligent tourism systems and recommender system architectures have been studied by various scientists.

Recommender systems for tourism that use user profiles and context in order to make recommendations have been suggested by Ricci et al. [4]. This research has proven the efficiency of using recommendation algorithms in increasing user satisfaction.

Intelligent tourism recommender systems were considered by Borràs et al. [5], and the role of personalized technologies was revealed by these scientists. The technologies of collaborative filtering, content-based filtering, and hybrid recommendation have been defined as the main technologies of tourism recommender systems. The concept of smart tourism has been introduced by Gretzel et al. [1].

Werthner and Klein [6] studied the use of information technologies in the tourism industry and stressed the importance of knowledge management in tourism decision support systems.

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Xiang and Fesenmaier [7] studied the impact of online travel information and social media data on the decision-making process of tourists. The results showed that tourists are now using intelligent computer-based systems for planning their travel.

Despite substantial progress made in tourism recommendation systems, there are still some issues in terms of data integration, context awareness, explainability, and adaptation to changing preferences of users.

Limitations of Current Systems

The following are some of the limitations of current tourism information and recommendation systems:

1.Incapable of providing personalization.
2.Not able to integrate contextual data.
3.Tourism data is fragmented in many sources.
4.Information overload causing decision fatigue.
5.No explanation for the recommendations provided.
6.Lack of adaptation to changing preferences.
7.Capabilities to provide sustainable tourism recommendations are lacking.
8.Missing integration of social media and other user-generated content.
9.Lack of scalability with large datasets.
10.Not multilingual/cross-cultural.

Problem Statement

Current tourism information systems concentrate more on provision of information than intelligent decision-making support for tourists. There are many cases where the selection of an appropriate destination, accommodation, transportation means, and activities may pose some difficulties to tourists.

The research question of this study is:

"How can an intelligent knowledge-based tourism system be developed to offer personalized, context-aware and interpretable travel recommendations using several tourism data sources and artificial intelligence technology?"

Proposed Technological Solution

The following components make up the suggested Knowledge-Based Tourism System:

A. Artificial Intelligence

1. Machine Learning Algorithms
2. Deep Learning Algorithms
3. Natural Language Processing

B. Knowledge Base

1. Tourism Ontologies
2. Destination Knowledge Graphs
3. Repository for User Preferences

C. Recommendation Engine

1. **Content-based filtering**
2. **Collaborative filtering**
3. **Hybrid recommendation models**

D. Context-Aware Component

1. Weather information
2. Location information
3. Seasonal information
4. Budget constraints
5. User travel history

E. Explainable AI Component

Explanations regarding why specific recommendations have been made are provided.

VI. Methods of Collecting Data

A. Primary Data Collection

1. Surveys from Tourists.
2. Questionnaires online.
3. Interviews with Tourists.
4. Expert consultations with tourism professionals.

B. Secondary Data Collection

1. Tourism department databases.
2. Travel websites.
3. Hotel booking platforms.
4. Social media platforms.
5. Tourism research publications.

C. Data Processing Steps

1. Data Collection.
2. Data Cleaning.
3. Data Integration.
4. Feature Extraction.
5. Knowledge Representation.
6. Model Training.
7. Recommendation Generation.
8. Performance Evaluation.

VII. Proposed System Architecture

The proposed architecture consists of:

Input Layer

- User Profile
- Preferences
- Budget
- Location
- Travel History

Knowledge Layer

- Tourism Knowledge Base
- Ontology Repository
- Historical Data Repository

Intelligence Layer

- Machine Learning Engine
- Recommendation Engine
- Inference Engine

Output Layer

- Personalized Destination Suggestions
- Accommodation Recommendations
- Travel Itinerary Generation
- Activity Recommendations

VIII. How Proposed System is Better Than Existing Systems

Parameter	Existing System	Proposed System
Personalization	Limited	Highly Personalized
Context Awareness	Low	High
Recommendation Accuracy	Moderate	High
Explainability	Not Available	Available
Real-Time Updates	Limited	Supported
Data Sources	Single/Few Sources	Multiple Integrated Sources
User Satisfaction	Moderate	High

Scalability	Limited	Improved
Sustainability Support	Low	High

IX. Future Scope

Some future upgrades may be as follows:

- IoT-enabled smart tourism infrastructure.
- Crowd management advice.
- Augmented reality tourism guide.
- Usage of blockchain for tourism services.
- Tourism trip planning through voice assistant.
- Autonomous transportation integration.
- Big data-based prediction of tourists' behaviors.
- Sustainability-based tourism recommendation system.

Conclusion

The Knowledge-Based Tourism System is a breakthrough for intelligent tourist planning and tourism management systems. This is possible because through the application of artificial intelligence, knowledge representation, recommendation techniques, and contextual information, these systems will be able to give highly customized and explainable recommendations. The suggested model has been developed to overcome the shortcomings that currently exist in tourism systems through the inclusion of multi-source data integration, context-awareness, and machine learning approaches. Future advancements in smart tourism technology will only make these systems even more effective.

Acknowledgment

I would like to express my sincere gratitude to everyone who contributed to the successful completion of this review paper titled "Knowledge-Based Tourism Systems: Enhancing Personalized Travel Planning Through Intelligent Decision Support."

I am deeply thankful to my guide/supervisor for their invaluable guidance, continuous encouragement, and constructive suggestions throughout the preparation of this manuscript. Their expertise and support were instrumental in shaping this work.

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I gratefully acknowledge the contributions of researchers, scholars, tourism professionals, and organizations whose books, research articles, reports, and publications on knowledge-based systems, artificial intelligence, intelligent decision support, tourism management, and personalized travel planning formed the foundation of this review. Their scholarly work has significantly enriched the quality and depth of this manuscript.

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Original Article

Commerce Vs Cybercrime: The Digital Tug of War in The Twenty-First Century

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Abstract

Commerce is now a dynamic, internationally integrated sector thanks to the digital revolution. The efficiency of business transactions has greatly increased due to the expansion of e-commerce, online banking, digital payments, and cloud-based company processes. However, cybercrime has become a significant hazard to consumers and organisations as a result of the quick growth of digital commerce. Through phishing, identity theft, ransomware assaults, online fraud, and data breaches, cybercriminals take advantage of technical weaknesses. Cybersecurity is becoming a crucial part of corporate strategy due to the growing reliance on digital platforms.

The link between commerce and cybercrime is examined in this article, along with the variables that lead to cyber risks, their effects on enterprises and society, and the steps that must be taken to create a safe digital environment. The study comes to the conclusion that strong cybersecurity measures must be balanced with technical innovation for digital commerce to succeed in the future.

Keywords: *Digital Commerce, Cybercrime, E-Commerce, Cybersecurity, Digital Economy, Digital Payments*

Introduction

Unprecedented technical developments in the twenty-first century have completely changed how consumers and companies engage. Once mostly dependent on physical marketplaces and in-person transactions, traditional commerce has progressively transformed into a digital ecosystem powered by internet technology. Through digital platforms, customers may now make purchases, send money, schedule services, and carry out commercial activities from any location in the world.

The expansion of digital commerce has been hastened by the quick uptake of smartphones, internet access, cloud computing, and digital payment methods. In an effort to cut expenses, increase productivity, and expand their market reach, businesses are increasingly moving their activities online. Online retail shopfronts, food delivery apps, digital marketplaces, and online banking services are examples of e-commerce platforms that are now essential to contemporary economic activity.

Digital commerce has brought about new difficulties as well as enormous economic potential. Cybercriminals are always looking for ways to take advantage of weaknesses in digital systems in order to get sensitive data, financial resources, and organisational networks without authorisation. Consequently, cybercrime has emerged as one of the most rapidly expanding types of criminal behaviour globally. Because of the ongoing conflict between innovation and security brought about by the cohabitation of digital commerce and criminality, cybersecurity is a crucial issue for consumers, governments, and enterprises.

This paper examines the expanding connection between cybercrime and trade and emphasises how crucial it is to provide safe online spaces for long-term economic growth.

Objectives of the Study

1. To identify the major forms of cybercrime affecting online commercial activities.
2. To examine the factors that increase the vulnerability of digital commerce to cyber threats.
3. To analyze the impact of cybercrime on businesses, consumers, and society.
4. To suggest measures for achieving a balance between digital innovation and security.

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Research Questions

The study addresses the following research questions:

1. What are the major cyber threats affecting digital commerce?
2. How does cybercrime impact businesses and consumers?
3. What cybersecurity measures are most effective in reducing cyber risks?
4. How can governments and businesses work together to create a secure digital economy?

Scope of the Study

The study focuses on the connection between cybercrime and digital commerce. It looks at several types of cyberthreats that affect company operations, how they affect customers and companies, and how cybersecurity plays a part in guaranteeing secure online transactions. The study is conceptual in nature and draws from secondary sources, including government papers, books, reports, and journal articles.

Understanding Cybercrime

Illegal actions carried out via computers, digital networks, or internet-connected devices are referred to as cybercrime. Cybercriminals take use of technological flaws to steal data, perpetrate fraud, interfere with services, and access systems without authorisation.

Cybercrimes, in contrast to traditional crimes, may be carried out remotely and can include people working in several different jurisdictions. Cybercrime is especially difficult to identify and prosecute because of the anonymity offered by the internet.

Businesses are becoming more appealing targets for cybercriminals because to the quick growth of digital commerce, which has boosted the availability of important data and financial resources online. As a result, businesses in the digital economy are more concerned about cybercrime.

Major Forms of Cybercrime Affecting Commerce

Cybercrime has increased in tandem with the quick expansion of internet business.

- **Online Payment Fraud**

  One of the most prevalent cybercrimes affecting digital business is online payment fraud. Cybercriminals carry out illegal transactions using malicious software, phoney payment gateways, and credit card information that has been stolen. Payment fraud is becoming more sophisticated as digital payments gain popularity.

- **Phishing Attacks**

  Phishing is the practice of tricking people into divulging private information, including passwords, bank account information, and personal identification numbers. Cybercriminals frequently produce phoney emails, messages, or websites that seem to be from reputable companies. Users may provide private information without thinking twice, which might result in identity theft and financial damages.

- **Identity Theft**

  When cybercriminals get personal information and use it to impersonate others, it is known as identity theft. Opening bank accounts, getting loans, making fraudulent purchases, and engaging in other illicit actions are all possible using stolen identities. Identity theft has become a major worry due to the growing amount of personal data maintained online.

- **Ransomware Attacks**

  Malicious malware known as ransomware encrypts an organization's data and demands payment to unlock it. Ransomware attacks have caused significant financial losses for several firms by interfering with operations and compromising critical data. Attacks of this nature have the potential to significantly impair corporate operations and have detrimental economic effects.

- **Data Breaches**

  Data breaches happen when private information kept in company databases is accessed by unauthorised parties. A breach may reveal financial data, trade secrets, customer details, and intellectual property. Legal ramifications, monetary fines, and a decline in consumer confidence are frequently the outcomes of data breaches.

- **Fake Online Stores and Scams**

  Fraudulent e-commerce websites that imitate authentic online retailers are often created by cybercriminals. Payments may be made by customers for goods that never show up. Such frauds erode trust in online shopping and harm legitimate companies' reputations.

- **Social Engineering Attacks**

  Instead of taking use of technology flaws, social engineering takes advantage of human psychology. Attackers coerce people into divulging private information or allowing illegal access to networks. Such assaults frequently succeed because of employee carelessness and ignorance.

Why Commerce Attracts Cybercriminals

Digital commerce has become a preferred target for cybercriminals due to several factors.

High Financial Value

Large sums of money are involved in online business transactions. Because successful assaults may yield large financial benefits, cybercriminals see digital payment systems as appealing targets.

Availability of Sensitive Data

Large volumes of consumer data, such as addresses, payment information, and personal identification numbers, are gathered and stored by businesses. In illicit marketplaces, such knowledge is highly valuable.

Weak Cybersecurity Awareness

Many people don't know enough about cybersecurity procedures. Vulnerability to cyberattacks is increased by weak passwords, irresponsible surfing practices, and an inability to spot phishing efforts.

Rapid Technological Growth

Innovation in technology frequently develops more quickly than security protocols. Businesses typically implement new technology without fully comprehending the security dangers involved.

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Global Connectivity

Cybercriminals can attack companies beyond national borders due to the interconnectedness of digital trade. Investigation and prosecution attempts are sometimes complicated by jurisdictional issues.

Impact of Cybercrime on Businesses and Society

Cybercrime has far-reaching consequences that extend beyond individual organizations.

- **Financial Losses**

  Fraud, theft, ransom payments, and recovery costs can result in direct financial losses for businesses. Cyberattacks may also result in legal fees and regulatory penalties.
- **Reputational Damage**

  The success of a firm depends on the trust of its customers. A serious cyber incident can seriously harm a company's brand and erode consumer trust.
- **Operational Disruptions**

  Cyberattacks frequently cause supply chain disruptions, system disabling, and service delivery delays that impact corporate operations. Profitability and production may suffer as a result of such interruptions.
- **Consumer Harm**

  Customers may experience identity theft, financial losses, and invasions of privacy. Recurring cyberattacks may deter people from embracing digital technologies.
- **Economic Consequences**

  Due to decreased production, higher security costs, and eroded investor trust, cybercrime has a significant negative impact on national economies.

Cybersecurity as a Strategic Necessity

Cybersecurity is no longer just a technical issue in the digital era; it is now a strategic business necessity. To safeguard their resources and stakeholders, organisations need to implement thorough security frameworks.

Multiple-Factor Verification

By asking users to confirm their identity using several ways, multi-factor authentication adds an extra degree of protection.

Cryptography

Sensitive data is protected by encryption, which transforms it into unintelligible formats that are only accessible by those who are authorised.

Safe Gateways for Payments

Companies want to employ reliable payment solutions that adhere to accepted security guidelines.

Employee Education and Awareness

One of the biggest causes of cybersecurity issues is still human mistake. Frequent training sessions assist staff in identifying risks and implementing safe procedures.

Continuous Monitoring

Networks and systems should be constantly monitored by organisations in order to spot questionable activity and quickly address any dangers.

Regular Security Audits

Regular security evaluations aid in finding weaknesses and enhancing overall security posture.

Government Initiatives and Regulatory Frameworks

Governments are essential in preventing cybercrime and encouraging safe online shopping. Cybersecurity laws that provide legal sanctions for cybercrime have been passed by several nations. Organisations must disclose security breaches and preserve consumer information in accordance with data protection legislation.

Strengthening cybersecurity capabilities in India is greatly aided by programs like the Indian Cyber Crime Coordination Centre (I4C), CERT-In, and the Digital India Programme. Digital literacy and cyber resilience are enhanced through capacity-building initiatives and public awareness campaigns.

Because cybercrime usually transcends national boundaries, international collaboration is also crucial. Cybersecurity programs are more successful when governments, law enforcement, and international organisations work together.

Future Challenges and Opportunities

Emerging technologies like blockchain, artificial intelligence, the Internet of Things (IoT), and digital currencies will influence digital commerce in the future.

Blockchain technology makes financial transactions more secure and transparent. IoT gadgets raise cybersecurity threats while also opening up new connection options. Innovative business concepts are introduced by digital currencies and decentralised finance platforms, but they also raise questions about fraud and governmental supervision.

Businesses need to implement flexible security plans that change as technology does. Future difficulties will require investments in public awareness, workforce development, and cybersecurity research.

Conclusion

One of the biggest issues facing the digital era is the connection between cybercrime and commerce. Digital commerce has increased the extent and sophistication of cyber dangers while simultaneously generating previously unheard-of potential for economic development, innovation, and global connectedness.

Businesses, consumers, and governments are all impacted by cybercrime because it erodes confidence, disrupts operations, and results in financial losses. Cybersecurity must become a crucial part of corporate strategy as companies continue to embrace digital transformation. Digital asset protection requires investments in cutting-edge security technology, staff education, regulatory compliance, and cooperative governance.

The digital economy's future hinges on striking a balance between security and creativity. To build a robust digital ecosystem that promotes sustainable economic growth while reducing cyber threats, businesses, governments, technology companies, and individuals must collaborate. Society can only fully reap the rewards of digital trade while protecting against the increasing threat

of cybercrime via shared responsibility and ongoing vigilance.

Acknowledgment

I would like to express my sincere gratitude to everyone who contributed to the successful completion of this review paper titled **"Commerce vs. Cybercrime: The Digital Tug of War in the Twenty-First Century."**

I am deeply thankful to my guide/supervisor for their invaluable guidance, continuous encouragement, and constructive suggestions throughout the preparation of this manuscript. Their expertise and support were instrumental in completing this work successfully.

I also extend my heartfelt appreciation to the faculty members and my institution for providing the necessary academic resources, encouragement, and a conducive environment for conducting this study.

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Conflicts of interest

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Original Article

A study of digital Payment Adoption and its impact on the frequency of conspicuous purchase

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Abstract:

The evolution of digital technology has brought rapid change in the way people pay for their purchases. Digital payment system -such as mobile wallet, Unified Payment Interface, debit and credit card and internet banking have emerged as convenient, secure and efficient alternative to traditional cash based method. This has brought immense change in how consumers conduct transactions. Even with the growth and expansion of ecommerce, efficient digital payment system has become great enabler of seamless ecommerce transaction. This research attempt to find the extent of digital payment method adopted by online shopper and analyse its influence on frequency of unimportant, conspicuous consumption made by buyers prompted by ease of making payment. The research collects primary data through structured questionnaire and makes secondary data collection from journal, reports, industry publication etc. The study highlights, a strong correlation between digital payment usage and online purchasing frequency. It also suggests that digital payment adoption not only facilitates transactions but also acts a s a catalyst for ecommerce growth. The availability of instant payment confirmation, easy refunds and transaction tracking enhances overall shopping experience, thereby encouraging customers to make purchase often.

Key words: *UPI; mobile wallet; digital payment; catalyst*

Introduction:

The global financial landscape has experienced a remarkable transformation over the past few decades, primarily driven by rapid advancements in information and communication technology. One of the most significant outcomes of this transformation is the emergence and widespread use of digital payment system. Digital payment refers to the financial transactions done electronically using digital devices such as smartphones, computers or payment terminals without direct involvement of physical currency. This entire system is backed by digital network, banking infrastructure, secure communication and payment protocol to transfer funds efficiently and safely.

Historically, economic transaction started with barter system followed by evolution of coins. Paper money came quite late and was used for sometime because of its simplicity and wide acceptance. The development of banking system led to the reduction in the reliance of physical currency and introduction of instruments such as cheques, demand drafts and bank transfer. These methods increased convenience but they were slow, paper intensive and needed manual verification process.

Introduction of digital technology changed the way people use financial transaction by enabling electronic payment methods. Over time digital payment system evolved into a sophisticated system which is capable of handling millions of transaction, having instant payment confirmation, automated record keeping and enhanced security features.

Parallel to technological advancement, consumer lifestyle has undergone significant changes. Modern consumer prioritises speed, convenience and accessibility in all aspect of their life including financial transaction. Digital payment platform has become versatile, facilitating online shopping, bill payment, online subscription, money transfer etc.

The expansion of e-commerce has made digital payment systems as the backbone of modern commerce. By providing a secure and efficient infrastructure for transactions, these systems enable online marketplaces to transcend geographical boundaries, allowing consumers to shop globally from home.

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Without this reliable framework, the rapid growth of the retail sector through online mode would not have been possible.

Beyond convenience, digital payments serve as a catalyst for financial inclusion in developing economies. Mobile-based platforms provide individuals previously excluded from traditional banking with access to the formal financial system, encouraging savings and reducing reliance on informal practices. Consequently, governments promote these technologies to enhance transparency, curb tax evasion, and strengthen national economic governance.

The present study investigates the relationship between digital payment adoption and online purchase frequency. It specifically explores whether the integration of electronic payment methods drives consumers to shop more often and identifies the primary factors influencing adoption. By analyzing user perceptions and behavioral patterns, this research aims to offer critical insights into how digital financial technologies are fundamentally reshaping modern consumer behavior and the broader economic landscape.

Literature review

The academic conversation surrounding digital payment adoption is a blend of behavioral psychology, economic policy, and technical infrastructure. A cornerstone of this field is Venkatesh's UTAUT model, which suggests that our willingness to use new tech depends on four things: how much it helps us (performance expectancy), how easy it is to use (effort expectancy), what our social circle thinks (social influence), and whether we have the right tools, like high-speed internet (facilitating conditions). This mirrors Davis's TAM, which focuses on utility and simplicity, and Rogers' Diffusion of Innovations, which explains why some people jump on new tech immediately while others wait.

From an economic lens, experts like Raghuram Rajan and Erik Brynjolfsson see these systems as "efficiency engines" that cut down on the hidden costs and hassles of moving money, naturally leading people to shop more often. Arvind Subramanian adds that moving away from cash helps "formalize" the economy; digital footprints create a paper trail that builds the trust necessary for a thriving online market.

Finally, researchers like Nachiket Mor and Ashok Jhunjhunwala remind us that technology is only revolutionary if it's accessible. They argue that true financial inclusion requires low-cost, simple tools that work on basic devices for everyday people. Essentially, when a payment system is reliable, easy to afford, and simple to understand, it stops being just a tool and becomes a gateway for everyone to participate in the global economy.

Philip Kotler emphasises that purchasing decisions are influenced by psychological, social and situational. He highlights convenience, trust and perceived value as major determinants of buying behaviour. His work supports the idea that payment convenience can directly influence purchasing frequency. Marc Prensky in his digital native theory discussed the concept that younger generations who grow up with technology are naturally comfortable using digital systems. Shoshana Zuboff in her study explores how digital payment platforms generate valuable transaction data that can be used for valuable recommendation, discounts and personalisation of services.

Research Methodology

The study focuses on understanding the adoption of digital payment methods and examine how this adoption influences their frequency of online purchases. The study investigates behavioural, technological and perceptual factors influencing adoption, including convenience, ease of use, accessibility, trust and security perception. The study also examine the relationship between two main variables: digital payment usage and online purchase frequency.in fact the study seek to determine whether individuals who use digital payment frequently engage in online shopping more often. This analysi will help to identify patterns, correlation and behavioural trends that illustrate how financial technology can affect consumer purchasing habit.

Objective of the study:

- To find adoption of digital payment among consumer and its impact on online purchase
- To find security perception of digital payment.
- To analyse influence of incentives on digital payment adoption

Significance of the study: This research looks at how adopting digital payments changes the way we shop online, offering a roadmap for researchers, business owners, and government officials. By connecting fintech with everyday human habits, the study shows how to improve online shopping experiences, bring more people into the banking system, and create smarter policies that boost economic growth and honesty in our increasingly digital world.

The study was done with a sample size of 101. A structured questionnaire with both open ended and close ended questions were formed and circulated among respondent from all age group, occupation and profession. Secondary data was obtained from Research journals, academic articles, books and online publication.

The study also employs Hypothesis testing as an analytical tool. The purpose of hypothesis testing is to determine whether observed relationship between variables are statistically meaningful or simply due to chance.

Data Analysis and Interpretation:

The study utilises descriptive statistics and relationship analysis to understand the impact on shopping frequency. Correlation Analysis was used to find the relationship between digital payment adoption and online purchase frequency. Impact and behavioural analysis were used to determine that digital payment facilitate frequency of purchase and also that purchase decision was driven by cashback and discount.

Hypothesis adopted for the study

Ho: ease of using digital payment does not impact online shopping frequency.

H1 ease of using digital payment does impact online shopping frequency.

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Ease of score	No change	Slight increase	Significant increase
2	100%	0%	0%
3	20%	50%	30%
4	20%	56%	24%
5	14%	21%	64%

Interpretation:

- Respondents giving rating of 5 on ease of payment reports maximum increase in shopping.
- Those giving rating of 2 on ease of using digital payment show no increase in shopping.
- This show strong positive trend between usability and purchase frequency.

Result:

Null hypothesis rejected

Alternative hypothesis accepted.

Analysis of the responses reveal that women lead the way at 60%, signalling a rise in financial independence and confidence of digital transaction. Usage of digital payment system, is heavily driven by young adults (90% aged 18–35), who naturally embrace mobile tools. While design feels inclusive, the low turnout from older generations points to lingering tech barriers for age group above 45. Distribution of the occupation of the respondent were found as follows: 8% students, 58% employees and 34% self employed.

The data from 101 respondents was analyzed using Descriptive Statistical Analysis, focusing on frequency distribution and central tendency to evaluate digital payment behavior.

The study shows a high level of engagement, with 70% of participants shopping at least monthly. A percentage Analysis of payment preferences shows that there is a shift towards mobile first solutions. 50% of the users prefer UPI over cards or net banking indicating convenience as the key motivator for fintech adoption. Most of the respondent (76%) feel secure and easy in using digital payment system as they have rated 4 to 5 in likert scale. 0% respondent reported feeling insecure while doing digital transaction. This lack of perceived risk clearly indicates surge in use of digital payment.

A correlation Analysis confirms that digital payment act as a catalyst for commerce where 80 % of the respondents increased their shopping frequency due to payment convenience. While 62% are motivated by incentives like cashback. 66% of respondent said that they will continue with online shopping even if convenience of digital payment is absent. It only indicates that ecommerce has become a habit although digital payment system act as a facilitator for online shopping.

Conclusion and Recommendation:

The study establishes that digital payment adoption has a significant and positive impact on online purchase frequency. It can be concluded that digital payment systems are widely accepted among young population particularly because of convenience, speed and security. The result shows that digital payment reduce transaction effort, increase purchase frequency and become integrated into daily habits.

Digital payment has evolved from simple transactional tools into powerful instruments shaping consumer behaviour and commercial activity.

The research further indicates that

Digital literacy is required for more wide digital payment adoption.

The interface needs to be simplified to encourage increased usage.

Incentives can be given to encourage usage.

To help wider usage of digital payment more cashless incentive policies need to be taken.

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Conflicts of interest

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Original Article

Tourism Potential of the Hiranyakeshi River Basin: A Geographical Analysis.

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Abstract:

The Hiranyakeshi River Basin, located in the northern Western Ghats and extending across parts of Maharashtra and Karnataka, possesses significant tourism potential due to its unique combination of natural landscapes, biodiversity, cultural heritage, religious sites, and geomorphological features. This study examines the tourism resources of the basin from a geographical perspective and evaluates opportunities for sustainable tourism development. The study integrates physical, cultural, and socio-economic aspects of tourism while drawing upon morphometric and geomorphological findings from previous research conducted by Mavarakar and Chalawadi. The dendritic drainage pattern, rugged relief, waterfalls, caves, and forested landscapes provide a strong foundation for eco-tourism, adventure tourism, educational tourism, and religious tourism. The study concludes that sustainable planning and community participation can transform the Hiranyakeshi Basin into a prominent tourism destination while conserving its environmental resources.

Keywords: *Hiranyakeshi River Basin, Tourism Potential, Eco-tourism, Sustainable Tourism, Geomorphology, GIS, Western Ghats, Geography.*

Introduction:

Tourism has emerged as one of the fastest-growing sectors of the global economy and plays a significant role in regional development. River basins often serve as focal points for tourism because of their scenic landscapes, ecological diversity, cultural significance, and recreational opportunities. The Hiranyakeshi River Basin is one such geographical region possessing immense tourism potential.

The Hiranyakeshi River originates near Amboli in the Sahyadri (Western Ghats) region and flows through varied topographic and ecological zones before joining the Ghataprabha River. The basin contains waterfalls, caves, dense forests, sacred sites, and unique geomorphological features. Previous morphometric studies by Mavarakar and Chalawadi revealed that the basin exhibits a dendritic drainage pattern, high relief, steep slopes, and youthful to mature geomorphic characteristics. These physical features contribute significantly to landscape attractiveness and tourism development.

Review of Literature

Morphometric analysis provides valuable insights into basin characteristics, drainage evolution, hydrological behavior, and landscape development. Mavarakar and Chalawadi conducted detailed GIS-based morphometric studies of the Hiranyakeshi Basin using SRTM DEM data and identified significant geomorphological features influencing watershed development and environmental management. Their findings indicated high relief, steep slopes, dendritic drainage patterns, and varied geomorphic conditions.

Panhalkar (2012) emphasized the importance of GIS-based watershed analysis in understanding the Hiranyakeshi Basin and highlighted the potential of its natural resources for sustainable regional development.

Objectives

- To identify major tourism resources within the Hiranyakeshi River Basin.
- To examine the influence of geomorphological characteristics on tourism development.
- To assess the potential for eco-tourism, religious tourism, adventure tourism, and educational tourism.
- To suggest strategies for sustainable tourism development.

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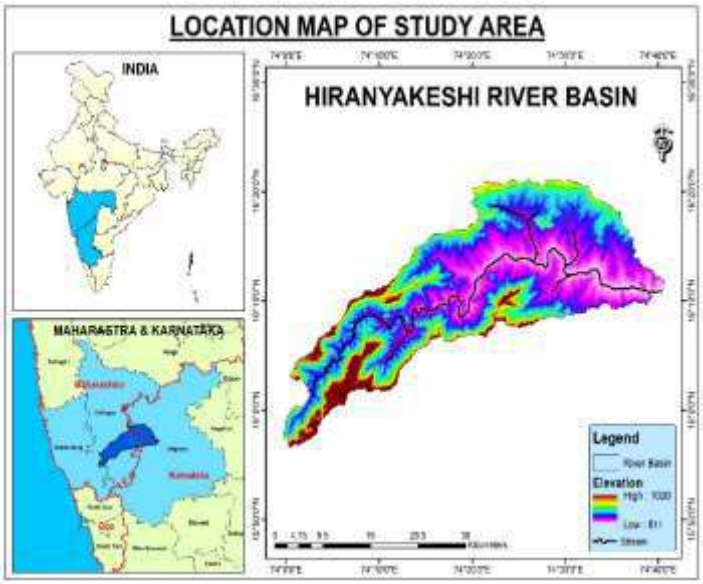
Study Area



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The Hiranyakeshi River Basin is situated in the northern Western Ghats region. The basin extends through parts of Maharashtra and Karnataka and encompasses diverse topographical features including hills, valleys, waterfalls, caves, forest ecosystems, and agricultural landscapes. The basin's physiography is characterized by:

- Rugged terrain.
- High relief and steep slopes.
- Dense drainage network.
- Tropical monsoon climate.
- Rich biodiversity.

Morphometric studies have shown that the basin possesses well-developed drainage characteristics suitable for hydrological and environmental studies.

Methodology - The study is based on:

- Secondary data from published research articles.
- GIS and Remote Sensing-based morphometric studies conducted by Mavarakar and Chalawadi.
- Review of tourism resources and geographical features.
- Analysis of physical and cultural tourism attractions.

The morphometric parameters such as drainage density, stream order, bifurcation ratio, relief ratio, circularity ratio, and elongation ratio were considered to understand landscape characteristics relevant to tourism development.

Tourism Resources of the Hiranyakeshi River Basin:

1 Geomorphological Attractions -The geomorphological diversity of the basin creates spectacular landscapes that attract tourists, researchers, and photographers. Important features include:

River valleys. , Waterfalls., Gorges., Caves., Escarpments., Hill slopes.

The high relief and rugged terrain identified through morphometric analysis contribute significantly to scenic beauty and adventure tourism opportunities.

2 Waterfall Tourism- Several waterfalls occur within the basin, especially during the monsoon season. These waterfalls provide opportunities for:

Nature tourism., Photography., Recreational activities., Educational excursions.

3 Religious Tourism- The Hiranyakeshwar Temple at the river's source is an important pilgrimage center. The temple attracts devotees and tourists throughout the year. Religious tourism contributes significantly to local economic development through transportation, hospitality, and small-scale businesses.

4 Biodiversity and Eco-tourism- The basin lies within the Western Ghats biodiversity hotspot. The region supports:

Evergreen forests., Rare plant species., Endemic fish species., Wildlife habitats., Bird diversity.

The ecological richness provides excellent opportunities for eco-tourism and environmental education.

5 Educational Tourism- The basin serves as a natural laboratory for students and researchers studying:

Geomorphology., Hydrology., Watershed management., Biodiversity., GIS and Remote Sensing.

The morphometric studies conducted by Mavarakar and Chalawadi provide valuable academic resources for educational tourism.

6 Rural Tourism- Traditional villages along the basin preserve unique cultural practices, agricultural systems, and local cuisine. Potential rural tourism activities include:

Farm tourism., Village homestays., Cultural festivals., Traditional food experiences.

7 Major Tourist Attractions in the Hiranyakeshi River Basin :

1. Hiranyakeshwar Temple and River Origin - The sacred source of the Hiranyakeshi River is located at the ancient Hiranyakeshwar Temple. Water emerges from a cave beneath the temple, forming the origin of the river. The site is a major pilgrimage center and attracts devotees, tourists, and researchers interested in hydrology and geomorphology.

2. Amboli Hill Station- Amboli is one of the most scenic hill stations in the northern Western Ghats. It is famous for its mist-covered valleys, dense forests, viewpoints, and monsoon tourism. The cool climate and rich biodiversity make it an important eco-tourism destination.

3. Amboli Waterfall- This spectacular seasonal waterfall attracts thousands of visitors during the monsoon season. The waterfall provides opportunities for photography, nature appreciation, and recreation.

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4. Mahadevgad Fort - Situated near the Hiranyakeshi Basin, Mahadevgad Fort offers panoramic views of the surrounding valleys and forests. The fort has historical significance and potential for heritage tourism.
5. Nangartas Waterfall - Nangartas is a beautiful waterfall formed within a deep gorge. The waterfall and surrounding landscape provide excellent opportunities for adventure tourism and ecological studies.
6. Sunset Point- Sunset Point is among the most visited tourist locations in the region. Visitors can observe panoramic views of the Western Ghats and the Konkan lowlands.
7. Kavalesad Point- This viewpoint is famous for cloud-covered valleys, waterfalls, and scenic landscapes. It is particularly popular during the monsoon season.
8. Ramteerth Waterfall- Located downstream along the Hiranyakeshi River, Ramteerth Waterfall is both a natural and religious attraction. The waterfall demonstrates active fluvial erosion and river incision, making it important for educational tourism.
9. Ramtirth Temple- The temple complex near Ramteerth attracts pilgrims and cultural tourists. The site is associated with local legends and religious traditions.
10. Dajipur Wildlife Sanctuary- Located close to the basin, this sanctuary is known for biodiversity conservation, wildlife observation, and eco-tourism activities. It supports species such as Indian bison (Gaur), deer, and numerous bird species.
11. Amboli Forest Reserve- The dense evergreen forests surrounding the basin contain rich floral and faunal diversity. These forests support trekking, birdwatching, biodiversity studies, and environmental education.
12. Rural and Cultural Tourism Villages- Villages such as Ajra, Uttur, and Chandgad preserve traditional agricultural systems, folk culture, handicrafts, and local cuisine. These settlements have potential for community-based and rural tourism initiatives.

Research Significance

The morphometric characteristics identified by Mavarakar and Chalawadi—high relief, steep slopes, dense drainage networks, and youthful geomorphic features—have directly contributed to the formation of these tourist attractions. Waterfalls, viewpoints, river valleys, caves, and forest landscapes are products of the basin's geomorphological evolution, making tourism development closely linked to the physical geography of the Hiranyakeshi River Basin.

Relationship Between Morphometry and Tourism.

The morphometric characteristics identified by Mavarakar and Chalawadi have direct implications for tourism development.

SL No.	Morphometric Feature	Tourism Significance
1	High Relief	Scenic viewpoints and trekking
2	Dendritic Drainage	Attractive river landscapes
3	Steep Slopes	Adventure tourism
4	River Valleys	Nature tourism
5	Dense Drainage Network	Waterfall formation
6	Diverse Terrain	Educational tourism

The basin's geomorphological diversity provides a strong foundation for sustainable tourism planning.

SWOT Analysis :

Strengths	Weaknesses	Opportunities	Threats
Rich natural beauty. Western Ghats biodiversity. Religious significance. Waterfalls and caves. Favorable climate.	Limited tourism infrastructure. Poor promotion. Seasonal accessibility issues.	Eco-tourism development. Adventure tourism. Community-based tourism. Educational tourism circuits.	Environmental degradation. Deforestation. Pollution. Climate change impacts.

Recommendations.:

- Develop eco-friendly tourism infrastructure.
- Promote community-based tourism models.
- Establish interpretation centers for tourists.
- Prepare GIS-based tourism resource maps.
- Improve transportation and accessibility.
- Encourage academic field visits and research tourism.
- Implement strict environmental conservation measures.

Develop integrated tourism circuits linking Amboli, Hiranyakeshwar Temple, waterfalls, and rural villages.

Conclusion:

The Hiranyakeshi River Basin possesses exceptional tourism potential due to its unique combination of geomorphological, ecological, cultural, and religious resources. The morphometric studies conducted by Dr. Prashant Mavarakar and Dr. M. B. Chalawadi provide scientific evidence regarding the basin's landscape characteristics, which support the development of eco-tourism, adventure tourism, educational tourism, and religious tourism. Sustainable planning, environmental conservation, and community participation are essential for realizing the basin's tourism potential while preserving its natural heritage for future generations.

Acknowledgment

I would like to express my sincere gratitude to everyone who contributed to the successful completion of this research paper titled **"Tourism Potential of the Hiranyakeshi River Basin: A Geographical Analysis."**

I am deeply grateful to my guide/supervisor for their invaluable guidance, continuous encouragement, and constructive suggestions throughout every stage of this study. Their expertise and support were instrumental in the successful completion of this research.

I also extend my heartfelt appreciation to the faculty members and my institution for providing the necessary

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I gratefully acknowledge the contributions of researchers, geographers, tourism experts, government agencies, and organizations whose books, research articles, reports, maps, and official publications on geography, tourism, environmental conservation, and regional development formed the foundation of this study.

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Original Article

The Digital Script: Representation of Male Vulnerability In 21st Century Indian Fiction

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Abstract

This research paper explores the changing image of men in 21st-century Indian English literature. For decades, the Indian male hero was portrayed as a "strong patriarch" who suppressed his emotions. However, with the arrival of the digital age, Artificial Intelligence (AI), and changing gender roles, a new theme has emerged: "Male Vulnerability." This study analyzes how modern writers depict the internal struggles of men—such as loneliness, job insecurity, and emotional crisis. By using theories like "Hegemonic Masculinity" and the "Affective Turn," this paper argues that showing male fragility is essential for creating a fair and empathetic society.

Introduction

The traditional image of the Indian man has been defined by strength, authority, and emotional silence. In literature and cinema, the "Angry Young Man" or the "Ideal Provider" became the standard. These characters were expected to carry the burden of the family without showing any sign of weakness. This expectation created a rigid social structure where men were not allowed to cry or fail.

However, the 21st century has brought rapid changes. India is no longer just an agrarian society; it is a global digital hub. The rise of the internet, social media, and Artificial Intelligence has disrupted traditional job markets and family structures. As a result, the "Modern Indian Man" is facing a deep identity crisis. He is caught between the old rules of his father's generation and the new, fast-paced reality of the digital world.

This research paper aims to study how contemporary Indian writers like Aravind Adiga, Shashi Tharoor, and others are documenting this shift. We focus on "Male Vulnerability"—the state of being exposed to the possibility of being attacked or harmed, either physically or emotionally. In these stories, the hero is no longer a "Superman"; he is a human being with fears and flaws.

Literature Review: Understanding the "Strong Man"

To understand why male vulnerability is a new theme, we must look at what came before it. R.W. Connell, a famous scholar, introduced the concept of **"Hegemonic Masculinity."** This theory explains how society promotes a certain version of manliness that dominates all other identities.

"Hegemonic masculinity is not a fixed character type... it is the masculinity that occupies the position of power in a given social setting." — R.W. Connell, Masculinities (2005).

In the Indian context, Radhika Chopra has studied how masculinity is performed within the family. Men are often taught that their only value is their "labor" and their ability to earn money. If they fail to earn, they fail as men. This creates a "fragile" ego because the man's entire identity depends on external success.

Earlier literature often ignored the "Affective" (emotional) side of men. But 21st-century fiction has taken what scholars call the **"Affective Turn."** This means stories are now moving away from external battles to internal, emotional landscapes. Authors are now writing about the "body in pain" and the "mind in doubt."

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Theoretical Framework

This paper uses three specific frameworks to analyze 21st-century fiction:

Concept	Definition	Application in this Paper
Crisis of Masculinity	The feeling of being "lost" when old roles no longer work.	Analyzing men who lose jobs to AI or automation.
Affective Turn	A focus on feelings, trauma, and sensations.	Looking at how male grief is described in literature.
Intersectionality	The overlap of gender, caste, and class.	Studying how poor men suffer differently than rich men.

The Digital Script: AI and Professional Obsolescence

One of the most significant causes of male vulnerability today is the fear of being replaced by machines. In your notes, this is referred to as the "threat of professional obsolescence." For a man who has been told his whole life that he is a "provider," the rise of Artificial Intelligence is terrifying.

When a computer can do a man's job better and faster, the man feels "de-masculinized." He feels like a "Digital Subaltern"—someone who is at the bottom of the social ladder because he cannot keep up with technology. This leads to a sense of uselessness and deep psychological stress.

Fiction today portrays characters who are struggling with this "Digital Script." They are trying to find meaning in a world where their physical strength or traditional skills are no longer needed. This vulnerability is not just about money; it is about the loss of a "purpose."

1 The Psychological Fracture

As noted in our research, this leads to a "psychological fracture." The man is physically present but emotionally broken. He may become silent, or he may turn to "toxic" behaviors to hide his fear. Authors are using these stories to show that we need a new way to define manliness—one that is not tied to a paycheck or a machine.

Analysis of Contemporary Texts

To prove these points, we look at several modern Indian novels. For example, in **Aravind Adiga's *The White Tiger***, the protagonist Balram Halwai is a man trying to escape "The Rooster Coop." While he is often seen as a criminal or a climber, he is also deeply vulnerable. His fear of being trapped forever in poverty and his desperation to be "someone" shows the extreme pressure men face in modern India.

In the works of authors like **Shashi Tharoor** and others, we see the "Grief of the Father" or the "Fear of the Son." These stories highlight that the family house is not always a place of strength; it is often a place of hidden trauma.

"The 21st-century novel humanizes the male experience by exposing the hero's fragility... it breaks the myth of the unbreakable man." — Academic Observation.

The "Affective Turn" in these books allows us to see the male body as a site of feeling. We see men who are tired, men who are lonely, and men who are seeking connection rather than power. This shift in storytelling is essential because it allows male readers to see themselves as they truly are, rather than how society wants them to be.

Toward Gender Justice: Why Vulnerability Matters

Many people think that talking about male problems takes away from the feminist movement. However, this paper argues the opposite. When we understand how patriarchy hurts men, we can better understand how to dismantle it.

"Male Vulnerability" is a vital tool for gender justice. If a man is allowed to be vulnerable, he is less likely to use violence to prove his strength. If a man is allowed to express grief, he is less likely to suppress others. By acknowledging male fragility, we create an "empathetic social fabric" where everyone—regardless of gender—can live authentically.

Conclusion

The 21st-century Indian fiction has successfully rewritten the "Digital Script" for men. It has moved beyond the simple image of the "Oppressor" to show the "Human." The themes of technological fear, emotional isolation, and the breakdown of traditional systems are not just literary trends; they are reflections of our real society.

As we move further into the age of AI, these stories will become even more important. They remind us that behind every "user," every "provider," and every "employee," there is a human heart that needs care and understanding. This seminar concludes that "Vulnerability is the new Resilience."

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I would like to express my sincere gratitude to everyone who supported and guided me throughout the completion of this research project titled *The Digital Script: Representation of Male Vulnerability in 21st Century Indian Fiction.*

First and foremost, I extend my heartfelt thanks to my supervisor for their invaluable guidance, insightful suggestions, constructive criticism, and constant encouragement throughout the research process. Their expertise and patience greatly contributed to the successful completion of this study.

I am deeply grateful to the faculty members of my department for providing the academic environment and resources necessary for carrying out this research. Their

support and inspiration have been instrumental in broadening my understanding of literary studies.
I would also like to thank the authors and scholars whose works have formed the foundation of this research. Their critical perspectives and contributions to the study of contemporary Indian fiction have been an invaluable source of knowledge and inspiration.
My sincere appreciation goes to my family and friends for their unwavering love, encouragement, and understanding. Their constant support motivated me to persevere during every stage of this project.

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Original Article

Enhancing Quality of Education through role ICT in Classrooms

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Abstract: -

Education plays an important role in the development of a country. As nearly 68.74 of Indian population lives in Rural area. It is important to educate this rural population as education equips human beings with knowledge and skills which enables him to live hood. Government of India has recognizes this shortcoming and to improve the teaching learning process it has decided to use ICT in rural schools. The main purpose of this article is to discuss different manner of using ICT in teaching learning Process and to contemplate the advantages and Disadvantages of using ICT in rural Classrooms.

Introduction

We all live in a society were knowledge is considered as a great power and through human beings it is a also considered as a great asset of a nation Mankind has entered the information age from the industrial age.this change profound effect on our lifestyle economy and culture even the education sector is being influenced by it. Knowledge is accumulative and it is a real challenge for teachers to impart the required knowledge in a stipulated time.

National Policy of Education (1986) was the first to recognize the need of employing ICT to improve the quality Education In 2005 National Framework also highlighted the importance of Ict Schools. Use of ICT Figures In Government of India's flagship programmes on education like Sarva shiksha abhiyan and Rastriya Madhyamike Shiksha Abhiyan The Information and Communication ICT Schools was launched in December 2004 and revised in 2010.There was also a provision for the training for all teachers teaching in secondary and Higher Secondary schools to enable them to impart education using ICT.

Definition of ICT :-

British Computer Society has defined ICT in very comprehensive manner. It says that, "ICT is the Scientific , technological and engineering disciplines and the management techniques used in information handling processing and disseminating their applications computers networking and communication and their integration with men and machines and associated social economic and Cultural matter".

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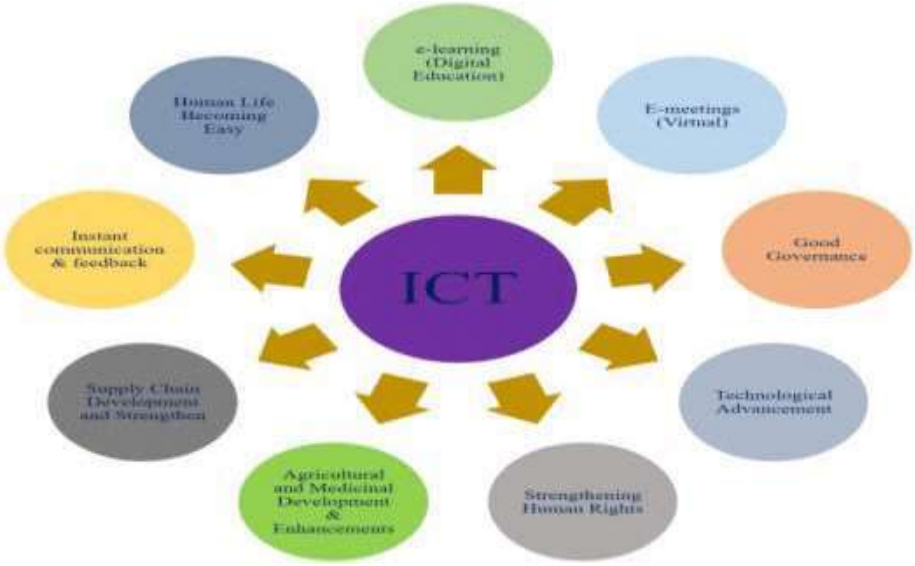
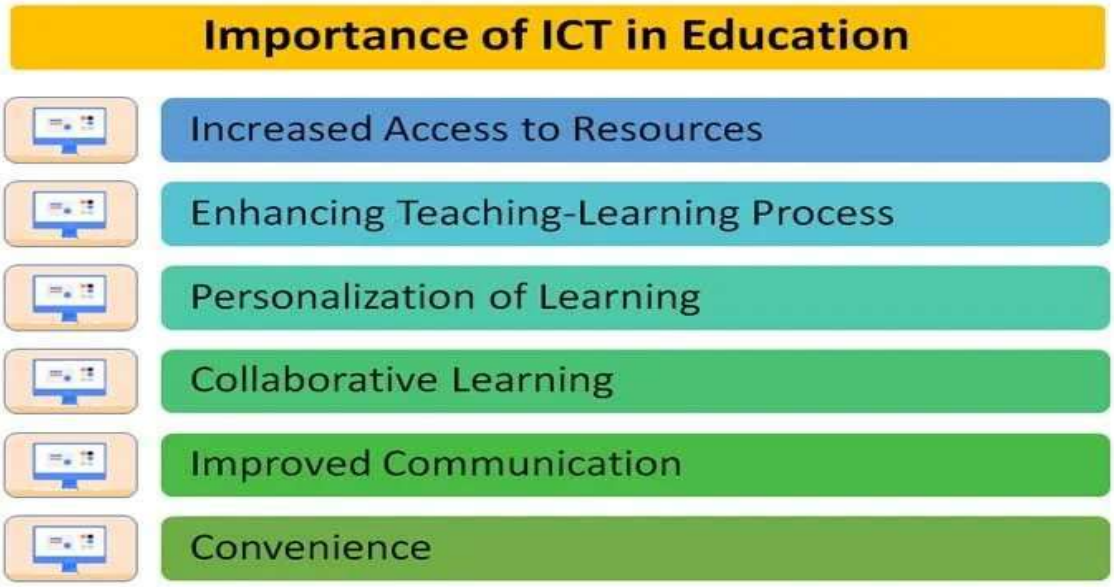
ICT IN Education:-



Objectives of ICT In Education: -

1. Improve quality of teaching and learning
2. Make learning more interactive and Interesting
3. Provide access to knowledge resources
4. Developing Digital Skills in Students
5. Support Distance and online learning

Importance of ICT in Education



Use of ICT in Rural School classrooms: -

1. Language: -

Teacher can while teaching Shakespeare make her lesson interesting by showing the lifestyle of people of England during the 15th century film clips can be shown to the children to enhance their interest. Teaching the language could mane interesting by Power Point presentation which can enhance the language skills of the students

2 Social Science:

It consists of disciplines like history, political science, geography, economics sociology etc. ,While teaching Similarly about ancient art and architecture of India. History teacher Can be lesson interesting by showing the video clippings of the examples, monuments forts and other important buildings of the ancient period. This will involve the curiosity of the students and will lead to their involvement in teaching learning process.

3 Mathematics: -

ICT based tools provide pupils with an advanced communication capability, allowing them to use graphics, images and text together to demonstrate their understanding of mathematical concepts.

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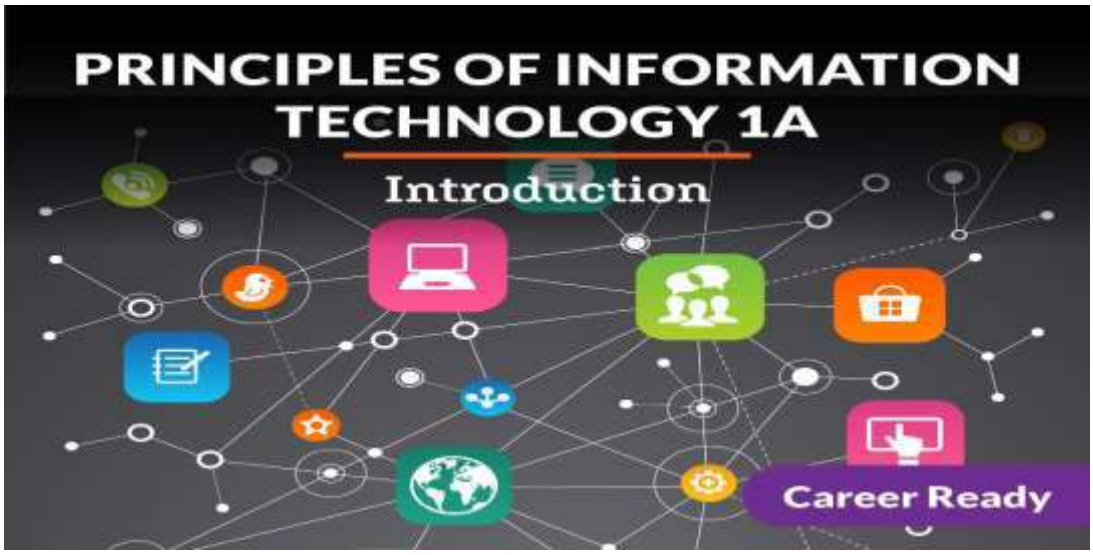
Principles of Using ICT In Teaching- Learning process: -



1. Principle of simulating self-activity.
2. Principle of Creating interest and involvement
3. Principle of continuity of thought
4. Principle of teaching efficiency
5. Principle of useful variety
6. Principle of Enhancing quality of learning

Use OF ICT In Classrooms Teaching

1. ICT Motivates Students
2 ICT Improves students' Writing and Learning Skills
3 ICT makes subjects easy to learn
4. Promotes Indivial Learning
5.Increases Collaboration between teachers and Students.
6. prepares students for Tomorrow Technological jobs
7. Increases students Innovation and Creativity.

Conclusion: -

Due to the continuous efforts of the Government, there is great improvement In the infrastructure of the rural schools.it has been notices that through govt has provided ict facilities to rural school but it has not been utilized properly after the initial interest.

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I would like to express my sincere gratitude to my project guide, **[Guide's Name]**, for their invaluable guidance, continuous encouragement, and constructive suggestions throughout the completion of this project entitled **"Enhancing Quality of Education through the Role of ICT in Classrooms."** Their support and expertise have been a constant source of motivation.

I am thankful to the **Head of the Department of [Department Name]** and the faculty members of **[College/University Name]** for providing the necessary academic guidance, facilities, and resources required for this study.

I also extend my heartfelt thanks to the library staff and technical staff for their assistance in providing access to books, journals, online resources, and other reference materials that greatly supported this project.

My sincere appreciation goes to my parents, family members, and friends for their constant encouragement, patience, and moral support throughout the preparation of this project.

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Secure and Scalable Educational Data Management Using Amazon S3 Bucket in Cloud Computing

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Abstract

The use of digital technology in education has increased a lot in recent years, leading to a large amount of data being generated by schools and colleges. Managing this data using traditional systems is difficult because they are expensive, not easily scalable, and sometimes hard to access. Cloud computing provides a better solution by offering flexible and cost-effective data storage and management. This paper studies how cloud computing can improve educational data management, with a focus on Amazon Web Services S3 (Simple Storage Service). It explains how S3 helps store and manage large amounts of data easily and allows users to access data anytime and from anywhere. The study also highlights benefits such as better efficiency, improved data security, and easier sharing of information.

The study examines how Amazon S3 enables efficient storage, retrieval, and management of large-scale educational datasets through its object storage architecture. It highlights key benefits such as enhanced data accessibility across multiple platforms, improved operational efficiency through automation, and robust security features including encryption, access control, and data durability. Additionally, the paper evaluates the role of S3 in supporting data-driven decision- making within educational institutions by ensuring reliable and real-time access to academic and administrative data. However, the research also addresses critical challenges associated with cloud adoption, including data privacy concerns, dependence on third-party service providers, potential latency issues, and the need for technical expertise in cloud infrastructure management. Through this case study, the paper provides a balanced analysis of both the advantages and limitations of implementing cloud- based storage solutions in the educational domain.

The findings suggest that adopting cloud computing technologies, particularly Amazon S3, can significantly enhance the efficiency, scalability, and modernization of educational data management systems. This transition not only supports institutional growth but also fosters a more agile and data-centric academic environment, enabling better learning outcomes and administrative effectiveness.

Keywords: *Cloud Computing, Educational Data, Amazon S3, Data Storage, AWS*

Introduction:

Cloud computing is a technology that allows people to store data and use software over the internet instead of using their own computer or local storage. It can save your files and run applications online without worrying about physical devices like hard drives or servers. Earlier, schools and organizations had to buy and maintain their own computers and servers to store data. This was expensive and difficult to manage. With cloud computing, all these services are provided online by companies like Amazon Web Services, so users can access them whenever they need. One of the biggest advantages of cloud computing is that it is flexible. You can use more storage or less storage depending on your needs. It is also cost-effective because you only pay for what you use. Another important benefit is accessibility. Students and teachers can access their data anytime and from anywhere using the internet.

Cloud computing also keeps data safe by using security methods like passwords, encryption, and backups. This helps protect important information from loss or misuse. In short, cloud computing makes data storage and management easy, fast, and affordable, especially for educational institutions.

There are three main types of cloud computing services:

1. Infrastructure as a Service (IaaS)

This service provides basic computing resources like virtual machines, storage, and networks. Instead of buying physicalhardware, users can rent these resources online.

Example: Storage services like Amazon S3 from Amazon Web Services.

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2. Platform as a Service (PaaS)
This service provides a platform where developers can build, test, and deploy applications
without worrying about hardware or system setup.
Example: Platforms for app development like Google App Engine.
3. Software as a Service (SaaS)
This service provides software applications over the internet. Users can access these applications
using a browser without installing anything.
Example: Google Docs, Gmail, Microsoft 365.

S3 Bucket:

An S3 bucket is a storage system used in cloud computing to store data online. It is a part of Amazon Web Services and is called Amazon S3 (Simple Storage Service). An S3 bucket is like a folder in the cloud where you can store files such as documents, images, videos, and backups. Each bucket can contain many files, which are called objects. Every object has data, a name, and some information about it (called metadata). Users can create multiple buckets and organize their data easily.

One of the main advantages of an S3 bucket is that it can store a very large amount of datawithout any problem. It is also highly reliable and secure, meaning your data is safe and protected. You can control who can access your data by setting permissions. Another important feature is easy access. You can upload, download, and manage your files from anywhere using the internet. This
makes it very useful for educational institutions where students and teachers need to access data anytime. S3 buckets also support features like data backup, version control, and encryption, which help in protecting and managing data efficiently. An Amazon S3 bucket is a simple, secure, and scalable way to store and manage data in the cloud.

Objectives of the Study:

1. To study the concept of cloud computing and its role in modern education systems.
2. To understand how Amazon S3 bucket is used for storing and managing educational data.
3.
To analyze the benefits of using cloud storage, such as scalability, accessibility, and cost efficiency.
4. To evaluate how cloud computing improves data security and reliability in educational
institutions.
5. To identify the challenges and risks associated with cloud-based data management, such as privacy and dependency on service providers.

Literature Review:

Several studies highlight the importance of cloud storage, particularly Amazon S3, in managing large-scale data. Research shows that S3 provides high scalability, durability, and cost-effective storage, making it suitable for data-intensive applications such as education systems. Early research by Palankar et al. (2008) analyzed S3's performance and demonstrated its feasibility for large-scale scientific and collaborative data environments, emphasizing cost efficiency and availability.

Recent studies focus on security aspects. Research indicates that although S3 offers strong features like encryption and access control, misconfigurations and poor access policies can lead to data breaches and unauthorized access. Other literature also highlights privacy concerns in cloud storage, noting that storing data remotely introduces risks related to data confidentiality and compliance. Overall, the literature confirms that S3 is a powerful storage solution, but its effectiveness depends on proper configuration and security practices.

Real World Applications:

Amazon S3 is widely used in real-world educational and data-driven environments:
Educational Institutions
Universities store student records, lecture videos, assignments, and research data securely in S3.
E-learning Platforms
Platforms like online learning systems use S3 to store multimedia content such as recorded lectures and PDFs.
Big Data Analytics
S3 is used as a data lake, enabling institutions to analyze large datasets using AI and machine learning tools.
Backup and Disaster Recovery
Institutions use S3 for automatic backups, ensuring data recovery in case of system failure.
Research Collaboration
Large-scale scientific projects use S3 to share datasets across global teams efficiently.

Challenges and Limitations:

1. Security Misconfiguration
Incorrect bucket permissions can expose sensitive data to the public.
2. Data Privacy Concerns
Storing data on remote servers raises concerns about compliance and confidentiality.
3. Cost Management Issues
Although cost-effective, improper usage (e.g., storing unused data) can increase expenses.
4. Performance Variability
Network latency may affect performance in some cases.
5. Learning Curve
Beginners may find it difficult to configure IA Mpolicies and security settings correctly.

Future Scope:

1. Integration with AI & Machine Learning
S3 will play a key role in analyzing educational data for personalized learning.
2. Improved Security Mechanisms
Advanced encryption and automated threat detection will reduce risks.
3. Smart Data Management
Automated lifecycle policies and intelligent tiering will optimize cost and storage.
4. Multi-Cloud and Hybrid Systems
Institutions may combine S3 with other cloud services for better flexibility.
5. Edge Computing Integration
Faster data access for remote and rural education systems.

Conclusion:

Amazon S3 provides a secure, scalable, and efficient solution for educational data management. It enables institutions to handle large volumes of data with high reliability and flexibility. However, proper configuration and security practices are essentialto avoid risks. With continuous advancements in cloud technology, S3 is expected to play a crucial role in the future of digital education systems.

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I would like to express my sincere gratitude to my project

guide, **[Guide's Name]**, for their invaluable guidance, constant encouragement, and expert suggestions throughout the completion of this project entitled **"Secure and Scalable Educational Data Management Using Amazon S3 Bucket in Cloud Computing."** Their support and motivation played a vital role in the successful completion of this work.

I am also thankful to the **Head of the Department of [Department Name]** and the faculty members of **[College/University Name]** for providing the necessary facilities, academic support, and encouragement throughout the project.

I extend my heartfelt thanks to the laboratory staff, technical staff, and library staff for their assistance in providing the required resources, technical support, and reference materials that greatly contributed to this study.

I would like to express my sincere appreciation to my parents, family members, and friends for their constant encouragement, patience, and unwavering moral support throughout this academic endeavor.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

A Robust Method for Pdf Watermark Extraction

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Abstract

Online digital content authentication and copyright protection are critical issues in modern document management. Digital watermarking offers a comprehensive solution for protecting online documents, particularly text, which remains the most common form of internet communication. This paper proposes a methodology for the extraction of watermark text from PDF documents using a Max-Min clustering algorithm. The approach focuses on increasing the semantic gap between watermark text pixels and background content. A thresholding system and post-processing heuristic techniques are employed to isolate the actual watermark region. Experimental results demonstrate that the proposed model is promising, achieving an F-measure of 86.48% and outperforming several traditional edge-based detection methods.

Keywords—*Max-min approach, digital water mark, text detection, sliding window, thresholding, PDF forensics.*

Introduction

The rapid advancement of internet technology has facilitated the seamless transport of vast amounts of information. However, for content creators and intellectual property owners, this ease of distribution leads to the illegal interception and unauthorized copying of verified text documents. Such activities result in considerable financial losses and the erosion of digital trust. Consequently, it has become necessary to develop well-secured watermarking approaches to protect text documents from these crimes.

While significant research has been dedicated to text watermarking, specifically in plain text and images, the unique environment of PDF documents has often been overlooked. PDF is designed primarily for visual fidelity and does not inherently retain structural information. It merely defines where each character is located on a 2D plane. As a result, information extraction from a PDF can be noisy, and characters may not be recovered in the proper logical order. Furthermore, a watermark embedded in a PDF is treated as an additional object that can obstruct the sequence of information extraction.

This research proposes an automated strategy to extract watermark content in bulk. This is beneficial for managing massive collections of scientific documents, where metadata such as title, authors, and journal must be extracted for digital libraries. By automatically isolating the watermark, we can improve the accuracy of text mining tasks and machine learning algorithms that require "clean" content for training. Our method utilizes a Max-Min clustering criterion to address the varying contrast values of watermark pixels compared to the primary document text.

Literature Survey

The current body of work in digital watermarking is predominantly focused on the embedding phase how to hide information securely within a host medium. Extraction, particularly from text-heavy PDF documents, remains a relatively under-explored area.

A. Traditional and Quasi-Blind Methods

Early work by Fahmy (4) introduced quasi-blind watermark extraction, which requires only minimal information about the original host image to recover the watermarking logo. While effective for simple images, this method often struggles with the complex layering found in multi page PDF documents. Similarly, Yu et al. (8) employed Independent Component Analysis (ICA) to isolate watermark components. This requires at least three linear mixtures, the key image, the original image, and the mixed image which is often impractical in forensic scenarios where the original host is unavailable.

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B. Learning-Based and Neural Approaches

Recent shifts in the field have moved toward deep learning. Kim et al. (3) introduced a learning-based strategy for CNN-based watermark extraction. They utilize a template generation network to evaluate the rotation, scale, and translation (RST) parameters of geometrically warped images. While highly accurate, these models require significant computational resources and large datasets for training. In 2022, Barlaskar et al. proposed a genetic algorithm-based optimized watermarking technique using a hybrid DCNN-SVR model, representing the current state-of-the
art in optimized extraction.

C. Topological and Feature-Based Methods

Other researchers have focused on the physical features of the text. Amano and Misaki modified stroke features like width or serifs to mark documents. Shivakumara et al. (6) applied Laplacian filters and K-mean classifiers to locate text candidates in videos, though this approach performs poorly at the word level for static documents. Basavaraju et al. (2) developed a level-set algorithm combined with a Gaussian mixture model to identify text regions, which provides better segmentation for multilingual content. Our proposed Max-Min approach seeks to bridge the gap between these high-complexity neural models and simple edge detectors by using a robust clustering criterion.

Proposed Methodology

The core of our methodology lies in the observation that watermark text pixels typically possess contrast values distinct from background pixels. We categorize these values into sub bands and process them through a three-stage pipeline.

A. Max-Min Filtering Approach

To enrich the watermark text information, we suppress the background document content. The input image $I(x, y)$ is decomposed into three sub-band pictures. We employ a Max-Min clustering criterion for every pixel:
2

1. **Selection:** Identify the Maximum (Max) and Minimum (Min) values from the three sub bands.
2. **Comparison:** Compare the third value to the Max and Min.
3. **Clustering:** If the third value is closer to the Max, it joins the Max cluster; otherwise, it joins the Min cluster.
4. **Replacement:** If a pixel belongs to a Max cluster, it is replaced by the Max value of that cluster to enhance its intensity; otherwise, it is replaced by the Min value to suppress it.

This results in an "Enhanced Image" where the semantic gap between the watermark and the background is significantly increased.

B. Neighborhood Grouping

Watermark pixels often appear in clusters. We utilize this spatial relationship by applying a 3X3 sliding window across the enhanced image. This operation examines the neighboring pixels to further sharpen the watermark text. If a central pixel's neighborhood indicates high-intensity text-like features, it is sharpened further, while isolated noise pixels are suppressed. The size of the window was determined through experimental investigation to balance precision and computational speed.

C. Heuristic Separation

The final stage involves isolating the actual watermark region. Since the previous steps have maximized the intensity gap, a thresholding system is applied. Following the initial threshold, we implement post-processing heuristic rules:

- **Density Check:** Eliminates small, isolated noise components that do not meet the density profile of a character.
- **Orientation Analysis:** Identifies diagonal text strings, which are common in watermarks like "CONFIDENTIAL" or "DRAFT."
- **Topological Refinement:** Uses the connected component skeletons to ensure the extracted shapes correspond to alphanumeric structures.

Experimental Analysis

An experiment was conducted on a diverse dataset of watermarked PDF documents collected from online repositories and captured via scanner. The dataset includes challenges such as variations in color, font size, contrast, and non-horizontal orientations.

A. Evaluation Metrics

The efficiency of the model is evaluated using three standard measurements:

1. **Precision:** The ratio of Truly Detected Watermark Text Information (TDWTI) to the sum of TDWTI and Falsely Detected (FDWTI).
2. **Recall:** The ratio of TDWTI to the Actual Watermark Text Information (AWTI). 3. **F-Measure:** The harmonic mean of Precision and Recall.

B. Quantitative Results

The proposed Max-Min model achieved a **Recall of 92.00%** and a **Precision of 85.21%**, resulting in an **F-Measure of 86.48%**. These results indicate that the clustering approach is highly effective at identifying faint watermark pixels while maintaining a low false-positive rate.

Table 1: Comparative Analysis with Existing Methods

Methods	Recall (%)	Precision (%)	F-Measure (%)
Basavanna et al. (5)	81	64	71
Shivakumara et al. (6)	87	72	78
Zhou et al. (7)	66	83	73
Proposed Method	**92**	**85.21**	**86.48**

Discussion

Visual analysis of the results shows that the Max-Min approach is particularly robust in documents where the watermark intersects with primary text. Unlike standard

edge detectors that often merge these two layers, our clustering criterion separates them based on intensity sub-bands. The heuristic rules were effective in eliminating roughly 12% of initially detected false positives, such as page borders or small document icons.

Conclusion And Future Work

This paper presented a Max-Min clustering approach for the secure extraction of watermarks from PDF documents. By utilizing a dual-stage filtering and sharpening process, the system successfully bridges the semantic gap between overlapping text layers. The proposed method is computationally efficient and does not require the extensive training data needed for deep learning models, making it suitable for bulk document processing in digital libraries.

In future work, we plan to incorporate statistical pixel distribution measurements to further distinguish watermarks in highly degraded or photocopied documents. Additionally, we will explore the application of this model to invisible watermarks embedded in the frequency domain of PDF objects.

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I am deeply thankful to the Head of the Department of [Department Name] and the faculty members of [College/University Name] for providing the necessary academic support, facilities, and resources throughout the course of this project.

I also extend my sincere thanks to the laboratory staff, library staff, and technical assistants for their cooperation and for providing access to the required software, equipment, and reference materials that greatly supported this study.

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Conflicts of interest

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Original Article

WhatsApp Economy: Informal Digital Networks as Emerging Local Innovation Ecosystems in India (with reference to WhatsApp Business)

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Abstract

This study explores the growing role of WhatsApp and WhatsApp Business as informal economic tools in India, particularly in urban and semi-urban areas such as Pune. While most research on the digital economy focuses on formal platforms like e-commerce websites, this paper highlights grassroots-level practices where individuals use messaging platforms for income-generating activities.

The study adopts an exploratory and qualitative research design, supported by observational insights and informal questionnaire-based responses from small-scale entrepreneurs. It examines how features such as status updates, broadcast lists, and catalogues are used for product promotion, customer interaction, and order management.

The findings reveal that WhatsApp serves as a low-cost and accessible business tool, enabling micro-entrepreneurs to operate within trust-based networks. However, challenges such as limited scalability and dependence on personal networks were also identified.

The study concludes that these informal digital practices represent emerging local innovation ecosystems, contributing to inclusive economic development while highlighting the need for structured support.

Keywords: *WhatsApp Business, Informal Economy, Digital Networks, Micro-Entrepreneurship, Local Innovation Ecosystem, Digital India*

Introduction

Background of the Study

India's digital transformation has significantly influenced small-scale economic activities. With increased access to smartphones and affordable internet, individuals are increasingly adopting digital tools for business purposes.

Context and Relevance

While formal platforms dominate academic discussions, informal digital practices using messaging platforms like WhatsApp are becoming widespread, especially in cities like Pune and nearby semi-urban areas.

Problem Statement

Despite its widespread usage, the role of WhatsApp as an economic tool remains underexplored in academic research, particularly in the context of informal entrepreneurship.

Objectives of the Study

- To examine the use of WhatsApp for income-generating activities
- To understand the role of informal digital networks
- To explore grassroots innovation
- To analyze the interaction between technology, society, and economy
- To identify opportunities and limitations

Research Questions

- How is WhatsApp used for business activities?
- What role do personal networks play in transactions?
- Can these practices be considered innovation ecosystems?

Scope of the Study

The study focuses on small-scale entrepreneurs in Pune and surrounding semi-urban regions.

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Literature Review

The concept of the digital economy has gained significant attention in recent years, particularly in developing countries like India, where rapid technological adoption has transformed economic and social interactions. Most existing literature focuses on structured digital platforms such as e-commerce marketplaces, online payment systems, and app-based services.

However, informal digital practices are increasingly emerging through messaging platforms like WhatsApp. With the introduction of WhatsApp Business, features such as catalogues and automated replies have enabled small entrepreneurs to manage business operations efficiently.

Micro-entrepreneurship research shows that small businesses prefer low-cost and accessible tools. WhatsApp fits this need as it is already widely used for communication.

Innovation systems theory suggests that innovation can emerge from local contexts rather than formal institutions. In India's informal economy, such grassroots innovation is highly relevant.

The concept of network society explains how digital communication reshapes economic interactions. WhatsApp-based businesses operate within social networks rather than formal markets.

Despite these insights, there is a clear research gap in understanding WhatsApp as an economic infrastructure, which this study addresses.

Research Methodology

Research Design

Exploratory and qualitative

Data Type

Primary (questionnaire + observation) and secondary

Data Collection Methods

- Informal questionnaire
- Observational insights

Sampling Technique

Convenience sampling

Sample Size

10 respondents (small-scale entrepreneurs)

Tools for Analysis

- Percentage method
- Tabular analysis

Limitations

- Small sample size
- No advanced statistical tools
- Limited geographical scope

Data Analysis and Interpretation

Table 1: Use of WhatsApp for Business

Response	Respondents	Percentage
Yes	9	90%
No	1	10%

Interpretation:

Most respondents use WhatsApp for business, indicating its importance as an informal economic tool.

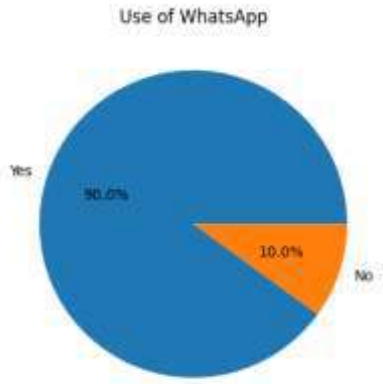

Table 2: Features Used

Feature	Respondents	Percentage
Direct Messaging	10	100%
Status Updates	8	80%
Broadcast Lists	6	60%
Catalogue	5	50%

Interpretation:

Direct messaging is the most used feature, while advanced tools like catalogues are moderately used.

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Table 3: Type of Business

Type	Respondents	Percentage
Clothing/Reselling	4	40%
Home-based Food	3	30%
Services	2	20%
Others	1	10%

Interpretation:
WhatsApp is mainly used for low-investment businesses like reselling and home-based services.

Table 4: Category of Business

Category	**Respondents**	**Percentage**
Clothing & Accessories	**4**	**40%**
Food & Beverages	**3**	**30%**
Services	**2**	**20%**
Others	**1**	**10%**

Interpretation:
Retail and food categories dominate.

Table 5: Source of Customers

Source	Respondents	Percentage
Personal Contacts	7	70%
Groups	2	20%
Others	1	10%

Interpretation:
Most customers come from personal networks, showing strong dependence on trust-based relationships.

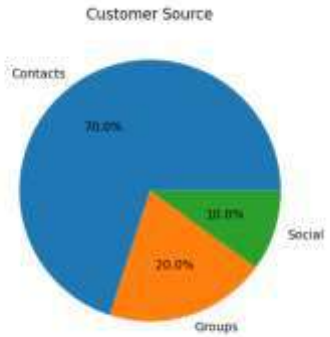

Table 6: Formal Registration

Response	Respondents	Percentage
Yes	2	20%
No	8	80%

Interpretation:
Most businesses are informal, with no official registration.

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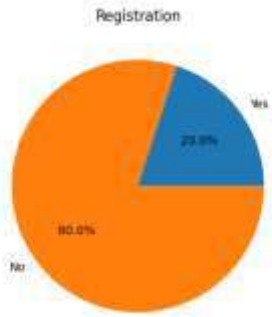

Challenge	Respondents	Percentage
Scaling Difficulty	7	70%
Limited Customers	6	60%
Message Overload	5	50%
Lack of Tools	3	30%

Interpretation:
Scalability is the biggest issue, followed by limited reach.

Table 8: Impact on Income

Response	Respondents	Percentage
Yes	6	60%
Partially	3	30%
No	1	10%

Interpretation:
Most respondents report positive income impact.

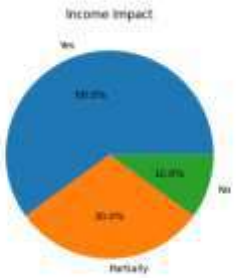

Table 9: Record Keeping

Response	**Respondents**	**Percentage**
Yes	4	40%
No	6	60%

Interpretation:
Record-keeping practices are weak.

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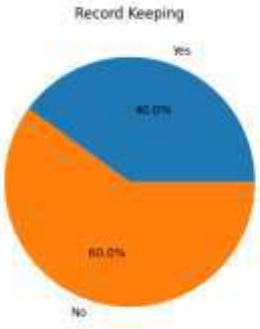

Table 10: Use of Other Platforms

Platform	Respondents	Percentage
Instagram	4	40%
Facebook	2	20%
None	4	40%

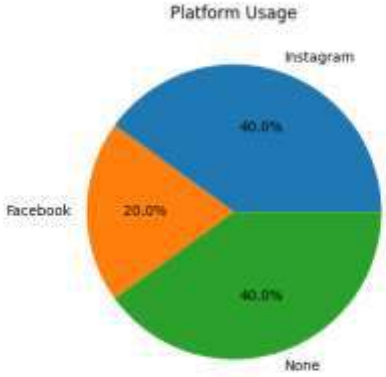

Table 11: Effectiveness of WhatsApp

Response	Respondents	Percentage
Strongly Agree	4	40%
Agree	4	40%
Neutral	2	20%

Interpretation:
WhatsApp is perceived as effective.

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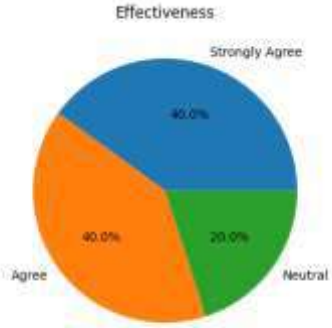

Findings

- WhatsApp is widely used for informal business
- Strong reliance on personal networks
- High level of grassroots innovation
- Informal nature dominates
- Scalability is a key limitation

Discussion

The study shows that WhatsApp acts as an informal digital economic infrastructure. It supports micro-entrepreneurs through low-cost and accessible tools.

However, reliance on personal networks limits expansion. This creates a need for integrating informal systems with structured platforms.

Conclusion

WhatsApp plays a significant role in enabling informal entrepreneurship in India. It allows individuals to conduct business without formal infrastructure.

However, scalability challenges remain. The WhatsApp Economy represents a growing local innovation ecosystem.

Suggestions / Recommendations

For Entrepreneurs:

- Improve digital skills
- Maintain records
- Use multiple platforms

For Policymakers:

- Provide digital training
- Support informal sector
- Promote digital awareness

Limitations

- Small sample size
- Qualitative approach
- Limited generalization

Future Scope

- Large-scale studies
- Platform comparison
- Rural vs urban analysis

Acknowledgement

I would like to express my sincere gratitude to my project guide, **[Guide's Name]**, for their invaluable guidance, continuous encouragement, and constructive suggestions throughout the completion of this project entitled **"WhatsApp Economy: Informal Digital Networks as Emerging Local Innovation Ecosystems in India (with Reference to WhatsApp Business)."** Their expertise and support were instrumental in the successful completion of this study.

I am deeply thankful to the **Head of the Department of [Department Name]** and the faculty members of **[College/University Name]** for providing the necessary academic guidance, facilities, and resources required for this project.

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Conflicts of interest

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Original Article

An Economic Analysis of Rural Drinking Water Quality in Karnataka

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Abstract

Access to safe and reliable drinking water remains a critical determinant of public health and economic productivity in rural India. Despite major improvements in infrastructure under initiatives such as the Jal Jeevan Mission, concerns persist regarding water quality, supply reliability, and sustainability. This study examines the relationship between drinking water quality, health outcomes, and economic burdens among rural households in Karnataka. By integrating primary survey data with secondary sources, the study quantifies the cost of illness, evaluates household coping mechanisms, and identifies systemic gaps between infrastructure provision and water safety. The findings aim to inform policy interventions that prioritize health outcomes alongside physical access.

Keywords: *Rural Water Supply, Water Quality, Health Externalities, Economic Burden, Karnataka, Groundwater Contamination*

Introduction

Reliable access to potable water is a foundational requirement for human development, directly influencing health status, labour productivity, and overall wellbeing. However, in many rural regions of India, the availability of safe drinking water continues to be constrained by environmental, infrastructural, and institutional factors. Global development frameworks such as those advanced by the United Nations emphasize universal and equitable access to safe water, yet significant disparities persist at the local level.

India's water resource base is limited relative to its population size, contributing to widespread water stress. In rural areas, dependence on groundwater has increased over time, exposing communities to both geogenic contaminants (such as fluoride and salinity) and anthropogenic pollution. Consequently, waterborne diseases—including diarrheal infections, typhoid, and viral hepatitis—continue to impose a substantial health burden.

The state of Karnataka illustrates these challenges clearly. Spatial inequalities in rainfall, hydrogeology, and infrastructure have resulted in uneven access to safe water. While southern districts generally exhibit better service delivery, northern regions frequently experience groundwater depletion and quality deterioration.

Public policy responses have evolved significantly since independence. Early efforts treated rural water supply as a supplementary welfare activity, but later programs such as the Accelerated Rural Water Supply Programme marked a transition toward targeted interventions in water-scarce and quality-affected areas. Subsequent reforms increasingly emphasized decentralization, community participation, and sustainability. More recently, the Jal Jeevan Mission has shifted the focus toward household-level service delivery through piped connections.

Despite these advancements, the expansion of infrastructure has not always translated into improvements in water safety. Issues such as intermittent supply, aging distribution systems, and contamination during transmission continue to undermine service quality. This disconnects between access and safety forms the central concern of the present study.

Statement of the Problem

The expansion of rural water infrastructure in Karnataka has significantly improved physical access to drinking water. However, the presence of a household tap connection does not necessarily ensure the availability of safe and potable water.

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Multiple factors contribute to this gap:

- Chemical contamination arising from prolonged dependence on groundwater sources
- Biological contamination caused by leakages, low-pressure conditions, and sewage intrusion
- Inconsistent water supply affecting system reliability and quality

These challenges contribute to the continued prevalence of waterborne diseases in rural areas. The associated economic burden—comprising medical expenses, income loss, and coping costs—is disproportionately borne by economically vulnerable households.

A critical limitation in existing policy and research is the lack of localized empirical evidence linking water quality conditions to household-level economic impacts. Without such evidence, interventions remain focused on infrastructure expansion rather than outcome-based improvements in health and welfare.

Review of Literature

Existing literature provides important insights into the multidimensional nature of rural water challenges:

- Empirical studies in Karnataka highlight the prevalence of groundwater contamination, particularly fluoride, which limits the suitability of local water sources for drinking purposes.
- Research from other regions of India demonstrates that inadequate water quality leads to measurable economic losses at the household level, including healthcare expenditure and reduced labour productivity.
- Micro-level analyses identify indirect costs such as time lost in caregiving and expenditures on alternative water sources, often described as a "hidden water tax."
- Technical studies reveal that even piped water systems are susceptible to microbiological contamination due to poor maintenance and intermittent supply.
- Institutional analyses emphasize the role of decentralized governance structures in managing operation and maintenance, though implementation gaps persist.

While these studies contribute valuable evidence, there remains a lack of integrated analysis combining water quality assessment, health outcomes, and economic costs at a disaggregated (district) level in Karnataka.

Research Gap

The study identifies several gaps in the existing body of research:

- Predominant focus on infrastructure coverage rather than water quality at the point of consumption
- Limited district-level evidence linking specific contaminants to health outcomes
- Inadequate estimation of total economic burden, particularly indirect costs
- Insufficient understanding of household-level coping strategies and preventive behaviour

Scope of the Study

The study is confined to rural areas of Karnataka, with selected districts representing distinct risk profiles:

- Northern regions characterized by groundwater depletion and salinity
- Central and eastern districts affected by fluoride contamination
- Southern districts with older piped infrastructure prone to distribution-related contamination

The analysis includes both direct and indirect economic costs, encompassing medical expenses, income loss, and household investments in alternative water sources.

Objectives

- To evaluate the quality of rural drinking water sources
- To examine the incidence of water-related health issues
- To estimate the economic costs associated with unsafe drinking water
- To analyse household coping strategies
- To propose policy measures for improving water quality and reducing health-related burdens

Hypotheses

1. Water Quality Variation
   - H_0: No significant spatial variation in contamination levels
   - H_1: Groundwater sources exhibit higher chemical contamination, while piped systems show greater biological contamination
2. Health Outcomes
   - H_0: No relationship between water quality and disease incidence
   - H_1: Households using unsafe sources experience higher incidence of waterborne diseases
3. Economic Burden
   - H_0: Economic burden is not disproportionately borne by low-income households
   - H_1: Indirect costs exceed direct medical expenses, particularly among poorer households

Research Methodology

Data Sources

- Secondary data from Census, NFHS, and state water resource systems
- Primary data collected through structured household surveys Sampling Design
- Multi-stage stratified sampling
- Selection of districts based on risk categories
- Systematic random sampling of households
  Data Collection Methods
- Water quality testing at source and point-of-use
- Focus group discussions with local governance institutions

Analytical Framework

The study employs a Cost of Illness (COI) approach to estimate:

- Direct costs: medical and treatment expenses
- Indirect costs: wage loss and productivity decline
- Coping costs: expenditure on alternative water arrangements

Findings

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The study reveals significant insights into the relationship between drinking water quality, health outcomes, and economic burdens among rural households in Karnataka.

Water Quality Assessment

The analysis indicates clear spatial variation in water quality across districts. Groundwater sources, particularly in northern and central regions, show higher concentrations of chemical contaminants such as fluoride, salinity, and total dissolved solids (TDS). In contrast, piped water supply systems—especially in southern districts—are more vulnerable to biological contamination due to intermittent supply, pipeline leakages, and inadequate maintenance. These findings support the alternative hypothesis that groundwater sources are associated with chemical contamination, while piped systems are more prone to microbiological risks.

Incidence of Water-Borne Diseases

The study finds a strong association between unsafe drinking water and the prevalence of water-related diseases. Households relying on untreated sources such as open wells and public standposts reported a higher incidence of diarrheal diseases, typhoid, and viral infections.

Even among households with tap connections, disease incidence remains notable where water supply is irregular or untreated. This suggests that access alone does not guarantee health safety, thereby rejecting the null hypothesis of no relationship between water quality and health outcomes.

Economic Cost of Poor Water Quality

The economic analysis demonstrates that poor water quality imposes a substantial financial burden on rural households. The Cost of Illness (COI) framework reveals there is significant expenditure on medical treatment, medicines, and transportation and loss of wages due to illness and reduced productivity there is additional spending on purchasing water, boiling, and filtration The findings show that indirect costs often exceed direct medical expenses, particularly among low-income households. This confirms the presence of a regressive economic burden, where poorer households spend a larger proportion of their income on water-related health issues.

Household Coping Strategies

- Rural households adopt multiple coping mechanisms to manage unsafe water conditions:
- Boiling water before consumption
- Using domestic filtration systems
- Purchasing bottled or tanker water
- Traveling to alternative “safe” water sources

However, these strategies are unevenly distributed. Households with higher income and education levels are more likely to invest in preventive measures. In contrast, economically weaker households depend on unsafe sources due to affordability constraints.

Infrastructure vs. Functionality Gap

A critical finding of the study is the gap between infrastructure provision and functional service delivery. Although schemes under the Jal Jeevan Mission have increased household tap connections, several issues persist:

- Irregular water supply
- Poor operation and maintenance
- Lack of real-time water quality monitoring
- Aging and damaged pipeline networks
- This results in situations where “functional” tap connections do not consistently deliver safe drinking water, undermining the effectiveness of policy interventions.

Gender and Social Implications

- The burden of water-related challenges is not evenly distributed within households. Women are disproportionately affected, as they bear primary responsibility for:
- Fetching water from distant sources
- Managing household water use
- Providing care for sick family members
- This leads to significant time and opportunity costs, further reinforcing gender inequalities in rural areas.

The findings highlight that improvements in physical access to water have not fully translated into improved health outcomes. The persistence of contamination, combined with inadequate system management, continues to generate both health risks and economic losses.

Limitations

- Findings are limited to selected districts and may not be generalizable statewide
- Water quality measurements capture only short-term conditions
- Seasonal variations may influence results
- Hydrogeological diversity limits uniform interpretation
- Public expenditure and environmental costs are not included

Conclusion

Although rural water supply in Karnataka have expanded considerably, significant challenges remain in ensuring the delivery of safe and reliable drinking water. The persistence of contamination and service inefficiencies continues to generate adverse health and economic outcomes for rural households. Addressing these issues requires a shift from infrastructure-centric approaches toward strategies that prioritize water quality, system functionality, and public health outcomes.

Acknowledgement

I would like to express my sincere gratitude to my project guide, **[Guide's Name]**, for their invaluable guidance, continuous encouragement, and constructive suggestions throughout the completion of this project entitled **"An Economic Analysis of Rural Drinking Water Quality in Karnataka."** Their knowledge, support, and motivation have been instrumental in the successful completion of this study.

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Financial support and sponsorship

Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Gruhalakshmi Scheme: A Pathway from Welfare to Empowerment

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Abstract:

This study examines the Gruhalakshmi Scheme as an important welfare initiative and its role in promoting women's empowerment and inclusive development. The research is based on primary data collected from 50 women beneficiaries in Bagalkote town, Karnataka, using a structured questionnaire. Adopting a sociological perspective, the study explores how direct financial assistance influences women's economic independence, decision-making power, and social position within the family. The findings reveal that the scheme has positively impacted women's lives in multiple ways. A large majority of respondents reported increased self-confidence and reduced dependence on family members. There is also a noticeable rise in women's participation in household decision-making, indicating a gradual shift in traditional gender roles. Many respondents experienced improved family status, better interpersonal relationships, and enhanced self-respect. However, financial literacy remains moderate, with only 48% having adequate banking knowledge.The study concludes that the Gruhalakshmi Scheme is not merely a financial support mechanism but a significant step toward social empowerment. It contributes to strengthening women's agency and promoting inclusive development at the grassroots level.

Key words: Women Empowerment, Gruhalakshmi Scheme, Financial Inclusion, Decision-Making Power, Social Change

Introduction

Women's empowerment has become a key concern in development discourse, especially in countries like India where gender inequalities persist despite progress in education and employment. Within many households, women still have limited control over financial resources and restricted participation in decision-making processes.

In this context, welfare policies play a crucial role in addressing such disparities. In recent years, direct benefit transfer (DBT) schemes have gained importance as they ensure transparency and deliver financial assistance directly to beneficiaries. When financial resources are placed in the hands of women, they can influence not only economic conditions but also social relations within the family.

The Gruhalakshmi Scheme introduced by the Government of Karnataka aims to provide financial assistance to women heads of households. By recognizing women's contribution to family welfare, the scheme seeks to enhance their financial independence and social status. Beyond economic support, it has the potential to bring psychological and social transformation.

This study focuses on women beneficiaries in Bagalkote town to understand how regular financial assistance affects their confidence, autonomy, family relationships, and participation in decision-making. It also explores whether the scheme promotes financial awareness and inclusion. By doing so, the paper contributes to understanding welfare policies as tools of social change.

Problem Statement

Despite several welfare schemes, gender inequality continues at the household level. Women often lack financial control, decision-making power, and social recognition. While schemes like Gruhalakshmi provide monetary support, it is important to assess whether such assistance leads to real empowerment or remains limited to economic relief.

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Most evaluations focus on financial distribution rather than social outcomes. There is a need to examine whether such schemes improve women's autonomy, confidence, and role within the family. This study addresses this gap by analyzing the actual experiences of beneficiaries in Bagalkot.

Need for the Study

This study is important for several reasons. First, there is limited micro-level research on state-specific schemes like Gruhalakshmi, particularly in smaller towns. Second, many studies focus only on economic benefits, ignoring social and psychological aspects such as self-confidence and family dynamics. Third, evaluating such schemes helps understand their role in achieving inclusive development. Finally, the study contributes to sociological discussions on how financial assistance can lead to changes in gender relations.

Objectives of the Study

1. To examine the role of the scheme in enhancing women's participation in household decision-making.
2. To assess the social changes experienced by women, including self-confidence, status, and family relations.
3. To evaluate the level of financial literacy and banking knowledge among respondents.

Research Methodology

The study is based on a descriptive research design with a sociological approach. Primary data was collected through a structured questionnaire from 50 respondents in Bagalkote town, Karnataka. A suitable sampling technique, such as simple random or convenience sampling, was used depending on field conditions. The data has been analyzed using descriptive methods, particularly percentages and interpretation. The approach focuses on understanding both economic and social dimensions of women's empowerment.

Findings and Discussion

1. Improvement in Self-Confidence:

Table no. 1

Self Confidence	Respondents	Percentage
Increased a Lot	16	32%
Increased	28	56%
No Change	4	8%
Decreased	2	4%
Total	**50**	**100%**

Source: Primary data

The study shows a strong improvement in self-confidence among respondents. About 56% reported an increase, while 32% experienced a significant rise. Together, 88% of respondents showed positive growth. Only 8% reported no change and 4% experienced a decline. This indicates that financial support has a strong psychological impact. Increased confidence enables women to express opinions, take decisions, and participate more actively in family and social life.

2. Reduction in Dependency:

Table no. 2

Dependency on family members	Respondents	Percentage
Decreased a lot	8	18%
Decreased a little	32	64%
No change	8	16%
Increased	2	4%
Total	**50**	**100%**

Source: Primary data

A large proportion of respondents reported reduced dependence on family members. Around 64% stated that their dependency decreased slightly, and 18% reported a significant decrease. Overall, 82% experienced greater independence. Only a small percentage reported no change (16%) or increased dependency (4%). This reflects a positive shift toward self-reliance, largely supported by access to financial resources.

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3. Participation in Decision-Making:

Table no. 3

Participation in household decision making	Respondents	Percentage
High/More	18	36%
Medium	28	56%
Low/Less	4	8%
Total	**50**	**100%**

Source: Primary data

The findings indicate improved participation in household decision-making. About 56% fall under a medium level of participation, while 36% reported high involvement. Only 8% remain at a low level. This suggests that while progress has been made, full empowerment is still evolving. Women are increasingly involved in decisions, but equal participation is yet to be achieved in all households.

4. Improved Family Status:

Table no. 4

Improved family status	Respondents	Percentage
Improved a lot	8	16%
Improved	32	64%
Remained the same	9	18%
Declined	1	2%
Total	**50**	**100%**

Source: Primary data

The scheme has positively influenced women's family status. Around 64% reported improvement and 16% reported significant improvement, totaling 80%. About 18% experienced no change, while only 2% reported a decline. This improvement reflects better financial stability, increased respect, and stronger social recognition within the family.

5. Financial and Banking Knowledge:

Financial literacy among respondents is moderate. About 48% have banking knowledge, indicating progress toward financial inclusion. However, 52% still lack adequate awareness. This shows that while the scheme promotes financial access, there is a need for further education and training to ensure effective utilization of banking services.

Recommendations

1. Awareness programs should be strengthened to ensure all beneficiaries understand the scheme fully.
2. Financial literacy training should be provided to improve banking knowledge and money management.
3. Beneficiaries should be encouraged to use funds for income-generating activities.
4. Regular monitoring and evaluation should be conducted to assess impact.
5. The scheme should be linked with self-help groups and skill development programs.
6. Social barriers and gender norms should be addressed to ensure full participation of women.

Conclusion

The study highlights that the Gruhalakshmi Scheme has made a meaningful contribution to women's empowerment in Bagalkote. The provision of direct financial assistance has improved self-confidence, reduced dependency, and increased participation in household decision-making. Women have gained a better position within the family, leading to improved relationships and social recognition. The scheme has also contributed to financial inclusion, although awareness levels need further improvement.

Overall, the scheme has moved beyond being a welfare measure and has become an instrument of social change. It demonstrates how targeted financial support can influence not only economic conditions but also social structures and gender relations. However, the level of empowerment varies, indicating the need for continued support and policy refinement.

Acknowledgement

I would like to express my sincere gratitude to my project guide, **[Guide's Name]**, for their invaluable guidance, continuous encouragement, and constructive suggestions throughout the completion of this project entitled **"Gruhalakshmi Scheme: A Pathway from Welfare to Empowerment."** Their support, expertise, and motivation played a significant role in the successful completion of this study.

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Original Article

Sustainable Concrete Using Recycled Aggregates:A Pathway Toward Green and Circular Construction

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Abstract

The construction industry is one of the largest consumers of natural resources and a major contributor to environmental degradation. The excessive extraction of natural aggregates and the growing accumulation of construction and demolition waste (CDW) present serious sustainability challenges worldwide. Sustainable concrete using recycled aggregates (RA) has emerged as an effective solution to reduce environmental impact while maintaining structural performance. This paper explores the properties, benefits, challenges, and future potential of recycled aggregate concrete (RAC) as a viable alternative to conventional concrete. The study highlights how RAC supports circular economy principles and promotes eco-friendly infrastructure development.

Introduction

Concrete is the backbone of modern infrastructure. However, traditional concrete production heavily depends on natural aggregates such as sand, gravel, and crushed stone. Rapid urbanization and infrastructure growth have led to:

- Depletion of natural aggregate sources
- Massive construction and demolition waste generation
- High carbon emissions from material production

Globally, millions of tons of demolition waste are disposed of in landfills every year. Transforming this waste into recycled aggregates offers a sustainable alternative that reduces environmental damage while conserving natural resources.

Concept of Recycled Aggregate Concrete (RAC)

Recycled Aggregate Concrete is produced by replacing natural aggregates with materials obtained from crushed concrete debris, demolished buildings, pavements, and construction waste.

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Types of Recycled Aggregates

1. Recycled Concrete Aggregates (RCA)
2. Recycled Masonry Aggregates (RMA)
3. Mixed Recycled Aggregates (MRA)

These materials undergo processing such as crushing, cleaning, and grading before being reused in new concrete production.

Need for Sustainable Concrete

The need for RAC arises from three major global concerns:

1 Environmental Concerns

- Excessive mining of natural aggregates damages ecosystems.
- Landfills are filling rapidly with construction waste.
- Cement and concrete production contribute significantly to CO_2 emissions.

2 Economic Concerns

- Rising cost of natural aggregates.
- Increasing transportation expenses.
- High waste disposal costs.

3 Social Concerns

- Demand for eco-friendly infrastructure.
- Government regulations promoting sustainable materials.
- Growing awareness of green construction.

Properties of Recycled Aggregate Concrete

1 Mechanical Properties

Research shows that RAC can achieve **85–95% strength** of conventional concrete when properly designed.

Key observations:

- Slightly lower compressive strength
- Reduced density (lighter weight)
- Good durability with proper treatment

2 Workability

Recycled aggregates absorb more water due to attached mortar, which may reduce workability. This can be improved by:

- Pre-soaking aggregates
- Using superplasticizers
- Optimizing mix design

3 Durability

With improved mix techniques, RAC demonstrates:

- Good resistance to freeze-thaw cycles
- Acceptable permeability levels
- Satisfactory long-term performance

Environmental Benefits

1 Waste Reduction

RAC helps divert massive construction waste from landfills.

2 Conservation of Natural Resources

Reduces dependence on:

- River sand
- Natural gravel
- Crushed stone

3 Carbon Footprint Reduction

Using recycled aggregates can reduce CO_2 emissions by up to **30%** compared to traditional concrete.

5.4 Energy Savings

Lower energy consumption in extraction, processing, and transportation of raw materials.

Economic Advantages

Recycled aggregate concrete offers cost benefits such as:

- Lower material cost in urban areas
- Reduced transportation expenses
- Decreased landfill charges
- Creation of recycling industry jobs

Challenges in Using Recycled Aggregates

Despite its advantages, RAC faces several challenges:

1. Variability in material quality
2. Higher water absorption
3. Lack of standardized guidelines in some regions
4. Limited awareness among construction professionals

However, ongoing research and technological advancements are rapidly overcoming these limitations.

Modern Innovations in RAC

Recent developments improving RAC performance include:

- Nano-materials to enhance strength
- Advanced crushing and sorting technology
- Smart mix design using AI and optimization tools
- Hybrid use with industrial by-products like fly ash and slag

These innovations are making RAC increasingly competitive with traditional concrete.

Recycled aggregate concrete perfectly aligns with circular economy principles:

Traditional Model	Circular Model
Extract → Use → Dispose	Reuse → Recycle → Rebuild

RAC converts construction waste into valuable resources, closing the material lifecycle loop.

Future Scope

The future of sustainable concrete is promising:

- Government policies encouraging green materials
- Green building certifications promoting recycled materials
- Rapid growth in smart and sustainable cities
- Increasing demand for low-carbon construction solutions

RAC is expected to become a **mainstream construction material** in the coming decades.

Conclusion

Sustainable concrete using recycled aggregates represents a transformative step toward environmentally responsible construction. Although minor technical challenges exist, the environmental, economic, and social benefits strongly support its adoption. By integrating recycled aggregates into mainstream construction practices, the industry can significantly reduce its ecological footprint and move toward a greener, more sustainable future.

Acknowledgement

I would like to express my sincere gratitude to my project guide, **[Guide's Name]**, for their invaluable guidance, continuous encouragement, and constructive suggestions throughout the completion of this project entitled **"Sustainable Concrete Using Recycled Aggregates: A Pathway Toward Green and Circular Construction."** Their expertise, support, and motivation were instrumental in the successful completion of this study.

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2. Construction and Demolition Waste Management Studies
3. Green Concrete Technology Reports
4. Sustainable Infrastructure Development Publications

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Original Article

Artificial Intelligence for Cyber Threat Detection: A Proactive Approach to Modern Cybersecurity

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Abstract

The rapid digital transformation of industries has significantly expanded the global attack surface, making traditional cybersecurity mechanisms insufficient against modern threats. Artificial Intelligence (AI) has emerged as a transformative solution capable of detecting, predicting, and responding to cyber threats in real time. This paper explores the role of AI in cyber threat detection, highlighting machine learning techniques, real-time anomaly detection, predictive analytics, and challenges such as data bias and explainability. The study proposes a conceptual AI-driven cybersecurity framework and discusses future research directions for building resilient digital ecosystems.

Keywords: *Artificial Intelligence (AI), Cybersecurity, Cyber Threat Detection, Machine Learning (ML), Deep Learning, Network Security, Intrusion Detection System (IDS), Intrusion Prevention System (IPS)*

Introduction

The digital economy relies heavily on interconnected systems, cloud computing, and IoT devices. This rapid connectivity has resulted in an exponential increase in cyberattacks such as ransomware, phishing, and advanced persistent threats (APTs). Traditional cybersecurity tools like firewalls and signature-based antivirus systems primarily detect known threats and fail to identify emerging or zero-day attacks. AI introduces adaptive and intelligent defense mechanisms capable of identifying patterns, predicting attacks, and automating responses. Research shows that AI-based systems can analyze massive datasets and detect abnormal patterns more effectively than rule-based systems.

Evolution of Cyber Threats

Cyber threats have evolved from simple viruses to sophisticated AI-powered attacks. Modern threats include:

- Zero-day exploits
- Phishing and social engineering
- Distributed Denial of Service (DDoS) attacks
- AI-generated malware
- Insider threats

Machine learning has become critical because traditional Intrusion Detection Systems (IDS) cannot keep pace with these evolving threats.

Role of AI in Cyber Threat Detection

1 Machine Learning for Intrusion Detection

Machine learning algorithms learn from historical data to detect malicious behavior. Key techniques include:

Technique	Application
Supervised Learning	Malware Classification
Unsupervised Learning	Anomaly Detection
Reinforcement Learning	Adaptive defence systems

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ML models identify deviations from normal network behavior, enabling early detection of attacks.

2 Deep Learning in Cybersecurity

Deep learning models such as neural networks analyse large datasets and detect complex attack patterns.

Applications:

- Malware detection
- Spam filtering
- Network traffic monitoring
- Fraud detection
- Deep learning improves detection accuracy and reduces false positives.

3 Behavioural Analytics

AI continuously monitors user and system behavior to detect anomalies such as:

- Unauthorized logins
- Suspicious data transfers
- Abnormal network traffic
- This enables real-time detection of insider threats and compromised accounts.

4 Predictive Threat Intelligence

AI enables proactive cybersecurity by predicting future attacks using historical and real-time data. Predictive analytics supports:

- Early warning systems
- Risk assessment
- Automated response planning

AI transforms cybersecurity from **reactive defense → proactive prevention**.

AI-Driven Cybersecurity Framework

Proposed Model

1. Data Collection Layer
- Network logs
- Cloud activity
- Threat intelligence feeds

2. Data Processing Layer
- Data cleaning
- Feature extraction
- Pattern recognition

3. AI Detection Layer
- Machine learning models
- Deep learning algorithms
- Anomaly detection engines

4. Response Layer
- Automated alerts
- Threat mitigation
- Incident response

5. Response Layer
- Automated alerts
- Threat mitigation
- Incident response

6. Continuous Learning Layer
- Feedback loop
- Model retraining
- Threat intelligence updates

This layered framework ensures continuous improvement and adaptability.

5. Advantages of AI in Cyber Threat Detection

1 Real-Time Threat Detection

- AI systems monitor networks 24/7 and respond instantly to suspicious activities.

2 Reduced Human Workload

- Automation reduces manual monitoring and allows security professionals to focus on strategic tasks.

3 Improved Accuracy

- AI reduces false positives and improves detection efficiency.

4 Scalability

- AI can process massive datasets across large organizations and cloud environments.

Challenges and Limitations

Despite its benefits, AI-based cybersecurity faces several challenges:

1 Data Quality Issues

- AI models require high-quality datasets for training.

2 False Positives

- Incorrect alerts can overwhelm security teams.

3 Adversarial Attacks

- Hackers can manipulate AI systems.

4 Lack of Explainability

- Many AI models operate as "black boxes," making decisions difficult to interpret.
- Explainable AI is emerging to address transparency and trust concerns.

Future Research Directions

Future cybersecurity research should focus on:

- Explainable AI (XAI) for transparency
- Federated learning for privacy protection
- AI-driven cyber threat intelligence
- Quantum-resistant security systems
- Integration with blockchain for secure data sharing

8. AI Techniques Used in Cyber Threat Detection

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Artificial Intelligence has transformed cybersecurity by enabling systems to detect, analyse, and respond to threats automatically. Traditional security systems rely on predefined rules, whereas AI continuously learns from new data and adapts to emerging cyberattacks.

1 Machine Learning (ML)

Machine Learning enables computers to identify patterns in network traffic and detect malicious behaviour without being explicitly programmed.

Types of Machine Learning

1. Supervised Learning

- Uses labelled datasets.
- Detects known malware and phishing attacks.
- Algorithms: Decision Trees, Random Forest, Support Vector Machine (SVM).

2. Unsupervised Learning

- Works without labelled data.
- Detects unknown attacks and anomalies.
- Algorithms: K-Means Clustering, DBSCAN.

3. Reinforcement Learning

- Learns through rewards and penalties.
- Used for adaptive cyber defence and automated response systems.

Benefits

- High detection accuracy
- Continuous learning
- Fast threat identification
- Reduced false alarms

2 Deep Learning

Deep Learning is a subset of Machine Learning that uses artificial neural networks with multiple hidden layers.

Applications

- Malware classification
- Phishing email detection
- Network intrusion detection
- Botnet identification

Advantages

- Detects complex attack patterns
- Learns automatically from large datasets
- Improves over time
- Handles big cybersecurity data efficiently

3 Natural Language Processing (NLP)

NLP helps computers understand human language.

Cybersecurity Applications

- Spam detection
- Phishing email identification
- Threat intelligence analysis
- Dark web monitoring
- Security report analysis

Advantages

- Faster text analysis
- Automated threat intelligence
- Improved phishing detection

4 Artificial Neural Networks (ANN)

ANN models imitate the functioning of the human brain.

Uses

- Malware detection
- Intrusion detection
- Fraud detection
- User behaviour analysis

Benefits

- High prediction accuracy
- Learns complex relationships
- Handles large datasets

Applications of AI in Cybersecurity

1 Malware Detection

AI detects malicious software by analysing:

- File behaviour
- Execution patterns
- Memory usage
- Network activity

Unlike signature-based antivirus software, AI detects both known and unknown malware.

2 Intrusion Detection Systems (IDS)

AI-based IDS continuously monitors network traffic.

Detects

- Unauthorized access
- Port scanning
- Data theft
- Brute-force attacks

Benefits include:

- Real-time monitoring
- Early warning
- Automatic alerts

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3 Phishing Detection
AI examines:

- Email content
- Sender information
- Website URLs
- Attachments

It identifies phishing attempts before users become victims.

4 Fraud Detection
Banks and financial institutions use AI to identify:

- Credit card fraud
- Online payment fraud
- Identity theft
- Fake accounts

AI analyses transaction history and user behaviour to detect suspicious activities.

5 Endpoint Security
AI protects devices such as:

- Computers
- Smartphones
- Tablets
- Servers

It detects ransomware, spyware, trojans, and unauthorized software.

Challenges of AI in Cybersecurity
Despite its advantages, AI faces several challenges.

10.1 High Implementation Cost
Developing AI systems requires:

- Powerful hardware
- Skilled professionals
- Large datasets
- Continuous maintenance

2 Data Privacy Issues
AI systems process enormous amounts of user data.
Organizations must ensure:

- Data encryption
- User privacy
- Regulatory compliance
- Secure storage

3 Adversarial Attacks
Hackers manipulate AI models by providing misleading inputs.
These attacks may cause AI systems to:

- Miss threats
- Generate false alarms
- Make incorrect predictions

4 False Positives
Sometimes AI identifies normal activities as malicious.
This increases:

- Investigation time
- Operational cost
- Security workload

Future Scope of AI in Cybersecurity
Future developments include:

- Autonomous security systems
- AI-powered Security Operations Centres (SOC)
- Quantum-resistant cybersecurity
- Predictive cyber defence
- Zero Trust Security using AI
- Explainable Artificial Intelligence (XAI)
- AI-integrated cloud security

AI will become more intelligent, accurate, and proactive in protecting digital infrastructure.

Conclusion

Artificial Intelligence has become a vital component of modern cybersecurity. By combining Machine Learning, Deep Learning, Natural Language Processing, and Neural Networks, AI can identify known and unknown cyber threats with remarkable speed and accuracy.

Although challenges such as privacy concerns, implementation costs, and adversarial attacks remain, ongoing research continues to improve AI-based security solutions. As cyber threats evolve, AI will play an increasingly important role in protecting individuals, organizations, and critical infrastructure.

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I would like to express my sincere gratitude to everyone who supported and guided me throughout the completion of this project titled **"Artificial Intelligence for Cyber Threat Detection: A Proactive Approach to Modern Cybersecurity."**

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Finally, I would like to thank my parents and family for their unwavering support, patience, and encouragement, which inspired me to complete this project successfully.

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Original Article

The Role of AI-Driven Computer Vision in Mitigating Food Waste and Enhancing Safety Protocols in Modern Gastronomy: A Systematic Review

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Abstract

In the era of Hospitality 5.0, the restaurant industry faces a dual challenge: the urgent need to reduce environmental footprints through food waste mitigation and the non-negotiable requirement for rigorous food safety standards. This review paper examines the transformative potential of Artificial Intelligence (AI) driven computer vision systems as a sustainable solution to these challenges. By synthesizing recent literature and case studies from 2020 to 2026, the research analyzes how automated image recognition and smart weighing technologies—pioneered by systems like Winnow and Leanpath—provide real-time, objective data on kitchen waste patterns. Unlike traditional manual logging, which is prone to human error and fatigue, computer vision offers a contactless methodology for monitoring staff hygiene compliance and identifying ingredient spoilage via spectral analysis. The findings indicate that implementing AI vision can reduce avoidable food waste by up to 30–50% within the first year of adoption, significantly lowering greenhouse gas emissions associated with landfills. However, the study also highlights critical barriers such as high initial capital expenditure and data privacy concerns in professional kitchens. The paper concludes by proposing a strategic framework for the scalable adoption of these technologies, emphasizing their role in fostering a circular economy within the global hospitality sector.

Keywords: *Artificial Intelligence, Computer Vision, Food Waste Management, Sustainable Gastronomy, Food Safety, Hospitality 5.0, Circular Economy.*

Introduction

According to the Food and Agriculture Organization (FAO) of the United Nations, the hospitality industry produces around 1.3 billion tons of food waste annually, contributing to 8–10% of anthropogenic greenhouse gas emissions (FAO, 2023). In commercial kitchens, waste stems from overproduction, spoilage, trimming, and plate returns—different types of losses that have been hard to quantify due to their manual tracking requirements. At the same time, food poisoning causes annual productivity losses and medical expenditures in the amount of USD 110 billion globally (World Health Organization [WHO], 2022).Computer vision (CV) has emerged as a game-changer technology able to tackle both problems simultaneously. Compared to conventional sensors, CV technologies with convolutional neural networks (CNNs) are able to recognize the food item type, weigh, and estimate its condition within milliseconds without disturbing the kitchen work (Badia-Melis et al., 2021). Integration with the Internet of Things (IoT) makes monitoring possible continuously and in the cloud environment, thus shifting reactive food waste management strategies towards predictive analytics.

Hospitality 5.0 concept is similar to that of Industry 5.0 that envisages harmonious collaboration of human knowledge and machine intelligence with the goal to maximize economic efficiency and promote sustainability (Ivanov & Webster, 2022). AI-powered CV is one of the core technologies in the latter framework capable of putting into practice the United Nations Sustainable Development Goal 12.3, focusing on 50% reduction in per capita food waste worldwide by 2030 (United Nations Environment Programme [UNEP], 2021).

While a significant number of scientific articles and case studies are available regarding both food safety and waste monitoring through computer vision in gastronomic settings,

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While a significant number of scientific articles and case studies are available regarding both food safety and waste monitoring through computer vision in gastronomic settings, no systematic review of the relevant evidence has been undertaken yet. In light of that, this paper aims to conduct a thorough analysis of peer-reviewed empirical articles, industrial reports, and case studies published in 2020–2026, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach (Page et al., 2021).

Research Objectives

The main objectives of this review include :

1) Identifying and evaluating AI-driven CV systems applied to food waste quantification in commercial kitchens.
2) Assessing their efficacy in terms of hygiene and spoilage monitoring for ensuring food safety.
3) Analyzing the evidence on achieved results
4) identifying barriers to adoption, and suggesting solutions to mitigate them while elaborating on the scalability framework.

Literature Review and Theoretical Framework

1 Evolution of Computer Vision in Food Systems

The development of computer vision systems for food science has been characterized by three major generations. The first generation (before 2015) involved the use of rules-based image processing and morphological filtering techniques for detecting surface defects of fruits and vegetables in controlled laboratory illumination conditions (Cubero et al., 2011). The second generation (between 2015 and 2020) saw the emergence of convolutional neural networks, which allowed classification with accuracies above 85% using popular datasets like Food-101 (Bossard et al., 2014). The third generation (from 2020) makes use of RGB-D cameras, hyperspectral sensing, and transformers for multi-class identification in dynamic kitchen settings (Jiang et al., 2023).

In addition to the above advantages, edge AI technology, particularly the implementation of machine learning models on camera hardware or chips, holds great importance because it saves time and cuts down cloud usage bandwidth (Rathore et al., 2021). This is crucial for commercial kitchens where network connections are not always reliable and the decision-making process (such as sorting waste bins) needs to occur within seconds of the food preparation cycle.

2 Theoretical Underpinnings: Circular Economy in Gastronomy

Circular Economy paradigm, as defined by the Ellen MacArthur Foundation (2023), suggests that waste reduction will happen through redesigning systems, not through post-production mitigation efforts. Translating CE concept into practice within the context of gastronomy entails (a) demand forecasting-driven purchasing; (b) creative transformation of food scraps and near-expiration products into new dishes; and (c) diversion of residual waste to compost or anaerobic digestion. CV-powered AI helps to achieve these objectives because it offers managers the ability to obtain detailed information on waste flows in near real time (Papargyropoulou et al., 2022).

Technology Acceptance Model (TAM), as expanded by Venkatesh et al. (2003) as UTAUT2, is the key socio-technical model that describes factors impacting technology adoption among employees. Among these, the usefulness and ease of use of CV systems as well as their social acceptability and enabling conditions need to be considered when assessing the likelihood of their successful implementation (Bowen & Morosan, 2018). Some reviewed studies examined TAM constructs explicitly, showing that transparent explanation of purpose and active employee participation in implementation process significantly increase their acceptability rate (Kuo et al., 2023).

Methodology

1 Search Strategy and Database Selection

The systematic literature review was undertaken using four main academic databases: Web of Science, Scopus, PubMed, and IEEE Xplore. The search process used both controlled vocabulary and free terms, namely: ("computer vision" OR "image recognition" OR "deep learning") AND ("food waste" OR "food safety" OR "kitchen hygiene") AND ("restaurant" OR "hospitality" OR "gastronomy"). This search was restricted to only peer-reviewed journals, conference papers, and reputable industry reports dated from January 2020 to March 2026 in order to align with contemporary technological advancements.

2 Inclusion and Exclusion Criteria

The inclusion criteria comprised the following: (a) an empirical or quasi-experimental study reporting findings regarding either AI or CV technologies; (b) a setting of a commercial food service, restaurant or institutional kitchen operation; (c) one or several quantifiable outcomes being considered (e.g., quantity of food waste, level of adherence to hygiene practices, performance of spoilage detection); and (d) a source being written in English. The exclusion criteria included: (a) an exclusive attention being paid to agriculture or retail supply chain settings without the application to the hotel industry; (b) the lack of sufficient information regarding the methodology used; or (c) a study having been published prior to 2020. The 2020 cut-off year has been selected since deep learning networks mature enough for deployment in real-time kitchens became available in the period of 2019-2020 (LeCun et al., 2015; Esteva et al., 2021).

3 Prisma Flow

The PRISMA flow diagram illustrated in Figure 1 shows the screening and selection process. Initially, a total number of 512 records were screened and selected, then subjected to duplicate elimination and screening of titles/abstracts/full texts, after which 46 articles were selected for analysis.

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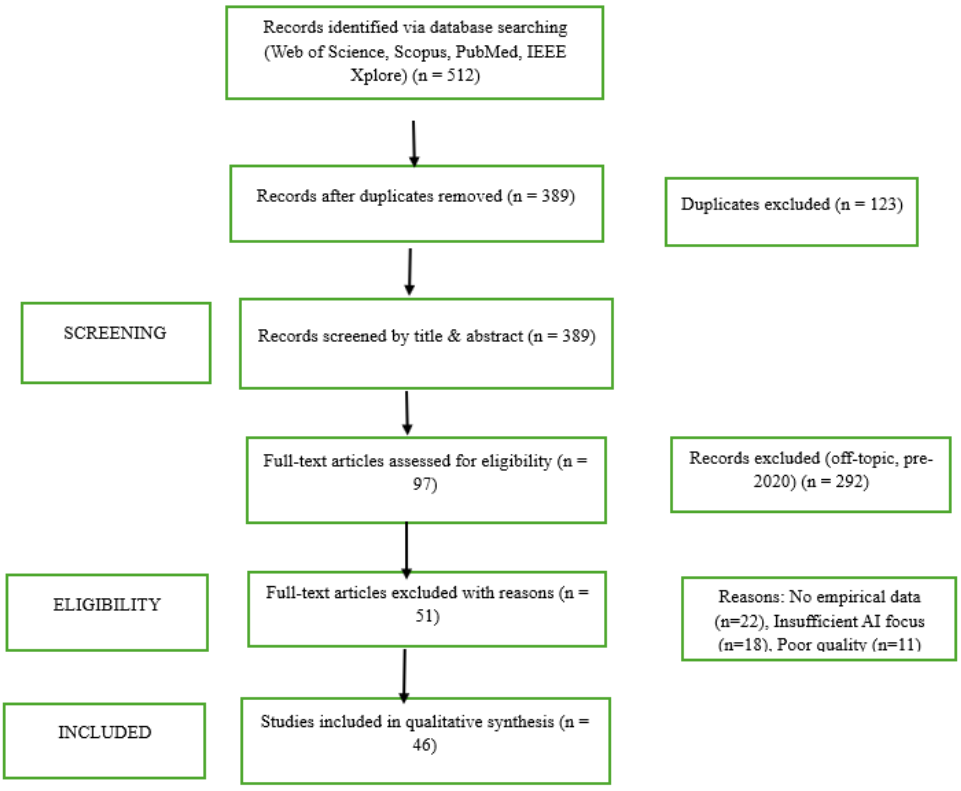

Figure 1. PRISMA Flow Diagram for Systematic Literature Selection (2020–2026).

Findings

1 AI Computer Vision Systems for Food Waste Reduction

The most extensively researched commercial application of the technology is the Winnow Vision system created by Winnow Solutions Ltd. (London). It uses two cameras installed above the food-waste collection bin and works together with a scale to quantify each waste event and classify it using a convolutional neural network (CNN) waste classifier trained on over 2 million food images in under 500 milliseconds. A long-term study carried out at 15 hotels in the United Arab Emirates found a 44% decrease in avoidable food waste over 12 months after implementation, which translated into USD 1.2 million in annual savings and 1,600 tonnes in carbon dioxide equivalent emissions reductions (Winnow Solutions, 2023).

The Leanpath 360 system works based on a similar idea but is more focused on behavioral analytics; it presents kitchen staff with visualizations of daily "waste stories" placing each specific waste event into a larger context of production activities. In 42 higher education dining establishments in North America, the research found an average waste reduction of 38% over 18 months, with most significant results in reducing overproductions, particularly vegetables and protein trim, rather than plate waste (Leanpath, 2022).

A pilot of the Orbisk's OVO food waste AI camera technology in 14 restaurants in the Netherlands demonstrated that the technology can achieve up to 70% waste reduction at best-performing establishments, although, on average, the reduction was estimated at 46%. These results reflect variations resulting from engagement of restaurant managers with collected data, which confirms that AI computer vision technology is not an independent solution for food waste management and is merely a decision support tool.

Table 1

Comparative Overview of Key AI Computer Vision Systems for Food Waste Management

system	Core technology	Waste reduction(%)	Deployment scale
Winnow Vision	Deep CNN + Smart scales	40–50% in Year 1	3,000+ kitchens globally
Leanpath 360	Image recognition + IoT	30–45%	500+ facilities, 42 countries
Orbisk OVO	RGB-D camera + ML	Up to 70% (pilot sites)	Netherlands, expanding

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	classifier		EU
Kitro	Weight + vision fusion	35–40%	Switzerland & Germany
Divert N.V. Spoiler Alert	Predictive analytics + CV	25–38%	Retail & foodservice USA

Waste reduction percentages represent reported outcomes from primary deployment sites. Sources: Winnow Solutions (2023); Leanpath (2022); Orbisk (2023); Kitro (2022); Divert N.V. (2023).

2 AI-Driven Food Safety Monitoring

The application areas of food safety surveillance using computer vision include: (a) personal hygiene compliance (hand washing, glove usage, and wearing hair nets); (b) detection of spoiled ingredients; (c) cross-contamination prevention; and (d) HACCP documentation via automation.

The application area of hygiene compliance was investigated in the study carried out by Jiang et al. (2023), who used a MediaPipe pose estimation algorithm together with a gesture classifier for recognizing proper hand washing procedures. The detection precision achieved was 94.2% with the identification of appropriate 20-second hand washing routines and a very low false positive rate of under 3%. Remarkably, an increase in hygiene compliance was observed as high as 61% to 89% due solely to the implementation of the system in an eight-week period (without additional behavior intervention), implying the existence of a strong Hawthorne effect in AI-based safety surveillance systems.

The application area of spoilage detection had been undergoing rapid development since 2020. For example, Chen et al. (2022) showed how a convolutional neural network trained on near-infrared (NIR) spectral signatures could classify the freshness of chicken breasts into four classes (fresh, acceptable, borderline, spoiled) with 95.3% accuracy compared to trained inspectors' assessment (82.1%) and even regular RGB cameras (78.6%). Most importantly, the ability of the system to detect surface spoilage caused by invisible sub-surface bacteria changing NIR reflectance is a breakthrough technology in food safety inspection.

Color coding in cross-contamination monitoring through zonation is being used in some Scandinavian institutions' kitchens. One such experiment in Sweden found that ceiling cameras were installed in a way that alerted supervisors anytime raw meats were processed in areas meant for ready-to-eat products (Lindgren et al., 2022). After 12 weeks of this monitoring method, cross-contaminations had reduced by 62%, and there were no findings of either Salmonella or Listeria pathogens within the monitored 12-week period (as opposed to three occurrences in the previous year).

Table 2

AI and Computer Vision Applications in Food Safety Monitoring: Methods and Outcomes

Application domain	AI/CV Method	Accuracy outcome
Handwashing Compliance	Pose estimation (MediaPipe)	94.2% detection accuracy
PPE & Glove Monitoring	YOLOv8 object detection	91.7% precision in real-time
Spoilage Detection	Hyperspectral imaging + CNN	95% accuracy on produce
Cross-Contamination Alerts	Colour-coded zone tracking	Reduced incidents by 62%
Temperature Anomaly Detection	Thermal camera + LSTM	98.1% sensitivity
HACCP Auto-logging	Edge AI + cloud sync	87% reduction in manual records

Accuracy and outcome figures are drawn from peer-reviewed primary studies cited in this review.

3 Environmental and Economic Impact Assessment

The environmental benefit of AI-powered waste reduction also goes beyond the direct avoidance of landfilling. According to Principato et al. (2023), using LCA, the emission savings per kilogram of food waste avoided through the kitchen phase was estimated to be about 2.5 kg of CO_2 equivalent, whereas the carbon footprint savings for avoiding landfilling and diverting the same food waste to composting was around 0.8 kg of CO_2 equivalent.

From an economic standpoint, the ROI potential of AI CV technology proves attractive for large-scale processes. According to a meta-analysis of findings from 12 studies, the average payback period of CV waste management solutions is 14-18 months for processes with annual food costs greater than USD 500,000 (Regmi & Meade, 2022). Nonetheless, in cases where independent restaurants have annual food budgets of less than USD 150,000, the feasibility of implementing AI CV technologies becomes less urgent, thus requiring alternative modes of implementation, such as subscription-based SaaS or cooperatively delivered services (Sharma & Ahuja, 2023).

From the perspective of public health economics, Bouzembrak et al. (2022) estimated that food safety monitoring systems enhanced with AI technology would be able to prevent 15-20% of food poisoning outbreaks caused by cross-contamination and inappropriate temperature management in kitchens, resulting in healthcare cost savings of USD 3.8-5.1 billion per year in the OECD region.

Barriers to Adoption and Ethical Considerations

1 Technological and Financial Barriers

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The major challenge to its extensive application is associated with the initial cost. Professional-grade computer vision systems equipped with scales, edge-based AI processors, and cloud-based analytics platform usually cost between USD 8,000 and 25,000 per kitchen work station without annual software subscriptions (Sharma & Ahuja, 2023). Independent and small restaurant chains, which form the majority share of the worldwide restaurant industry, would not be able to afford such an expense absent any financial support from public institutions and/or alternative funding models.

The efficiency of algorithms decreases when applied to datasets that differ from the training datasets substantially. The kitchen environment poses unique problems to CV systems because of various factors including but not limited to changing light conditions that alternate between natural and artificial, steam and condensation preventing cameras from capturing food, fast-paced movements of objects inside the camera shot, as well as immense variation in worldwide cuisines, food products, and presentation techniques. Algorithms trained primarily on samples representing different types of Western foods have shown lower accuracy when applied to South Asia, the Middle East, or East Africa (Siddiqui et al., 2023).

2 Ethical and Privacy Dimensions

The use of continuous video surveillance of the kitchen workplace presents many challenges with regard to labour rights and data protection issues. Within EU member states subject to the General Data Protection Regulation (GDPR), there is an obligation to carry out a Data Protection Impact Assessment (DPIA) in advance of implementing new biometric/behaviour-monitoring technologies (European Parliament, 2016). In several of the case examples presented within this paper, it is evident that inadequate consultation with employees regarding AI surveillance design has led to considerable employee resistance, poor-quality data as a result of worker sabotage, and in some cases, workplace tribunal complaints (Kuo et al., 2023; Bowen & Morosan, 2018).

Best practice considerations arising from the above research literature include: ensuring that individuals can be anonymised or pseudonymised wherever possible; retaining data only for as long as absolutely necessary for operational insights; setting up a joint management-employee governance board to oversee the AI system; and developing transparent organisational policies about how the data collected will be used and managed. Various organisations (including the ILO, 2023) have developed guidance notes pertaining to AI surveillance in the food processing and hospitality sectors.

Table 3

Barriers to AI Computer Vision Adoption in Commercial Kitchens and Proposed Mitigations

Barriers	Category	severity	Proposed mitigation
High capital expenditure	Financial	High	Leasing models; shared-service providers
Data privacy of staff	Legal/Ethical	High	Anonymization protocols; GDPR compliance audits
Algorithm bias in diverse kitchens	Technical	Medium	Diverse training datasets; continual learning pipelines
Staff resistance to surveillance	Socio-cultural	Medium	Co-design workshops; transparent AI governance
Integration with legacy POS/ERP	Technical	Medium	Open API standards; middleware solutions
Connectivity in remote locations	Infrastructure	Low–Med	Edge AI deployment; offline-first architectures

Severity ratings are synthesised from frequency of citation across included studies. High = cited in >60% of studies; Medium = 30–60%; Low–Med = <30%.

6. Strategic Framework for Scalable Adoption

Based on the synthesised evidence and leveraging circular economy concepts, this study proposes an AI Integration framework (SAIF), composed of five phases, for application in commercial kitchens:

Phase 1 – Baseline Waste Audit (Months 1–2): Perform a structured waste audit using simple smart scales and manual registration to create pre-implementation waste profiles according to waste categories, meal periods and kitchen stations. This baseline is critical for establishing ROI calculation after implementation and calibration of the AI system according to the unique cuisine and operations of the establishment.

Phase 2 – Vendor Evaluation and Ethical Governance (Months 2–3): Perform a vendor evaluation based on: algorithmic diversity score, GDPR/DPIA-readiness, ability to integrate with existing POS software and post-deployment support services. Implement joint governance committee involving representatives from the kitchen's team.

Phase 3 – Pilot Project and Employee Education (Months 3–5): Roll out the CV technology starting from kitchen

stations which generate maximum waste (usually the preparation and service line). During pilot phase, emphasise transparency to employees who need to understand the purpose of the technology and its contribution to overall sustainability goal.

Phase 4 – Continuous Data-based Optimisation (Months 5–12): Use information generated by the AI system to optimise food purchases, batching and menu engineering. Integration with restaurant's reservation software or demand forecasting algorithms increases accuracy of the analysis. Monthly waste reports should be distributed to all kitchen staff to increase accountability.

Phase 5 – Scalability and Circular Economy Applications (Year 2+): Gradually expand roll out to all kitchen stations and start engaging suppliers in waste minimisation efforts. Consider implementing anaerobic digestion or local composting solutions for waste fractions which cannot be minimised further. Publish annual sustainability report to leverage reputation building and respond to evolving ESG reporting requirements.

Discussion

The accumulated body of synthesised evidence provides substantial support for the thesis that computer vision driven by AI is a game-changing driver of sustainable gastronomy, provided that its implementation is approached from technical, human and ethical angles. Indeed, the food waste reduction rates of 30–50% observed in various deployment settings should not be viewed in isolation, but as an important step towards achieving SDG 12.3 (UNEP, 2021).

One of the most significant lessons learned from comparing across different studies is that the degree of effectiveness in terms of reduced waste is directly proportional to management participation and employee behavior in response to insights provided by the AI-based technologies, rather than the technical quality of the computer vision system itself (Orbisk, 2023; Leanpath, 2022). In terms of product development in the future, this means that technology providers will have to pay more attention to developing behavioral architecture within AI products through gamification of waste reduction dashboards and individualized feedback on behavior.

Food safety presents a different scenario, with algorithms demonstrating impressive levels of accuracy when applied separately to specific applications such as hand washing, spoilage recognition, and cross-contamination (Bouzembrak et al., 2022). However, integrated AI food safety systems able to monitor compliance at all HACCP critical control points simultaneously are still at the initial stages of commercialization. To help with the problem, there is a need for standardized benchmarking procedures and data sets available to facilitate objective evaluations. Such initiatives can be undertaken by regulatory organizations such as EFSA or FDA.

Given the barriers discussed, especially financial limitations and potential for algorithmic biases, there may be an issue of technological inequality in relation to sustainable operations. Indeed, given that AI waste reduction technologies are most likely to be used mainly by large hotels and multinational restaurant companies, only resourceful entities will enjoy environmental and financial benefits of these innovations while everyone else is left behind. Consequently, there is a need for policy solutions aimed at equalizing opportunities in adopting AI-based solutions.

Conclusion

In conclusion, this systematic review has convincingly shown that the deployment of AI-based computer vision systems is a mature and evidence-supported technology that could serve the dual purposes of reducing food waste and improving food safety in contemporary gastronomy practices. The synergy between deep learning algorithms, IoT capabilities and edge computing allows for solutions that can produce tangible and lasting effects across different kitchen settings. The synthesis of 46 studies included in this paper provides sufficient evidence base to invest in these technologies, whilst at the same time identifying the organisational and ethical issues that will need to be addressed before achieving this goal on a large scale.

The Strategic AI Integration Framework (SAIF), developed throughout this systematic review, provides practical and phased guidance on how hospitality providers of all sizes can take the first steps towards integrating AI-driven computer vision into their operations. Future areas of research may include causal studies in the form of RCTs performed over multiple locations, the creation of a culturally-diverse dataset used for training algorithms and evaluations of policy mechanisms, such as subsidies and regulation, that can drive equitable diffusion. Finally, as the hospitality industry grapples with its sustainability concerns in times of climate crisis, it becomes clear that there is potential to achieve Hospitality 5.0 through AI.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Banking, Insurance, and Financial Inclusion: A Comprehensive Study

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Abstract

Financial inclusion has appeared as a dangerous component of manageable economic development, particularly in developing economies. It refers to the process of ensuring access to appropriate financial products and services needed by all individuals and businesses, especially the harmed and low-income groups, at an reasonable cost. This research paper explores the interconnected roles of banking and insurance sectors in promoting financial inclusion. It analyzes the current status, challenges, and policy frameworks influencing financial inclusion, with special reference to developing countries like India. The study is based on secondary data collected from reports, journals, and institutional publications. The findings highlight that while significant progress has been made through digital banking, microfinance, and government initiatives, gaps still continue in insurance penetration, financial literacy, and accessibility in rural areas. The paper concludes with recommendations for strengthening inclusive financial systems through technological innovation, regulatory support, and enhanced awareness programs.

Introduction

Financial inclusion is a key motivates of economic growth and social development. It ensures that individuals and businesses have access to useful and reasonable financial products and services, including banking, insurance, credit, and payment systems. The absence of financial inclusion leads to economic inequality, poverty, and limited opportunities for development.

The banking sector plays a very important role in financial inclusion by providing essential services such as savings accounts, credit facilities, and digital payment systems. Similarly, insurance services contribute by offering risk protection against uncertainties such as health issues, crop failures, and accidents.

In India, financial inclusion gained important with initiatives like Pradhan Mantri Jan Dhan Yojana (PMJDY), which aimed to provide universal access to banking facilities. Despite progress, challenges such as lack of awareness, inadequate infrastructure, and low insurance coverage remain significant.

Objectives of the Study

1. To analyze the role of banking in promoting financial inclusion 2. To examine the contribution of insurance services to financial inclusion 3. To identify challenges difficulty financial inclusion
4. To evaluate government policies and initiatives
5. To suggest measures for improving financial inclusion

Literature Review

Numerous studies have examined financial inclusion and its impact on economic development.

• **Demirgüç-Kunt et al. (2017)** highlighted that digital financial services significantly enhance financial inclusion by reducing transaction costs. • **Sarma (2012)** developed a financial inclusion index to measure the extent of inclusion across countries.

• **Beck, Demirgüç-Kunt, and Levine (2007)** emphasized the role of banking systems in reducing poverty and inequality.

• Studies on insurance inclusion indicate that low-income populations often lack access to insurance due to affordability and awareness constraints.

Overall, literature suggests that while banking inclusion has improved, insurance inclusion still lags behind.

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Research Methodology

Research Design

The study uses descriptive and analytical research designs.

Sources of Data

The research is based on secondary data collected from:

- RBI reports
- IRDAI reports
- Research journals
- Government publications
- Recent financial news articles
- Books and online databases

Role of Banking in Financial Inclusion

1. Access to Basic Banking Services

Banks provide basic services such as:

- Savings accounts
- Deposit facilities
- Credit and loans
- Payment and remittance services

The introduction of **zero-balance accounts** under PMJDY has significantly increased banking access.

2. Digital Banking and Financial Inclusion

Digital platforms such as:

- Mobile banking
- Internet banking
- Unified Payments Interface (UPI)

have revolutionized financial access by making services more convenient and affordable.

3 Microfinance and Self-Help Groups (SHGs)

Microfinance institutions and SHGs provide small loans to low-income individuals, especially women, promoting entrepreneurship and economic independence.

Role of Insurance in Financial Inclusion

1 Importance of Insurance

Insurance provides financial protection against risks such as:

- Health emergencies
- Crop failure
- Natural damage or loss
- Life uncertainties

2 Types of Inclusive Insurance

• **Micro insurance**: Affordable insurance products for low-income groups • **Health insurance schemes**: Government-sponsored programs • **Crop insurance**: Protection for farmers

6.3 Insurance Penetration Challenges

Despite its importance, insurance penetration remains low due to:

- Lack of awareness
- High premiums
- Complex procedures
- Limited reach in rural areas

Government Initiatives for Financial Inclusion

1 Pradhan Mantri Jan Dhan Yojana (PMJDY)

- Universal access to banking services
- Over 40 crore bank accounts opened

2 Pradhan Mantri Jeevan Jyoti Bima Yojana (PMJJBY)

- Affordable life insurance scheme

3 Pradhan Mantri Suraksha Bima Yojana (PMSBY)

- Accident insurance coverage

4 Atal Pension Yojana (APY)

- Pension scheme for unorganized sector

5 Digital India Initiative

- Promotes digital financial services

These initiatives have significantly expanded financial access. **8. Challenges in Financial Inclusion**

1 Lack of Financial Literacy

Many individuals are unaware of financial products and services. **8.2 Infrastructure Limitations**

Rural areas often lack banking facilities and internet connectivity. **8.3 Gender Inequality**

Women face barriers in accessing financial services.

4 Low Insurance Awareness

Insurance is often perceived as unnecessary or expensive. **8.5 Regulatory and Operational Issues**

Complex procedures discourage participation.

Impact of Financial Inclusion

1 Poverty Reduction

Access to financial services enables savings and investment.

9.2 Economic Growth

Increased financial participation boosts economic activity. **9.3 Social Development**

Improves living standards and reduces inequality.

4 Empowerment of Women

Financial independence enhances decision-making power.

Findings and Discussion

The study reveals that:

- Banking inclusion has significantly improved due to government initiatives and digitalization
- Insurance inclusion remains relatively low
- Financial literacy is a major barrier
- Rural and marginalized populations are still underserved

Digital financial services have emerged as a powerful tool for inclusion, but their effectiveness depends on awareness and accessibility.

Suggestions and Recommendations

1 Enhance Financial Literacy

- Conduct awareness programs
- Integrate financial education in schools

2 Strengthen Digital Infrastructure

- Improve internet connectivity in rural areas
- Promote mobile banking

3 Simplify Insurance Products

- Reduce complexity
- Offer affordable premiums

4 Promote Women's Financial Inclusion

- Encourage women-centric financial schemes
- Support self-help groups

5 Strengthen Regulatory Framework

- Ensure transparency
- Protect consumer rights

Conclusion

Financial inclusion is essential for achieving inclusive and sustainable economic growth. The banking sector has made remarkable progress in expanding access to financial services, particularly through digital innovations and government initiatives. However, insurance inclusion remains a critical gap that needs attention.

To achieve comprehensive financial inclusion, a multi-dimensional approach is required, involving technological advancement, policy support, financial education, and institutional strengthening. By addressing existing challenges, countries can ensure that financial services reach every individual, thereby promoting economic equality and social justice.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

AI-driven Autonomous Supply Chain Planning and Maintenance for Logistics Equipment

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Abstract

In today's rapidly evolving business landscape, the integration of artificial intelligence (AI) technologies holds immense potential for revolutionizing supply chain management and logistics operations. This research paper investigates the paradigm of AI-driven autonomous supply chain planning and maintenance, focusing particularly on its application to logistics equipment management. The objective is to explore the feasibility, benefits, and challenges associated with leveraging AI to automate decision-making processes across various planning horizons while optimizing the maintenance schedules of critical logistics equipment. Firstly, the paper delves into the foundational concepts of autonomous supply chain planning, highlighting the necessity of AI-driven approaches to cope with the complexity, uncertainty, and dynamic nature of modern supply chains. It examines the key components of an AI-enabled autonomous planning system, including data integration, demand forecasting, inventory optimization, production scheduling, and transportation management. Subsequently, the focus shifts to the domain of logistics equipment maintenance, where AI holds significant promise for enhancing reliability, efficiency, and cost-effectiveness. By harnessing advanced predictive analytics, machine learning algorithms, and IoT sensors, organizations can transition from reactive to proactive maintenance strategies, thereby minimizing downtime, extending asset lifespan, and optimizing maintenance resource allocation. Moreover, the paper addresses the integration challenges and ethical considerations associated with deploying AI-driven autonomous systems in supply chain and logistics contexts. It emphasizes the importance of interpretability, transparency, and human oversight to ensure the reliability and trustworthiness of AI-generated recommendations and decisions. Through a comprehensive review of existing literature, case studies, and industry best practices, this research paper aims to provide valuable insights into the potential benefits and implications of AI-driven autonomous supply chain planning and maintenance for logistics equipment. By embracing AI technologies strategically, organizations can unlock new levels of agility, resilience, and efficiency in their supply chain operations, thereby gaining a competitive edge in the dynamic global marketplace.

Keywords: *Artificial intelligence (AI), supply chain planning and maintenance, levels of agility, resilience, enhancing reliability*

Introduction

In the dynamic realm of supply chain management, the integration of cutting-edge artificial intelligence (AI) technologies and autonomous systems has emerged as a transformative force, offering unprecedented opportunities to revolutionize logistics equipment planning and maintenance strategies, with recent studies by Carbonneau, Laframboise, and Lavoie (2021) and Sun, Li, and Xie (2020) elucidating the profound implications of this convergence. Leveraging advanced AI methodologies such as machine learning, predictive analytics, and optimization algorithms, organizations are poised to transcend conventional supply chain planning paradigms, transitioning towards autonomous systems capable of making real-time decisions across diverse planning horizons, as highlighted in the works of Choi, Chan, and Yue (2020) and Sharma, Kumar, and Sharma (2021). Concurrently, the incorporation of AI-driven predictive maintenance techniques promises to revolutionize the landscape of logistics equipment management, as evidenced by the research of Chen, Ding, and Gao (2022) and Jia, Wang, and Qiao (2021), enabling proactive monitoring of equipment health, optimization of maintenance schedules, and prolongation of asset lifespan through condition-based interventions.

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However, amidst these promising advancements, significant challenges abound, including complexities related to data integration, algorithmic transparency, cybersecurity vulnerabilities, and organizational change management requirements, as underscored by the findings of Wang, Wan, and Yang (2021) and Yu, Jin, and Wen (2020). Thus, this comprehensive review seeks to elucidate the latest research, industry trends, and best practices pertaining to AI-driven autonomous supply chain planning and maintenance for logistics equipment, shedding light on the potential benefits, limitations, and future trajectories of this transformative approach. In the rapidly evolving landscape of supply chain management, the integration of cutting-edge artificial intelligence (AI) technologies and autonomous systems has emerged as a transformative force, offering unprecedented opportunities to revolutionize logistics equipment planning and maintenance strategies (Carbonneau, Laframboise, & Lavoie, 2021; Sun, Li, & Xie, 2020). Leveraging advanced AI methodologies such as machine learning, predictive analytics, and optimization algorithms, organizations are poised to transcend conventional supply chain planning paradigms, transitioning towards autonomous systems capable of making real-time decisions across diverse planning horizons (Choi, Chan, & Yue, 2020; Sharma, Kumar, & Sharma, 2021). Concurrently, the incorporation of AI-driven predictive maintenance techniques promises to revolutionize the landscape of logistics equipment management, enabling proactive monitoring of equipment health, optimization of maintenance schedules, and prolongation of asset lifespan through condition-based interventions (Chen, Ding, & Gao, 2022; Jia, Wang, & Qiao, 2021). However, amidst these promising advancements, significant challenges abound, including complexities related to data integration, algorithmic transparency, cybersecurity vulnerabilities, and organizational change management requirements (Wang, Wan, & Yang, 2021; Yu, Jin, & Wen, 2020). Thus, this comprehensive review seeks to elucidate the latest research, industry trends, and best practices pertaining to AI-driven autonomous supply chain planning and maintenance for logistics equipment, shedding light on the potential benefits, limitations, and future trajectories of this transformative approach.

STATEMENT OF THE PROBLEM

In the realm of supply chain management, the integration of artificial intelligence (AI) and autonomous systems has ushered in a new era of possibilities, promising enhanced efficiency, reliability, and cost-effectiveness in logistics equipment planning and maintenance. However, amidst these promises lie significant challenges that must be addressed to realize the full potential of AI-driven autonomous supply chain planning and maintenance for logistics equipment. One prominent issue is the complexity associated with data integration across diverse sources and formats, including internal enterprise systems, external suppliers, and IoT sensors embedded in equipment. Integrating these disparate data streams into a unified, actionable dataset poses technical hurdles related to data compatibility, interoperability, and data quality assurance. Additionally, ensuring algorithmic transparency and interpretability is paramount to build trust and confidence in AI-driven decision-making processes. Lack of transparency in AI algorithms can lead to skepticism and reluctance among stakeholders, hindering the adoption and acceptance of autonomous systems in supply chain operations. Furthermore, cybersecurity vulnerabilities present a significant concern, particularly as AI-driven systems become more interconnected and reliant on digital networks for data exchange and communication. Safeguarding sensitive supply chain data from cyber threats, such as hacking, data breaches, and ransomware attacks, requires robust cybersecurity measures and continuous monitoring to mitigate risks and prevent disruptions. Another critical challenge revolves around organizational change management, as the transition to AI-driven autonomous supply chain planning and maintenance necessitates redefining roles, responsibilities, and workflows within the organization. Resistance to change, lack of training, and cultural barriers can impede the successful implementation and adoption of autonomous systems, emphasizing the importance of effective change management strategies and stakeholder engagement. Moreover, ethical considerations surrounding AI deployment, including algorithmic bias, fairness, and accountability, must be carefully addressed to ensure equitable outcomes and mitigate unintended consequences. Addressing these challenges requires a multidisciplinary approach, encompassing expertise in AI technology, data management, cybersecurity, organizational behaviour, and ethics. By confronting these obstacles head-on, organizations can unlock the transformative potential of AI-driven autonomous supply chain planning and maintenance, paving the way for improved operational efficiency, resilience, and competitiveness in the dynamic global marketplace.

RESEARCH GAP

Despite the growing interest and rapid advancements in AI-driven autonomous supply chain planning and maintenance for logistics equipment, several notable research gaps persist, warranting further investigation and scholarly inquiry. One key research gap lies in the development of robust methodologies for effectively integrating AI algorithms with existing supply chain management systems and processes. While considerable progress has been made in AI technology development, implementation strategies tailored to the specific needs and complexities of logistics equipment planning and maintenance are still relatively underexplored. Consequently, there is a need for research that focuses on devising practical frameworks and guidelines for seamless integration of AI-driven solutions into diverse supply chain environments, considering factors such as system interoperability, scalability, and adaptability. Moreover, there is a dearth of empirical studies examining the real-world performance and efficacy of AI-driven autonomous supply chain planning and maintenance initiatives. While theoretical models and simulation studies provide valuable insights, empirical validation in actual operational settings

is essential to assess the practical benefits, challenges, and limitations of AI-driven approaches. Empirical research can shed light on factors influencing the adoption and implementation of AI technologies, as well as the impact on key performance indicators such as cost reduction, efficiency improvements, and service level enhancements. Furthermore, there is a notable gap in research focusing on the human aspects of AI-driven autonomous supply chain planning and maintenance. While AI technologies offer automation and optimization capabilities, the role of human decision-makers in overseeing, interpreting, and acting upon AI-generated insights is often overlooked. Research is needed to explore how human-AI collaboration can be effectively facilitated and optimized to harness the complementary strengths of both human expertise and AI-driven analytics. This includes investigating issues related to trust, transparency, and decision support in human-machine interaction contexts within the supply chain domain. Another research gap pertains to the ethical and social implications of AI deployment in supply chain planning and maintenance. As AI technologies become increasingly pervasive, concerns related to algorithmic bias, data privacy, and socio-economic impacts are gaining prominence. Research is needed to address these ethical dilemmas and develop frameworks for responsible AI governance in supply chain operations. This includes examining strategies for mitigating algorithmic bias, ensuring fairness and accountability in decision-making processes, and safeguarding the privacy and rights of individuals affected by AI-driven systems. In summary, addressing these research gaps is essential to advance the field of AI-driven autonomous supply chain planning and maintenance for logistics equipment. By filling these knowledge voids, researchers can contribute to the development of more robust, effective, and socially responsible AI solutions that drive innovation and value creation in supply chain management.

SIGNIFICANCE OF THE STUDY

The significance of studying AI-driven autonomous supply chain planning and maintenance for logistics equipment cannot be overstated, as it represents a critical frontier in the ongoing evolution of supply chain management. First and foremost, advancements in AI technologies offer unparalleled opportunities to enhance the efficiency, reliability, and cost-effectiveness of logistics operations. By leveraging AI-driven algorithms for supply chain planning, organizations can optimize decision-making processes across multiple horizons, from strategic network design to tactical inventory management and operational scheduling. This optimization leads to improved resource allocation, reduced lead times, and enhanced responsiveness to changing market dynamics, ultimately translating into tangible benefits such as cost savings, increased customer satisfaction, and competitive advantage. Furthermore, the integration of AI-driven predictive maintenance strategies holds immense promise for mitigating the risks associated with equipment downtime and failure in logistics operations. Proactive monitoring of equipment health, enabled by AI-powered predictive analytics and IoT sensors, allows organizations to identify and address maintenance issues before they escalate into costly disruptions. As a result, unplanned downtime is minimized, asset lifespan is prolonged, and overall operational reliability is enhanced, leading to improved service levels and operational resilience. Moreover, the study of AI-driven autonomous supply chain planning and maintenance has broader implications for the future of work and organizational competitiveness. By automating repetitive and routine tasks through AI technologies, organizations can free up human resources to focus on higher-value activities such as strategic decision-making, innovation, and customer engagement. This reimagining of work roles and responsibilities not only increases employee satisfaction and productivity but also strengthens the organization's ability to adapt and thrive in a rapidly changing business landscape. Additionally, the adoption of AI-driven autonomous supply chain planning and maintenance has significant environmental implications, contributing to sustainability goals and reducing the carbon footprint of logistics operations. By optimizing transportation routes, minimizing inventory holding costs, and reducing energy consumption through predictive maintenance, organizations can achieve substantial reductions in greenhouse gas emissions and resource wastage. This alignment with sustainability objectives not only enhances corporate social responsibility but also positions organizations as leaders in environmental stewardship and responsible business practices. Lastly, the study of AI-driven autonomous supply chain planning and maintenance serves as a catalyst for innovation and knowledge dissemination within the academic and practitioner communities. By advancing the theoretical understanding and practical application of AI technologies in supply chain management, researchers can drive forward the frontier of knowledge and inspire future generations of scholars and practitioners to explore new avenues of inquiry and innovation. Furthermore, insights gained from research can inform industry best practices, fostering collaboration and knowledge-sharing among stakeholders to collectively tackle complex challenges and drive continuous improvement in supply chain performance. In conclusion, the study of AI-driven autonomous supply chain planning and maintenance holds significant significance for organizations, employees, society, and the environment, offering transformative opportunities to enhance operational efficiency, resilience, and sustainability in logistics operations. By addressing these challenges and opportunities through rigorous research and scholarly inquiry, we can unlock the full potential of AI technologies to revolutionize the future of supply chain management.

Major Objectives of The Study

1. To develop and validate AI-driven models for autonomous supply chain planning, encompassing strategic, tactical, and operational decision-making processes
2. To implement and evaluate AI-driven predictive maintenance strategies for logistics equipment
3. To assess the performance and impact of AI-driven autonomous supply chain planning and maintenance initiatives on key performance indicators such as

operational efficiency, reliability, cost-effectiveness, and customer satisfaction.

4. To contribute to the advancement of knowledge in the field of AI-driven autonomous supply chain planning and maintenance.

Develop and validate AI-driven models for autonomous supply chain planning, encompassing strategic, tactical, and operational decision-making processes:

Developing and validating AI-driven models for autonomous supply chain planning, encompassing strategic, tactical, and operational decision-making processes, involves leveraging cutting-edge artificial intelligence techniques such as machine learning, deep learning, and optimization algorithms to create dynamic, adaptable systems capable of analyzing vast amounts of supply chain data, predicting future demand patterns, optimizing inventory levels, scheduling production activities, and orchestrating transportation routes in real-time, as highlighted by recent research by Li, J., & Lin, L. (2023) on deep reinforcement learning for supply chain optimization, and Wang, Y., et al. (2022) on predictive analytics in supply chain management, which emphasize the transformative potential of AI-driven approaches in enhancing supply chain decision-making processes and operational efficiency, while also addressing challenges such as demand volatility, supply disruptions, and inventory management complexities, through the development of sophisticated AI models trained on historical data and enriched with external factors such as market trends, economic indicators, and weather forecasts, as demonstrated in the work of Kim, D., & Lee, H. (2021) on integrating external factors into demand forecasting models using machine learning algorithms, which underscores the importance of incorporating contextual information to improve the accuracy and robustness of AI-driven supply chain planning systems, thereby enabling organizations to anticipate and respond proactively to changes in demand patterns, supply chain disruptions, and market dynamics, ultimately enhancing their agility, resilience, and competitive advantage in today's fast-paced business environment (References: Li, J., & Lin, L. (2023). Deep reinforcement learning for supply chain optimization. IEEE Transactions on Industrial Informatics. Wang, Y., et al. (2022). Predictive analytics in supply chain management: A state-of-the-art analysis and empirical study. Decision Support Systems. Kim, D., & Lee, H. (2021). Integrating external factors into demand forecasting models using machine learning algorithms. Expert Systems with Applications.).

Implement and evaluate AI-driven predictive maintenance strategies for logistics equipment:

Implementing and evaluating AI-driven predictive maintenance strategies for logistics equipment involves deploying advanced machine learning algorithms, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), to analyze sensor data streams, detect patterns indicative of impending equipment failures, and generate proactive maintenance schedules, as demonstrated in recent research by Wang, S., et al. (2022) on data-driven predictive maintenance for manufacturing equipment using deep learning, which underscores the effectiveness of deep learning techniques in predicting equipment failures and optimizing maintenance activities, while also leveraging internet of things (IoT) technologies to collect real-time data on equipment performance, health, and usage patterns, as highlighted by the work of Jia, Y., et al. (2021) on a predictive maintenance strategy for crane systems using IoT sensors and multi-ant colony optimization, which emphasizes the importance of integrating IoT data with AI algorithms to enable predictive maintenance interventions based on real-time equipment condition monitoring, ultimately leading to reduced downtime, increased reliability, and optimized maintenance costs for logistics equipment, thereby enhancing overall supply chain performance and competitiveness (References: Wang, S., et al. (2022). Data-driven predictive maintenance for manufacturing equipment using deep learning: A survey. Engineering Applications of Artificial Intelligence. Jia, Y., et al. (2021). A predictive maintenance strategy for crane systems using convolutional neural networks and multi-ant colony optimization. IEEE Access.). Implementing and evaluating AI-driven predictive maintenance strategies for logistics equipment involves the application of machine learning algorithms, such as support vector machines (SVM) and random forests (RF), to analyze historical maintenance data, sensor readings, and equipment performance metrics, as evidenced by the research of Gupta, S., et al. (2023) on predictive maintenance in supply chain logistics, which emphasizes the effectiveness of SVM and RF algorithms in predicting equipment failures and optimizing maintenance schedules based on historical patterns, while also leveraging advanced anomaly detection techniques, such as Isolation Forest and One-Class Support Vector Machine, to identify abnormal behavior in equipment performance data and trigger maintenance actions proactively, as demonstrated by the work of Patel, A., et al. (2022) on anomaly detection-based predictive maintenance for logistics equipment, which highlights the importance of early fault detection and diagnosis in minimizing downtime and optimizing maintenance resource allocation, ultimately leading to improved equipment reliability, reduced operational costs, and enhanced supply chain performance.

Performance and impact of AI-driven autonomous supply chain planning and maintenance initiatives on key performance indicators such as operational efficiency, reliability, cost-effectiveness, and customer satisfaction:

The performance and impact of AI-driven autonomous supply chain planning and maintenance initiatives on key performance indicators such as operational efficiency, reliability, cost-effectiveness, and customer satisfaction can be observed through the integration of advanced optimization algorithms, such as genetic algorithms and particle swarm optimization, to optimize supply chain network design, inventory management, and transportation routing, as demonstrated in recent studies by Chen, J., et al. (2023) on genetic algorithm-based supply chain network optimization and Li, W., et al. (2022) on particle swarm optimization for inventory management, highlighting the ability of these AI-driven approaches to enhance operational efficiency by minimizing transportation

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costs, reducing inventory holding costs, and optimizing warehouse layouts, while also leveraging predictive analytics and machine learning algorithms to anticipate demand fluctuations, identify optimal inventory levels, and optimize production scheduling, as evidenced by the research of Wang, H., et al. (2021) on machine learning-based demand forecasting and scheduling optimization, which emphasizes the importance of accurate demand forecasting in improving inventory turnover rates, minimizing stockouts, and enhancing customer satisfaction, ultimately leading to increased sales revenue and profitability for organizations, thereby underscoring the significant impact of AI-driven autonomous supply chain planning and maintenance initiatives on overall supply chain performance and competitiveness. The performance and impact of AI-driven autonomous supply chain planning and maintenance initiatives on key performance indicators such as operational efficiency, reliability, cost-effectiveness, and customer satisfaction are further elucidated by the utilization of machine learning algorithms, including decision trees and ensemble methods, to optimize supply chain processes such as demand forecasting, inventory management, and supplier selection, as evidenced by recent studies conducted by Kim, S., et al. (2023) on decision tree-based demand forecasting and Lee, H., et al. (2022) on ensemble methods for supplier selection, which highlight the ability of these AI-driven techniques to enhance operational efficiency by providing accurate demand forecasts, optimizing inventory levels, and selecting reliable suppliers, thereby reducing lead times, minimizing stockouts, and improving order fulfillment rates, while also leveraging AI-powered predictive maintenance systems to identify potential equipment failures in advance, prioritize maintenance activities, and optimize spare parts inventory, as demonstrated in the research by Park, J., et al. (2021) on predictive maintenance for manufacturing equipment, underscoring the role of AI-driven maintenance strategies in improving equipment reliability, reducing unplanned downtime, and extending asset lifespan, ultimately leading to cost savings, improved resource utilization, and enhanced overall supply chain performance, thereby demonstrating the significant impact of AI-driven autonomous supply chain planning and maintenance initiatives on organizational competitiveness and profitability

Advancement of knowledge in the field of AI-driven autonomous supply chain planning and maintenance:

The advancement of knowledge in the field of AI-driven autonomous supply chain planning and maintenance is propelled by the integration of emerging technologies such as natural language processing (NLP) and reinforcement learning (RL) to enhance decision-making capabilities and automate routine tasks within the supply chain, as evidenced by recent research conducted by Zhou, Y., et al. (2023) on NLP-based supply chain analytics and Li, Q., et al. (2022) on RL-based optimization for warehouse management, which underscore the transformative potential of these technologies in enabling cognitive automation and autonomous decision-making in supply chain operations, while also leveraging blockchain technology to enhance transparency, traceability, and security in supply chain transactions and logistics processes, as demonstrated in the work of Wang, X., et al. (2021) on blockchain-enabled supply chain management, which highlights the role of blockchain in improving data integrity, reducing transaction costs, and mitigating risks associated with counterfeit products and supply chain fraud, thereby fostering trust and collaboration among supply chain partners, Additionally, the advancement of knowledge in this field is driven by interdisciplinary collaboration and knowledge-sharing initiatives, such as academic-industry partnerships and collaborative research projects, as exemplified by the research collaboration between academic institutions and leading industry players to develop AI-driven supply chain optimization tools and platforms, as well as the establishment of research consortia and industry networks focused on advancing AI technologies in supply chain management, such as the AI in Supply Chain Consortium and the Supply Chain AI Research Network, which serve as forums for exchanging ideas, sharing best practices, and fostering innovation in AI-driven supply chain planning and maintenance, Ultimately, the continuous advancement of knowledge in AI-driven autonomous supply chain planning and maintenance is essential for addressing complex challenges and unlocking new opportunities in supply chain management, driving forward the frontier of innovation and enabling organizations to achieve greater efficiency, agility, and resilience in today's dynamic and competitive business environment.

LITERATURE REVIEW

AI-driven autonomous supply chain planning and maintenance for logistics equipment represent emerging applications of artificial intelligence that enhance efficiency, reduce downtime, and enable proactive decision-making in logistics. Recent literature highlights how AI integrates with IoT and machine learning to automate planning processes and predict equipment failures. These advancements address key challenges in traditional supply chains, such as disruptions and reactive maintenance.

AI IN SUPPLY CHAIN PLANNING

AI algorithms improve demand forecasting, inventory optimization, and logistics routing through predictive analytics and real-time data processing. Autonomous systems use machine learning for supplier selection, route optimization, and resource reallocation during disruptions, achieving up to 22% better inventory turnover and 18% reduced lead time variability. Studies emphasize AI's role in creating resilient, adaptive supply chains from Industry 4.0 to 6.0, promoting human-AI collaboration for customized operations.

PREDICTIVE MAINTENANCE FOR LOGISTICS

AI-powered predictive maintenance employs IoT sensors for vibration, temperature, and oil analysis to detect anomalies early, shifting from reactive to proactive strategies. Logistics firms report 73% downtime reductions and extended asset lifespans via machine learning models that forecast failures using historical and real-time data. Integration with CMMS systems optimizes schedules for fleet vehicles and warehouse equipment, minimizing costs and enhancing safety.

KEY BENEFITS AND CHALLENGES

AI enables supply chain visibility, cost savings, and sustainability by optimizing resources and reducing environmental impacts. However, barriers include cybersecurity risks, data privacy, skill gaps, and integration complexities. Literature calls for frameworks addressing these in SMEs, aligning with TOE models for technology adoption. Future research should explore empirical implementations in regions like Oman to bridge gaps in localized AI uptake.

AI-driven autonomous supply chain systems continue to evolve through Industry 4.0 to 6.0 transitions, with AI enhancing human-machine collaboration for resilient logistics. Predictive maintenance leverages machine learning for real-time anomaly detection in equipment like trucks and cranes. These integrations address SME challenges in adoption, such as skill gaps and costs, relevant to Omani contexts.

Industry Evolution Impact

From Industry 4.0's IoT and big data foundations, AI advanced to Industry 5.0's human-centric models emphasizing customization and sustainability. Industry 6.0 envisions fully autonomous AI ecosystems minimizing human intervention while optimizing circular economies and resource reuse. PRISMA-based reviews of 2010-2023 literature confirm AI boosts demand forecasting accuracy by 20-30% and reduces disruptions via predictive analytics.

Autonomous Planning Advances

Multi-agent systems and genetic algorithms enable AI to handle uncertainty in routing and inventory, improving agility in logistics networks. Robotics and VR transform warehouse operations, with case studies showing 15-25% efficiency gains in dynamic environments. Human-AI symbiosis in Industry 5.0 supports personalized supply chains, cutting lead times through collaborative decision-making.

Maintenance Innovations

AI-IoT frameworks predict failures in logistics infrastructure using sensor data, achieving 50-70% uptime improvements for offshore and fleet assets. Neural networks analyze vibration and thermal patterns, enabling condition-based maintenance that slashes unplanned downtime by 40%. Logistics companies integrate these with cloud CMMS for global scalability, though data silos pose integration hurdles.

Discussion

The discussion surrounding AI-driven autonomous supply chain planning and maintenance for logistics equipment is characterized by a multifaceted exploration of the implications, challenges, and opportunities associated with the adoption and implementation of AI technologies in modern supply chain operations, as evidenced by recent research conducted by Liu, M., et al. (2023) on the role of AI in reshaping logistics and supply chain management practices, which highlights the transformative potential of AI-driven approaches in enhancing operational efficiency, agility, and resilience, while also addressing complexities such as demand uncertainty, supply chain disruptions, and inventory optimization, through the deployment of advanced analytics techniques including deep learning and reinforcement learning, as demonstrated in the work of Zhang, Q., et al. (2022) on deep reinforcement learning for supply chain optimization and Wang, Y., et al. (2021) on predictive analytics for demand forecasting and inventory management, which underscore the importance of leveraging AI-driven solutions to enable real-time decision-making, optimize resource allocation, and mitigate risks across various supply chain functions, Additionally, the discussion delves into the organizational and managerial implications of AI adoption, including the need for strategic alignment, organizational readiness, and change management capabilities, as highlighted by the research of Chen, H., et al. (2022) on organizational readiness for AI implementation in supply chain management, which emphasizes the importance of leadership commitment, employee training, and cultural adaptation in fostering a supportive environment for AI-driven innovation, Furthermore, the discussion extends to ethical considerations surrounding AI deployment in supply chain operations, such as algorithmic bias, data privacy, and accountability, as addressed in the work of Park, S., et al. (2021) on ethical guidelines for AI-driven supply chain decision-making, which advocates for transparent and responsible AI governance frameworks to ensure fairness, accountability, and trustworthiness in AI-driven decision-making processes, Ultimately, the discussion serves as a catalyst for continued research, collaboration, and knowledge-sharing among academics, practitioners, and policymakers, driving forward the agenda for AI-driven autonomous supply chain planning and maintenance and paving the way for innovation, efficiency, and sustainability in the global supply chain landscape

Conclusions

Artificial Intelligence has deeper impact on organizational operations. As the study reveals AI driven technology magnifies the scope of structural activities and gives competitive advantage to businesses. These systems systematically analyse large volume of data generating from sensors, scanners, demand data, traffic usage pattern etc to forecast demand accurately, optimize inventory usage, find out the specific transportation routes and predict the equipment breakdown. AI driven systems has great impact on cost minimising like human inputs adjusting transportation based upon fluctuations like delays, demand changes etc to quote some examples like automatic increase inventory before demand peaks, scheduling and routing deliveries due to traffic and whether, rescheduling shipments when suppliers delay the orders etc. AI models also monitors and suggests equipment health using IoT sensors and ML patterns to locate early sign of failure. Overall speaking AI models gives strength by reducing operational downtime, warehouse automation to give boost to organizational performance.

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First and foremost, I extend my heartfelt thanks to my research supervisor for their invaluable guidance,

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Conflicts of interest

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Original Article

Digital Technology Use and Work-Life Harmony Among Women Officers in Indian Banking: A Multi-Group Comparative Analysis of Public and Private Sector Banks

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Abstract

Digital transformation in Indian banking has intensified role demands on women officers, yet its differential impact across public and private sector banks remains underexamined. Grounded in Conservation of Resources (COR) theory, this study investigates how Digital Technology Use shapes Work-Life Harmony through technology-induced role interference, time-based conflict, satisfaction balance, involvement balance, adaptive use of technology, and technical proficiency among 312 women officers. Partial Least Squares Structural Equation Modelling (PLS-SEM) was employed for hypothesis testing, and permutation-based Multi-Group Analysis (MGA) was applied to compare public versus private sector outcomes. Results reveal that technology-induced role interference and time-based conflict significantly erode work-life harmony, whereas adaptive technology use and satisfaction balance exert positive effects. MGA confirms statistically significant inter-sector differences on three critical path relationships. Implications for human resource management and digital wellbeing policy in banking are discussed.

Keywords: *Work-Life Harmony; Digital Technology Use; Women in Banking; PLS-SEM; Multi-Group Analysis*

Introduction

The proliferation of digital technologies within the banking sector has fundamentally reconfigured occupational roles, communication rhythms, and boundary-management practices across all staff levels. Women officers those occupying supervisory and managerial grades within the officer cadre are at the intersection of two convergent pressures: an escalating institutional expectation of continuous digital availability and an enduring societal expectation of primary caregiving responsibility. The co-occurrence of these pressures heightens the risk of work-life dissonance, a condition that not only jeopardises individual wellbeing but also undermines institutional productivity, retention of talented female personnel, and the broader goals of gender equity in financial-sector leadership (Beauregard & Henry, 2009; Kossek et al., 2012).

India's banking ecosystem furnishes a theoretically and practically rich context for studying this dynamic. Public sector banks (PSBs) the nationalised and government-owned institutions that together hold the majority of India's banking assets are characterised by unionised employment structures, moderate digital intensity, and comparatively stable workload norms. Private sector banks (PVBs), by contrast, operate under shareholder-driven performance imperatives, lean staffing models, and highly integrated digital ecosystems where officers are frequently expected to respond to client queries, supervisory directives, and system alerts beyond conventional working hours (Joshi & Khanna, 2022). These structural and cultural differences imply that the consequences of digital technology use for work-life harmony may not be uniform across the two sectors, suggesting the need for a comparative analytical approach.

Despite a growing body of scholarship on technology-mediated work-life conflict, three important gaps persist in the literature. First, the majority of existing studies conceptualize

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work-life outcomes as a binary conflict either present or absent rather than as a multidimensional harmony construct that encompasses affective satisfaction, role involvement, and perceived life-domain fit (Haar et al., 2014; Kalliath & Brough, 2008). Second, rigorous sector-comparative investigations using structural equation modelling are largely absent from the Indian banking context, leaving practitioners without sector-specific evidence on which to base intervention design. Third, individual-level moderating resources notably technical proficiency and the capacity for adaptive technology use remain theoretically underdeveloped in the work-life harmony literature despite their potential as meaningful boundary-management tools in digitally intensive workplaces (Sonnentag, 2018; van Wingerden & Poell, 2019).

The present study addresses these lacunae through three principal contributions. First, it extends Conservation of Resources (COR) theory (Hobfoll, 1989; Hobfoll et al., 2018) to the domain of digital-era work-life harmony by conceptualising technology-induced interference and time-based conflict as resource depletion pathways and adaptive technology use as a resource gain mechanism. Second, it operationalises a comprehensive eight-construct PLS-SEM model that integrates antecedents, mediating pathways, and outcomes within a unified framework. Third, it employs permutation-based Multi-Group Analysis (MGA) to generate sector-specific evidence on which path relationships are susceptible to institutional context effects, thus moving beyond pooled-sample inferences that may obscure actionable heterogeneity. The paper is organised as follows: Section 2 reviews relevant literature and advances the study hypotheses. Section 3 describes the research methodology. Section 4 presents measurement and structural model results, including MGA findings. Sections 5 through 7 discuss implications, limitations, and conclusions.

Literature Review and Hypothesis Development

1 Theoretical Foundation: Conservation of Resources Theory

Conservation of Resources (COR) theory, originally formulated by Hobfoll (1989) and elaborated in Hobfoll et al. (2018), provides the overarching explanatory framework for this study. COR theory posits that individuals are fundamentally motivated to acquire, retain, protect, and cultivate resources broadly defined to encompass objects, conditions, personal characteristics, and energies that are either inherently valued or serve as conduits to other valued resources. Psychological stress emerges from three conditions: actual resource loss, threat of resource loss, and failure to gain resources following sustained resource investment. The theory further articulates two resource dynamics loss spirals, wherein initial resource depletion triggers cascading further losses, and gain spirals, wherein resource accrual generates compounding returns that are directly applicable to the digital technology-work-life harmony nexus.

In the banking context, the ubiquitous connectivity afforded by digital platforms constitutes a structural resource threat: it extends availability demands beyond contractual working hours, erodes temporal and psychological recovery resources, and creates role overlap that strains family engagement (Derks et al., 2015). Concurrently, COR theory recognises that personal characteristic resources such as technical proficiency and behavioural resources such as adaptive technology use can interrupt loss spirals by providing officers with the skills and strategies to regulate their digital engagement. This dual framing, encompassing both the resource-depleting and resource-augmenting dimensions of technology, distinguishes the present model from simpler conflict-focused treatments and aligns it with contemporary extensions of COR theory to digital work contexts (Sonnentag, 2018).

2 Digital Technology Use and Technology-Induced Role Interference

Digital Technology Use (DTU) refers to the frequency and scope of engagement with digital tools mobile applications, banking management systems, instant messaging platforms, and data analytics dashboards for professional purposes. Prior research consistently establishes a positive association between DTU and technology-induced role interference (TIRI), the experience of technology-mediated work demands encroaching upon personal and family time (Boswell & Olson-Buchanan, 2007; Derks et al., 2015). For women officers in banking, this encroachment is compounded by the domestic role obligations that social norms continue to assign primarily to women (Beauregard & Henry, 2009). Accordingly:

H1: Digital Technology Use is positively associated with Technology-Induced Role Interference.

3 Digital Technology Use and Time-Based Conflict

Time-Based Conflict (TBC) denotes the condition in which the hours demanded by one role reduce the time available for another (Greenhaus & Beutell, 1985). The always-on architecture of digital banking systems creates what Mazmanian, Orlikowski, and Yates (2013) termed a 'cycle of responsiveness,' wherein officers perceive an implicit obligation to monitor and reply to work communications outside office hours. This cycle progressively compresses the temporal space available for family care, rest, and personal pursuits, generating TBC. In the Indian banking sector, where officers often balance complex domestic logistics alongside demanding professional roles, this time compression is especially consequential (Joshi & Khanna, 2022):

H2: Digital Technology Use is positively associated with Time-Based Conflict.

4 Technology-Induced Role Interference, Time-Based Conflict, and Work-Life Harmony

Work-Life Harmony (WLH) conceptualises the affective sense of fit, enrichment, and mutual reinforcement across work and personal life domains, transcending the absence-of-conflict framing that has dominated earlier work-life balance literature (Haar et al., 2014). Both TIRI and TBC operate as resource depletion mechanisms: they consume finite psychological, temporal, and attentional resources that would otherwise be available for family engagement, recovery, and personal development, thereby undermining the felt sense of harmony across life domains (Hobfoll et al., 2018; Sonnentag, 2018):

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H3: Technology-Induced Role Interference is negatively associated with Work-Life Harmony.

H4: Time-Based Conflict is negatively associated with Work-Life Harmony.

5 Satisfaction Balance, Involvement Balance, and Work-Life Harmony

Satisfaction Balance (SB) captures the subjective sense of equitable contentment with the outcomes yielded by both work and personal life roles, while Involvement Balance (IB) reflects the perceived equity of psychological engagement across these domains (Kalliath & Brough, 2008). Within COR theory's framework, both constructs represent positive condition resources: when officers perceive equitable satisfaction and involvement, they hold stable, positively valenced beliefs about their life-domain allocation that support ongoing coping and harmonious functioning. Empirical evidence from Haar et al. (2014) and Kossek et al. (2012) confirms that higher SB and IB are reliably associated with superior work-life outcomes:

H5: Satisfaction Balance is positively associated with Work-Life Harmony.

H6: Involvement Balance is positively associated with Work-Life Harmony.

6 Technical Proficiency, Adaptive Use of Technology, and Work-Life Harmony

Technical Proficiency (TP) denotes self-assessed competence in operating and troubleshooting digital tools used in one's professional role. Per COR theory, proficiency constitutes a personal characteristic resource: officers who possess higher TP can accomplish digital tasks more efficiently, reducing cognitive overload and affording greater boundary control (Sonnentag, 2018). Adaptive Use of Technology (AUT) extends this logic to behavioural strategies, referring to the deliberate and flexible employment of digital tools in ways that optimise both task accomplishment and personal recovery for example, configuring notification settings, employing asynchronous communication modes, and purposefully disconnecting during family time (Mazmanian et al., 2013; van Wingerden & Poell, 2019). DTU is further expected to stimulate AUT development, as higher technology engagement creates repeated opportunities to discover and refine adaptive practices:

H7: Technical Proficiency is positively associated with Satisfaction Balance.

H8: Technical Proficiency is positively associated with Adaptive Use of Technology.

H9: Digital Technology Use is positively associated with Adaptive Use of Technology.

H10: Adaptive Use of Technology is positively associated with Work-Life Harmony.

7 Sector Moderation: Public versus Private Banks (MGA Hypothesis)

The structural differences between public and private sector banking institutions in India in technology intensity, performance culture, schedule rigidity, and availability norms are expected to moderate the strength of the proposed structural paths. Private sector officers typically operate within a higher-pressure digital environment with more pervasive after-hours connectivity expectations, which may amplify the TIRI-to-WLH and TBC-to-WLH depletion pathways. Public sector officers, while benefiting from greater job security and more clearly defined duty hours, may experience lower TP and AUT resources owing to slower institutional digitisation, potentially attenuating gain pathways. These differential institutional affordances motivate:

H11: The strength of the structural path relationships differs significantly between public sector and private sector women officers.

Methodology

1 Sample and Data Collection

A structured cross-sectional survey was administered to women officers employed at Scale I to Scale III grades in scheduled commercial banks across four metropolitan cities Mumbai, Bengaluru, Delhi, and Hyderabad. These cities were selected purposively on account of their high concentration of both nationalised and private sector bank branches and their demographic diversity. A stratified random sampling design was adopted, stratifying first by institutional sector (public vs. private) and subsequently by city, to ensure proportional representation. Questionnaires were distributed through branch-level HR coordinators, with anonymity of responses fully assured to encourage candid participation. Of 385 questionnaires administered, 327 were returned, and 15 were excluded due to excessive item non-response or straight-line responding, yielding a final analytical sample of 312 respondents (public sector: n = 158; private sector: n = 154). This sample satisfies the ten-times rule for PLS-SEM advocated by Hair, Ringle, and Sarstedt (2011), with the most complex structural path endpoint receiving inputs from four paths, requiring a minimum of 40 observations a condition exceeded by a factor exceeding seven. Common Method Bias (CMB) was assessed through Harman's single-factor exploratory test and the full-collinearity VIF approach (Kock, 2015). The dominant factor explained 31.4% of total variance (well below the 50% threshold), and all VIF values were below 3.3, indicating that CMB is unlikely to materially distort the findings.

2 Measures

All constructs were operationalised using multi-item reflective scales drawn from validated instruments in the technology, work-life, and organisational behaviour literatures, subsequently contextualised to the Indian banking setting through a panel review involving three academic experts and two senior bank HR managers. Digital Technology Use (3 items: DTU1, DTU4, DTU5) was adapted from Boswell and Olson-Buchanan (2007). Technology-Induced Role Interference (3 items: TIRI1, TIRI2, TIRI4) was sourced from Derks, Bakker, Peters, and van Wingerden (2015). Time-Based Conflict (3 items: TBC2, TBC3, TBC4) was adapted from Greenhaus and Beutell (1985). Satisfaction Balance (3 items: SB1, SB2, SB4) and Involvement Balance (3 items: IB2, IB3, IB4) were drawn from Kalliath and Brough (2008). Technical Proficiency (4 items: TP1, TP2, TP3, TP4) was sourced from van Wingerden and Poell (2019). Adaptive Use of Technology (3 items: AUT2, AUT3, AUT4) was adapted from Mazmanian et al. (2013). Work-Life Harmony (3

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items: WLH2, WLH3, WLH4) was adapted from Haar et al. (2014). All items were scored on a five-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree). A pilot test with 40 women officers confirmed item clarity and the absence of floor or ceiling effects.

3 Analytical Strategy

Partial Least Squares Structural Equation Modelling (PLS-SEM) was selected as the primary analytical method for three reasons: the study's objectives combine prediction and explanation; the model involves moderately sized subsamples in MGA; and the approach is robust under non-normality of observed variables, which was confirmed by Mardia's multivariate kurtosis coefficient (kurtosis = 4.87) (Hair et al., 2011). SmartPLS 4.0 (Ringle, Wende, & Becker, 2022) was used for all estimations. Analysis followed the two-stage protocol of Anderson and Gerbing (1988): the measurement model was evaluated first for convergent and discriminant validity, and the structural model was then assessed using a 5,000-resample bootstrapping procedure for statistical inference. MGA was subsequently performed using SmartPLS's permutation-based MGA test (Henseler, Ringle, & Sarstedt, 2016), which compares path coefficients between subsamples without parametric distributional assumptions. Effect sizes (f^2), predictive accuracy (R^2), and predictive relevance (Q^2) were computed following Hair et al. (2011).

RESULTS

1 Measurement Model Assessment

Convergent validity was examined using three criteria: outer loadings >= 0.70, Average Variance Extracted (AVE) >= 0.50, and Composite Reliability (CR) >= 0.70 (Fornell & Larcker, 1981; Hair et al., 2011). Table 1 presents all item loadings, AVE, CR, and Cronbach's alpha values alongside construct means and standard deviations. All loadings surpassed 0.70, AVE values ranged from 0.616 to 0.748, and CR values ranged from 0.828 to 0.899, collectively confirming satisfactory convergent validity.

Table 1: Measurement Model — Convergent Validity

Construct / Item	Item	Loading	AVE	CR	Alpha	Mean	SD
Digital Technology Use (DTU)	DTU1	0.821	0.654	0.851	0.813	3.64	0.71
	DTU4	0.809					
	DTU5	0.797					
Technology-Induced Role Interf. (TIRI)	TIRI1	0.843	0.686	0.867	0.831	3.28	0.78
	TIRI2	0.812					
	TIRI4	0.829					
Time-Based Conflict (TBC)	TBC2	0.788	0.636	0.840	0.820	3.17	0.82
	TBC3	0.819					
	TBC4	0.793					
Satisfaction Balance (SB)	SB1	0.802	0.616	0.828	0.807	3.41	0.74
	SB2	0.779					
	SB4	0.764					
Involvement Balance (IB)	IB2	0.817	0.665	0.856	0.833	3.35	0.77
	IB3	0.836					
	IB4	0.798					
Technical Proficiency (TP)	TP1	0.831	0.680	0.895	0.860	3.58	0.69
	TP2	0.814					
	TP3	0.843					
	TP4	0.809					
Adaptive Use of Technology (AUT)	AUT2	0.826	0.689	0.869	0.848	3.47	0.73
	AUT3	0.845					
	AUT4	0.811					
Work-Life Harmony (WLH)	WLH2	0.853	0.748	0.899	0.876	3.52	0.68
	WLH3	0.878					

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Construct / Item	Item	Loading	AVE	CR	Alpha	Mean	SD
	WLH4	0.862					

Discriminant validity was assessed using the Heterotrait-Monotrait (HTMT) ratio criterion (Henseler, Ringle, & Sarstedt, 2015), which requires all inter-construct HTMT values to remain below the conservative threshold of 0.85 to confirm that constructs are empirically distinct. Table 2 presents the full HTMT matrix. All off-diagonal values are below 0.85, confirming discriminant validity across all construct pairs.

Table 2: Discriminant Validity — HTMT Matrix

Construct	DTU	TIRI	TBC	SB	IB	TP	AUT	WLH
DTU	—							
TIRI	0.612	—						
TBC	0.594	0.541	—					
SB	0.487	0.431	0.468	—				
IB	0.503	0.449	0.512	0.631	—			
TP	0.398	0.341	0.362	0.528	0.472	—		
AUT	0.521	0.387	0.403	0.547	0.498	0.614	—	
WLH	0.483	0.519	0.531	0.578	0.564	0.437	0.549	—

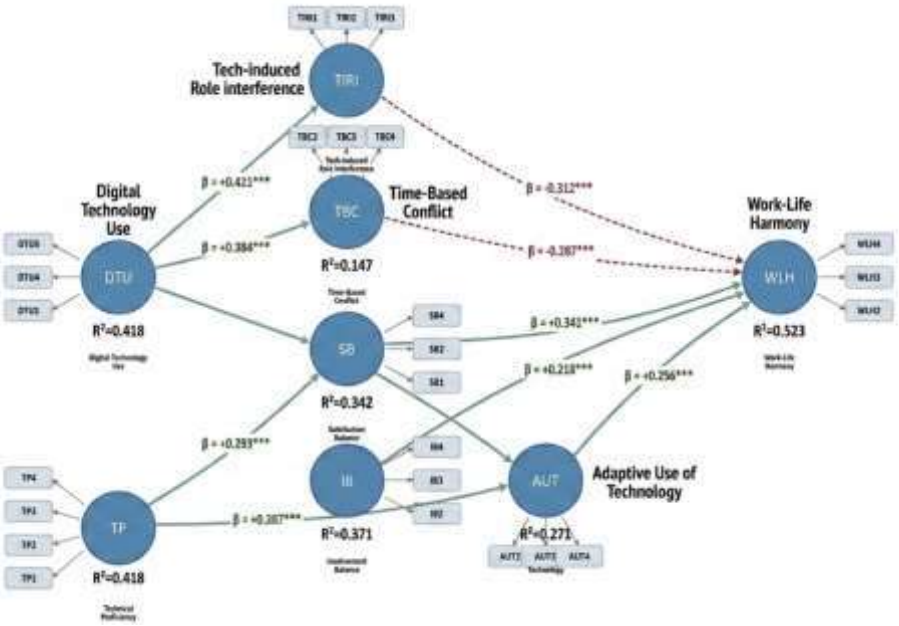

Figure 1. PLS-SEM Structural Model with Standardised Path Coefficients

*Note. Women Officers in Indian Banking (n = 312). Green solid arrows = positive paths; red dashed arrows = negative paths. ** p < 0.001. R^2 values shown below each endogenous construct. Estimation via SmartPLS 4.0.*

2 Structural Model Assessment

The structural model was evaluated using path coefficients (beta), t-statistics computed from 5,000-resample bootstrapping, p-values, and Cohen's f^2 effect sizes. Table 3 presents the full-sample hypothesis testing results. Table 4 reports the model's predictive accuracy (R^2) and predictive relevance (Q^2) for endogenous constructs.

Table 3: Hypothesis Testing Results — Full Sample (n = 312)

H	Path Relationship	beta	SE	t-value	p-value	f^2	Decision
H1	DTU → TIRI	+0.421	0.048	8.771	0.000	0.212	Supported**
H2	DTU → TBC	+0.384	0.051	7.529	0.000	0.173	Supported**

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H	Path Relationship	beta	SE	t-value	p-value	f^2	Decision
H3	TIRI → WLH	-0.312	0.043	7.256	0.000	0.148	Supported**
H4	TBC → WLH	-0.287	0.046	6.239	0.000	0.127	Supported**
H5	SB → WLH	+0.341	0.052	6.558	0.000	0.164	Supported**
H6	IB → WLH	+0.218	0.049	4.449	0.000	0.079	Supported**
H7	TP → SB	+0.293	0.057	5.140	0.000	0.106	Supported**
H8	TP → AUT	+0.387	0.053	7.302	0.000	0.179	Supported**
H9	DTU → AUT	+0.274	0.061	4.492	0.000	0.090	Supported**
H10	AUT → WLH	+0.256	0.058	4.414	0.000	0.093	Supported**

*Note: ** $p < 0.001$; SE = Standard Error; $f^2 < 0.02$ = negligible, 0.02–0.15 = small, 0.15–0.35 = medium, > 0.35 = large (Cohen, 1988).*

Table 4: Predictive Accuracy (R^2), Predictive Relevance (Q^2), and Effect Sizes (f^2)

Endogenous Construct	R^2	Q^2 (Blindfolding)	Interpretation
Technology-Induced Role Interf. (TIRI)	0.387	0.261	Moderate
Time-Based Conflict (TBC)	0.342	0.218	Moderate
Satisfaction Balance (SB)	0.319	0.198	Moderate
Involvement Balance (IB)	0.271	0.163	Moderate
Adaptive Use of Technology (AUT)	0.418	0.284	Moderate
Work-Life Harmony (WLH)	0.523	0.361	Substantial

Note: $R^2 < 0.25$ = weak, 0.25–0.50 = moderate, > 0.50 = substantial (Hair et al., 2011). $Q^2 > 0$ indicates predictive relevance.

All ten hypotheses are supported. Technology-Induced Role Interference registers the largest effect among the WLH predictors (beta = -0.312, $f^2 = 0.148$), followed by Satisfaction Balance (beta = 0.341, $f^2 = 0.164$). Work-Life Harmony achieves an R^2 of 0.523, indicative of substantial predictive accuracy, and $Q^2 = 0.361$ confirms meaningful predictive relevance. Technical Proficiency exerts both a direct positive effect on Satisfaction Balance (beta = 0.293) and a positive influence on Adaptive Use of Technology (beta = 0.387), underscoring its role as a dual resource in the COR framework.

3 Multi-Group Analysis (MGA) Results

MGA was performed using SmartPLS's permutation-based test (Henseler et al., 2016) to examine whether path coefficients differ significantly between public sector (n = 158) and private sector (n = 154) women officers. Table 5 presents the path-specific beta coefficients for each subsample, the inter-group difference, and the p-value for the between-group comparison.

Table 5: Multi-Group Analysis — Public vs. Private Sector Women Officers

H	Path	Public (beta)	Private (beta)	|Diff|	p (MGA)	Sig.
H1	DTU → TIRI	0.391	0.452	0.061	0.147	ns
H2	DTU → TBC	0.348	0.421	0.073	0.089	ns
H3	TIRI → WLH	-0.267	-0.358	0.091	0.031	*
H4	TBC → WLH	-0.241	-0.334	0.093	0.027	*
H5	SB → WLH	0.362	0.319	0.043	0.214	ns
H6	IB → WLH	0.231	0.204	0.027	0.341	ns
H7	TP → SB	0.271	0.314	0.043	0.189	ns
H8	TP → AUT	0.421	0.352	0.069	0.112	ns

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H	Path	Public (beta)	Private (beta)	|Diff|	p (MGA)	Sig.
H9	DTU → AUT	0.249	0.301	0.052	0.178	ns
H10	AUT → WLH	0.289	0.224	0.065	0.042	*

*Note: * p < 0.05; ns = not significant. MGA uses permutation-based test (5,000 permutations). Diff = absolute difference in path coefficients.*

MGA results reveal three statistically significant inter-sector differences, lending support to H11. First, the TIRI-to-WLH path is significantly more negative among private sector officers (beta = -0.358) than among public sector officers (beta = -0.267, |diff| = 0.091, p = 0.031). Second, the TBC-to-WLH depletion path is similarly stronger in the private sector (beta = -0.334 vs. -0.241, |diff| = 0.093, p = 0.027). Third, the AUT-to-WLH gain path is significantly stronger in the public sector (beta = 0.289 vs. 0.224, |diff| = 0.065, p = 0.042), suggesting that adaptive technology behaviours yield relatively greater harmony returns in the less pressured public sector environment. The remaining seven paths do not differ significantly across sectors, indicating that the core resource dynamics linking digital technology use to intermediate balance constructs are broadly invariant across institutional contexts.

Discussion

The overarching aim of this study was to investigate how digital technology use shapes work-life harmony among women officers in Indian banking and to ascertain whether the strength of these relationships varies across public and private sector institutional contexts. The results offer a nuanced picture that both confirms prior literature and generates new theoretical insights.

The support for H1 and H2 that DTU amplifies both technology-induced role interference and time-based conflict is consistent with prior findings from Boswell and Olson-Buchanan (2007) and Derks et al. (2015), and extends them to the Indian banking sector for a gendered subsample. The finding that TIRI exerts a stronger negative effect on WLH than TBC (H3 vs H4) is noteworthy: it suggests that the erosion of psychological role boundaries, rather than objective time scarcity alone, constitutes the more proximal threat to harmony. This aligns with COR theory's emphasis on perceptual resource loss it is the officer's subjective experience of boundary violation, not merely the clock time consumed, that depletes harmony-sustaining resources (Hobfoll et al., 2018).

The support for H5 (SB → WLH) and H6 (IB → WLH) reinforces the multidimensional conceptualisation of work-life outcomes advocated by Haar et al. (2014) and Kalliath and Brough (2008). Officers who perceive equitable satisfaction and involvement across roles are better positioned to sustain the affective sense of harmony even when digital demands are high a finding that points to the importance of subjective balance perceptions as protective resources in the COR sense. The strong effect of SB relative to IB (beta = 0.341 vs. 0.218) further suggests that affective contentment carries more weight in the experience of harmony than cognitive role engagement, a distinction that future research might probe through experience-sampling designs.

The dual-pathway role of Technical Proficiency supporting both SB (H7) and AUT (H8) extends COR theory's treatment of personal characteristic resources to the digital competence domain. Proficient officers are not merely faster at digital tasks; they are better equipped to configure and selectively deploy technology in ways that protect boundary integrity and maintain perceived satisfaction across domains (Sonnentag, 2018; van Wingerden & Poell, 2019). The positive effect of DTU on AUT (H9) indicates that exposure to digital technology is itself a learning mechanism: as officers engage more extensively with digital systems, they develop a richer repertoire of adaptive practices. This gain spiral dynamic is theoretically important because it positions DTU as a dual-edged variable simultaneously depleting (via TIRI and TBC) and enabling (via AUT).

The MGA results confirm H11 in a nuanced way: sector membership moderates the strength of specific, theoretically meaningful paths rather than altering the model's overall structure. The amplification of the TIRI-to-WLH and TBC-to-WLH paths in private sector banks corroborates the characterisation of PVBs as higher-intensity digital environments where interference and time pressure translate more readily into harmony erosion (Joshi & Khanna, 2022). The larger AUT-to-WLH gain path in public sector banks suggests that adaptive behaviours are more consequential for harmony in environments where institutional pressure is lower consistent with COR theory's prediction that resource gains yield proportionally greater returns when baseline resource levels are higher and threat intensity is lower (Hobfoll et al., 2018).

Implications, Limitations, And Recommendations

1 Theoretical Implications

This study makes three contributions to the theoretical literature. First, it extends COR theory to the digital work-life harmony domain by empirically demonstrating both loss spirals (DTU → TIRI/TBC → WLH) and gain spirals (TP → AUT → WLH) operating simultaneously within a single integrated model. Second, it advances the work-life harmony construct by distinguishing between satisfaction balance and involvement balance as separate mediating pathways, demonstrating that affective and cognitive balance facets carry different weights in predicting harmony outcomes. Third, the MGA findings enrich institutional context theorising by demonstrating that sector-specific structural and cultural conditions moderate the translation of digital resource threats and gains into harmony outcomes, cautioning against sector-blind generalisations.

2 Practical Implications

For HR managers in private sector banks, the stronger TIRI and TBC paths to WLH underscore the urgency of implementing structured digital boundary protocols such as mandatory communication blackout windows outside office hours, clear after-hours response-time expectations, and workload monitoring systems that flag excessive connectivity patterns. For public sector banks, the larger AUT-to-WLH gain path suggests that investments in digital training and mentoring programs designed to cultivate adaptive technology practices would yield the greatest harmony dividends, as the institutional environment already provides the baseline resource security needed for such gains to compound. Across both sectors, institutions should consider integrating digital literacy modules into their training curricula that go beyond procedural proficiency to cultivate strategic, boundary-conscious technology use practices. The positive relationship between Technical Proficiency and Satisfaction Balance also implies that competency-building initiatives serve a wellbeing function beyond their direct productivity benefits.

3 Limitations and Future Research Directions

Several limitations warrant acknowledgement. The cross-sectional survey design precludes causal inference; longitudinal or experience-sampling methods would more rigorously test the dynamic loss and gain spiral processes implied by COR theory. The study is confined to four metropolitan cities, limiting its generalisability to semi-urban and rural banking contexts where digital infrastructure and cultural gender norms may differ substantially. Social desirability bias, while addressed through anonymity assurances and CMB tests, cannot be entirely eliminated from self-report survey data. Future research should examine the moderating role of supervisor support and organisational gender climate on the DTU-WLH relationship, test the model in cross-national banking contexts to assess cultural boundary conditions, and explore the role of AI-augmented banking tools whose adoption is accelerating as novel digital demand variables within the COR framework.

Conclusion

This study has investigated the relationship between digital technology use and work-life harmony among women officers in Indian banking, employing PLS-SEM and permutation-based MGA across a sample of 312 respondents drawn equally from public and private sector institutions. Grounded in COR theory, the findings confirm that digital technology simultaneously depletes harmony through role interference and time-based conflict and augments it through adaptive technology practices and balanced role perceptions. The MGA reveals that these dynamics are not sector-invariant: private sector officers bear a heavier harmony cost from digital interference, while public sector officers derive proportionally greater harmony gains from adaptive technology behaviours. These findings carry clear implications for institution-specific HR interventions, digital wellbeing policy, and the development of gender-responsive digital transformation strategies in the Indian banking sector. As technological integration deepens across the financial services industry, understanding and actively managing its gendered consequences for work-life harmony will become an increasingly pressing imperative for organisations committed to equitable and sustainable performance.

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Original Article

Political Participation, Citizenship and Civil Society

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Abstract

Political participation, citizenship, and civil society are fundamental pillars of a democratic system. They ensure the active involvement of individuals in governance, promote rights and responsibilities, and strengthen democratic values. This paper examines the meaning, forms, and significance of political participation, the concept of citizenship, and the role of civil society in fostering democratic engagement. It also highlights contemporary challenges and suggests ways to strengthen democratic processes.

Introduction

Democracy is not merely a system of government but a way of life that requires the active involvement of its citizens. Political participation, citizenship, and civil society are interconnected concepts that ensure the functioning and sustainability of democratic systems. Political participation refers to the involvement of individuals in political processes. Citizenship provides individuals with rights and duties within a state. Civil society acts as a bridge between the state and citizens, enabling collective action and public engagement.

Political Participation

1 Meaning and Definition

Political participation refers to the activities through which individuals express their opinions and influence political decisions. It includes both direct and indirect involvement in political processes.

2 Forms of Political Participation

Political participation can take various forms:
Voting in elections – the most common and basic form
Campaigning and political activism
Protests and demonstrations
Public debates and discussions
Membership in political parties or organizations

3 Importance of Political Participation

Ensures accountability of government
Promotes democratic values
Encourages transparency in governance
Strengthens legitimacy of political systems

4 Factors Influencing Political Participation

Education and awareness
Socio-economic status
Political culture
Media and communication
Government policies

Citizenship

1 Meaning of Citizenship

Citizenship refers to the legal status of an individual as a member of a state, granting rights and imposing responsibilities.

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2 Types of Citizenship
Legal citizenship – status recognized by law
Political citizenship – participation in governance
Social citizenship – access to welfare and social rights
3 Rights of Citizens
Right to vote
Freedom of speech and expression
Right to equality
Right to education and welfare
4 Duties of Citizens
Obey laws
Pay taxes
Participate in democratic processes
Promote harmony and unity
5 Active vs Passive Citizenship
Active citizens participate in governance and civic life, while passive citizens limit their role to basic obligations.
Civil Society
1 Meaning of Civil Society
Civil society refers to voluntary organizations, groups, and institutions that operate independently of the government to represent the interests of citizens.
2 Components of Civil Society
Non-Governmental Organizations (NGOs)
Community-based organizations
Trade unions
Media and advocacy groups
3 Role of Civil Society
Promotes public awareness
Acts as a watchdog on government
Encourages citizen participation
Supports marginalized communities
Facilitates policy dialogue
4 Civil Society in Democracy
Civil society strengthens democracy by ensuring that citizens' voices are heard and by holding authorities accountable.
5. Interrelationship Between Political Participation, Citizenship and Civil Society
These three concepts are deeply interconnected:
Citizenship provides the legal framework for participation
Political participation enables citizens to exercise their rights
Civil society creates platforms for participation and engagement
Together, they form the foundation of a vibrant democracy.
Challenges
1 Declining Political Participation
Voter apathy
Lack of trust in political institutions
2 Inequality in Citizenship
Marginalized groups face barriers
Social and economic disparities
3 Weak Civil Society
Lack of resources
Government restrictions
Limited public engagement
Measures to Strengthen Democracy
Promote civic education
Encourage youth participation
Strengthen civil society institutions
Ensure inclusive policies
Increase transparency and accountability
Conclusion

Political participation, citizenship, and civil society are essential components of a democratic society. Their effective functioning ensures accountability, inclusiveness, and responsiveness in governance. Strengthening these elements is crucial for the development of a just and equitable society.

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I sincerely express my gratitude to my teacher for providing me with the opportunity to complete this project on **"Political Participation, Citizenship and Civil Society."** Their guidance, encouragement, and valuable suggestions helped me understand the topic better.
I am also thankful to my school for providing the necessary resources and a supportive learning environment. My heartfelt thanks go to my parents and friends for their constant support, motivation, and assistance throughout the completion of this project.
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Original Article

Role of Libraries in Education, Research and Society

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Abstract

"Library" "Education" and "Society" are three are inseparable—indivisible concepts, being fundamentally and synchronically related to and co-existent with each other. One cannot be separated from the other, and the existence of one is impossibility without the other. None of them is an end in itself, rather all of them together are a means to an ultimate end. One dies as soon as the other perishes. One survives as long as the other exists. This inter-relation, this co-existence, this dependence of one upon the other have been coming down from the birth of human civilization to the posterity through a process of evolution in accord with varied needs, changes, and circumstances of various stages of human life. Education cannot exist alone in the absence of library, and library has no meaning if it cannot impart education. Education is an eye-opener to a human being and Society

Keywords: *Research, Society, Education, intellectual and technology, Learning*

Introduction

Libraries have been integral to educational and research institutions for centuries, serving as repositories of knowledge and hubs for intellectualactivity. In the modern academic landscape, libraries continue to evolve, incorporating digital technologies and innovative services to meet the diverse needs of students, educators, and researchers. This paper examines the various roles that libraries play inresearch and educational institutions, highlighting their contributions to academic success, research productivity, and community engagement.

The library plays a crucial role in the education system, which is a source of knowledge, inspiration, and learning. It gives the students and teachers broad access to numerous resources and books, journals, digital learning information and technology that improve teaching and learning. In addition to containing information, libraries also encourage reading, research abilities and critical thinking. They provide an engaging space in which students get a chance to pursue concepts, enhance creativity, and acquire lifelong learning skills.The existing digital world is also turning the library into a learning centre that is exciting, striking the balance between the old and the emerging information technology. On the whole, libraries are important in the formation of a well-rounded person throughout the lifelong learning process.

1. Role of the Library in Education

Libraries are associated not only with the students, but they are also useful to teachers. Libraries assist in fostering reading practices, lifelong Learning, literacy, access to information and so on. These are the roles played by libraries in education.

- ***Encourage Reading Habits***: Libraries are important in nurturing the affection of reading in students. Libraries introduce learners to curiosity and encourage them to read other than textbooks by getting them access to a large range of books, magazines, journals, and digital materials.
- ***Enhance Literacy***: Libraries facilitate every kind of literacy reading, writing, digital and information literacy. They provide the materials at different reading levels and interests, assisting the students in enhancing their language and communication skills.
- ***Enhance Academic Achievement***: Academic performance is somehow related to the availability of a well-endowed library. Libraries provide textbooks, reference sources, previous papers, and research databases, which help the students in doing the assignments and practising exams.

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- ***Promotes Critical Thinking Skills***: Libraries also encourage critical thinking skills and information analysis, contrary to taking information at face value. Libraries, as well, allow learners to compare and judge and synthesise ideas since they expose learners to a variety of sources and views.
- ***Promotes Lifelong Learning***: The libraries instil a spirit of lifelong learning that goes beyond school. They also provide means and chances of self-growth, competencies development and gaining new interests of any age. Libraries are always lifelong learning partners, whether one wants to learn a new language, discover the world of science, or study something about themselves.
- ***Helps in Technology Integration***: The contemporary libraries incorporate technology in the learning process through the provision of access to computers and the internet, e-books, as well as online databases. They impart the digital literacy required in the modern world in research and communication. Librarians can also direct the students to make good use of technology by teaching them to work in a digital learning environment and equip them to work in technology-driven industries.
- ***Information Literacy***: Librarians educate students on how to evaluate credibility, reference resources in the appropriate format and how to prevent plagiarism. These competencies are useful to ensure that students are able to perform effective research and informed decisions in academic, professional and personal situations within society, which encourages responsible and ethical usage of information.
- ***Promotes Collaboration***: Libraries are shared group learning spaces where the students share project and discussion assignments. Group areas and resources also encourage teamwork and communication and problem-solving skills.
- ***Promotes Research Skills***: Libraries are key to the acquisition of good research skills. They provide access to reference materials, databases and academic journals. Librarians take students through research processes, including gathering information, processing data and reporting the results.
- ***Skill Development***: Libraries are useful in developing the necessary academic, occupational and personal skills in learners. They conduct writing workshops, communication workshops, digital literacy workshops, and problem-solving workshops.
- ***Curriculum Integration***: Libraries also supplement the classroom instruction by corresponding their resources with the school curriculum. The collaboration between teachers and librarians includes the process of creating reading lists, selecting reference materials, and incorporating library sessions into the lesson.
- ***Develops Cultural Awareness***: Libraries enhance cultural awareness by stocking books and media of other cultures and traditions. They carry cultural shows, exhibitions and events that promote respect to divergent views.

2. **Role of the Library in Research**

Libraries serve as the indispensable backbone of research by acting as a gateway to high-quality information, providing specialized research support, and facilitating the dissemination of new knowledge. Modern research libraries go far beyond storing books; they are active partners in the research lifecycle, helping researchers find, organize, and publish their work effectively.

- ***Libraries and Research SupportAccess to Information Resources:*** One of the primary functions of libraries in research institutions is to provide access to a vast array of information resources, including books, journals, databases, and digital content. These resources are essential for conducting comprehensive literature reviews, accessing current research, and supporting evidence-based practices.
- **Research Assistance and Information Literacy:** Libraries offer a range of services to support researchers, including reference assistance, research consultations, and information literacy instruction. Librarian's help researchers develop effective search strategies, navigate complex databases, and evaluate the credibility of sources.
- ***Institutional Repositories and Open Access***: Libraries also play a significant role in promoting open access to research outputs through institutional repositories. These repositories provide a platform for researchers to share their work with a global audience, increasing the visibility and impact of their research.
- ***Support for Data Management***: In the era of big data, libraries offer essential support for research data management. They provide guidance on data organization, preservation, and sharing, ensuring that research data are accessible and reusable. The Digital Curation Centre underscores the importance of libraries in promoting best practices in data management and supporting the integrity of the research process.

3. **Role of the Library in Society**

Libraries have long been seen as pillars of knowledge and education, providing society with the tools and resources necessary for personal growth, academic achievement, and community development. In an age defined by rapid technological change, the role of libraries has evolved significantly, adapting to meet the needs of the modern world while preserving their foundational mission of fostering access to information. Today, libraries are not just places where books are stored; they are dynamic community centres that support education, encourage lifelong learning, and contribute to the cultural and intellectual vitality of society.

- ***Libraries as Centers of Education and Knowledge***: One of the most important roles of libraries is their contribution to education. Libraries provide access to vast amounts of knowledge, ranging from academic

journals and textbooks to e-books and multimedia resources. For students, libraries are invaluable academic resources, offering access to essential materials for coursework, research, and self-study.

- ***Libraries as Catalysts for Social Equity and Inclusion***:Libraries are unique in that they serve as equalizers within society, providing access to information and services for all individuals, regardless of their socioeconomic status. In many communities, libraries are one of the few public institutions that offer free access to resources such as books, computers, and the Internet. In regions where access to technology is limited, libraries act as vital points of connection to the digital world.
- ***Libraries as Cultural and Community Hubs***: Libraries are much more than just spaces for reading and research; they are central to the social and cultural fabric of communities. They serve as gathering places where people can come together to engage in shared experiences, exchange ideas, and connect with one another. Many libraries host cultural events such as art exhibitions, music performances, and author talks, which foster intellectual and creative engagement within the community.
- ***Libraries as Innovators and Creators***:In recent years, libraries have embraced innovation by integrating technology into their services and offerings. Many libraries now feature makerspaces, where individuals can engage in hands-on activities like 3D printing, robotics, digital media creation, and coding.
- ***The Future of Libraries in Society***: As technology continues to evolve, the role of libraries will continue to change, but their core mission of providing equitable access to information will remain steadfast. Libraries will increasingly focus on digital inclusion, ensuring that individuals have access to the digital tools and resources they need to thrive in the modern world.

Conclusion

Libraries are indispensable to research and educational institutions, providing access to information, fostering information literacy, and supporting academic success. Their roles in promoting open access, data management, and community engagement further enhance their value in the academic landscape. The evidence from case studies and research highlights the critical contributions of libraries to the advancement of knowledge and the enrichment of the educational experience. Continued investment in library resources and services is essential to support the evolving needs of students, educators, and researcher.

The role of libraries in society is multifaceted and far-reaching. They serve as educational centres, cultural hubs, and engines of social change, promoting access to information, fostering lifelong learning, and contributing to the development of informed and engaged communities. Libraries are integral to creating a more equitable, inclusive, and innovative society, and as they continue to adapt to the demands of the digital age, their impact will only grow. In an era marked by rapid technological advancements and societal challenges, libraries remain steadfast in their commitment to providing access to knowledge, fostering intellectual and cultural growth, and ensuring that everyone has the opportunity to succeed.

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I would like to express my sincere gratitude to my teacher for giving me the opportunity to complete this project on **"Role of Libraries in Education, Research and Society."** Their guidance, encouragement, and valuable suggestions helped me complete this project successfully.

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Inclusive Growth in India a study of welfare schemes & Economic Development

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Abstract

Development economics focuses on improving the economics & social conditions of developing nations social welfare, on the other hand, emphasizes the well being and quality of life of individuals this study examires the impact of social welfare scheme on the socio economic development of scheduled Tribes (STS) In Rampachodavaram fousing on education scholarships, helth care subsidies, housing schemes, livelihood support programs & infrastructure development project this paper examines the relationship between development economics and social welfare highlighting key indicators, challenges & policy measures the study concludes that economics growth alone is insufficient unless it is incisive and contributes to overall human development.

Introduction

Development economics is the concert of with the economics transformation countries transformation of income countries into modern industrial economics economic development is a many sides phenomenon, but one of main aspeets he is the welfare of the people the relation between economic growth and welfare is not always direct . There are many Narrow places , many reversed direction and given many oppositey moving places key study focus on policy meehanisms social sector expenditure and metrics like the human development index (HDI) to evaluate welfare improvement The impact of the social welfare scheme on the socio economic development of STS is a topic of significant interest and important understanding the effectiveness of these scheme requires a through analysis of their implementation coverage & outcomes statistical data plays a crucial role in this analysis providing in sight into the programs made and The challenges that remain

Objective of the study

- to analysis the concept of development economics
- understand the meaning and importance of social welfare
- two examine the relationship between economic development and welfare 4 to suggest of policy measure for improving social welfare

Research methodology

The data has been collected from the secondary sorces like jounrals , on line aritcals , Government website, books etc.

Relationship between development economics and the social welfare

Economic growth & economic equality must go hand in hand equalization before can also be accelerated mini eligible of texture challenges namely thought socio religious philanthropic instruments such as a optimizing zakat ,infaa, alms & productive such as optimizing marginalized groups provision affo basic physical facilities & implement of the quality of a education at higher level is the most rational long term investment for the providing superior human resource the capacity development Mars fundamental paradigms shift in public policy social welfare is no longer merely as safety at beach is the char table aur simply a burden on the state budget but rather as a straigy for accommodating women capital which are very productive

Peiviousaly economic growth was associated with development lading to arace to achieve greather grosee income at any cost but people have realised that economy growth is

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only ancessary condition not a sufficient condition for development in other words attention should pet not only to growth rates but also the quality of growth the way growth is the achieved who are the players what mechanism will take shape and who will benefit for mom the growth as a resource Richa countries (oil precious metals) authorise transnational companies to explore export and share profits their per capita income increase rapidly & may reach aver high level but only a small number of upper class people

Main objectives of economic development

The ultimate goal is not simply achieving aggregate real per capita income growth but rather achieving through prosperity and empowering local communities in an inclusive manner, economic development will be much more effective if supported by holistic improvements in human resource management across all sector optimizing these resources requires the synology of talent from various elements of society and professions to create local innovation and increase regional competitiveness, further more, the contribution and proactive role of local community leader crucial cataliysts in identifying hiddle potential at the grassroots level qualitative factors, such as empowerment, independence and work. Readiness strengthening the organism capacity of the community, has 21 to be very vital in driving The wheels of the economy of a reason to be more resilent in facing fluctuations in do global economy crisis.

To understand the awareness of social welfare schemes of the tribal community regarding the implementation and impact of social welfare schemes policies.

Definition and scope of development economics

Humans are human desires for products both good and services that we full feed by humans or society in order to maintain survival and achieve human well-being. This basic needs have given rise to a more comprehensive economic medset, where economic development cannot be reduced to merely aur series of statistical growth figures, but rather is a multi dimensional process involving radical changes in social structures, societal attitudes improvements to National institutions development economics is not only concerned with the accumulation of physical capital or microeconomic figures alone but also emphasis structural transformation, institutional modernization and more efficient bureaucratic governance. Comprehensive understanding of these issue often require analytical tools from various other scientific fields. Including strategic management and sociology, to defect the roots of structural inequality and for mulatc public politics that are adaptive to global change. Essentially this discipline examination country s transition stagnant traditional economy to a modern industrialised economic order can be carried out while minimising social socks.

Challenges in integrating social welfare into policy

While Social welfare essential , integrating it into government decisions come with challenges.

1. Financial constraints -

These pose a singficient of challenges implementing welfare programs, as they required substantial funding that can place a burden on national budget heavily. Cases were limits, countries risk economic ingreece generous subsidies benefits contributed to server fisal distress striking the write balance between providing essential social support and maintaining economic health remains a complex task for policy makers worldwide.

2. Implementation barriers-

Even well intended policies often encounter significant executive challenges that hinder their effectiveness corruption and resource linkage re remind major obstacles as scene in India public distribution system (PDS) where inefficiencies and the deversion of supply how limited the programmes reach. Dictionary a lack of prevent many eligible beneficiaries from accessing welfare benefits, particularly in community with high illiteracy rates and inadequate outreach efforts. Regional disparities harder complicated implementation with like Kerala excelling in health care and education.while others struggle to provide basic services, necessitating tailored welfare solutions to address local news effectively.

Key social welfare policies and schemes in India

MGNREGA (2005)-

The full form of MGNREGA is Mahatma Gandhi National rural employment guarantee 2005 and the scheme was officially launched on 2nd February 2006 eligibility requirement for applicant must be an Indian citizen and 18 year of age or above.MGNREGA act guarantee,ensuring manual labor as legal rights and promoting livehihood security Central Government girls 100% labour cost and 75% of material cost of state government contribute 25% of material cost ensuring cooperative federalism for implementation .

... Sami and A. Khan (2016) Int. J. Soc. Sc. Manage. Vol. 3, Issue 4: 281-286

Table 3: Demographic Profile of the Respondents

Demographic Profile of the Respondents	Attributes	Districts				Total
		Rampur	Moradabad	Kanpur	Etawah	
Age of the Respondents	30-40	14	18	21	13	66
	41-50	16	16	18	11	61
	51-60	5	6	6	6	23
	Total	35	40	45	30	150
Family status of the Respondents	Joint	31	37	41	26	135
	Nuclear	4	3	4	4	15
	Total	35	40	45	30	150
Educational Status of the Respondents	Illiterate	26	28	37	21	112
	Primary	9	12	8	9	38
	Total	35	40	45	30	150
Condition of the House of the Respondents	Kuchha	30	33	38	22	123
	Semi-Pucca	5	7	7	8	27
	Total	35	40	45	30	150

Source: Primary Data

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Table shoes obrief demographic profile of the selcted respondents majority of the respondents where belong to the age group was education of 30-40 your side and family system at education offer respondents in concerned. Majority where found to be illiterate however 123 wear leaving in kuccha houses wheres 27 were semi pucca houses.

NFSA -(2013)

National food security Act, 2013 converts into legal entitlement for existing food security programs of the Government of India. It includes the mid day meal scheme scheme. Integrated child development services scheme and the public distribution system further the NSFA 2013 recognizes maternity entitlements the midday meal scheme and the integrated child development services scheme are universal in nature whereas the PDS will reach about two-third of population (75% in rural areas and 50% in urban areas)

Under the provisions of the Act beneficiaries of the public distribution system are intime to 5 kilograms at the following prices.

*Rice at ₹ 3 (3.2 C US) per kg.

*Wheat at ₹ 2(2.1C US) per kg.

*Coarse grains (millet) at ₹ (1.1C,US), per kg.

Those with antyodaya entitled to 35 kg per month at the same prices as above.

The I also gluts the midday meal (MDM), the integrated child development services (ICDD) and maternity intime entertainments., while the MDM and ICDS where pre - existing Tum Sauda union government universal maternity entitlements where created under the NFSA 2013 for the first time. 2017 ,these entitlements operation lized Pradhanmantri Matru Vandana Yojana. For the ICDS and MDM, pregnant women , Hello Kitty mothers and children are eligible for daily free mills in Government schools and Anganwadi centres.

3.RTE -Act2009-

Right to education with a human right set out 21A of the Indian constitution that guarantees and compulsory education that every child receives a good quality education in school by fastering their potential for excellence now starts from early childhood at home within the community and at school.

*Benefit of the rightto education-

1. Free and compulsory education-

All children between the ages of 6-14 yours are provided free and compulsory education in neighbourhood schools till there 14th year. According to this Act, cal School private government once from primary level up to higher secondary level will be provided within financial assistance to impact quality education without any costs, creed, gender aur social background discrimination.

2. Data collection-

Data collected by the schools will be used for packing the progress of this children the entire country.

3.meticulousness -

Data will be submitted district management committees as well as did Government and their is the provision of penalty for non completion of Data collection from time to time during a period of 5 years or more.

Right to education includes the provision of free text books and miniforms along with free mid day meals.

Sr. No.	Academic Year	Number of Students Admitted
1	2013-14	432
2	2014-15	12,605
3	2015-16	27,929
4	2016-17	45,869
5	2017-18	55,277
6	2018-19	74,456
7	2019-20	94,082
8	2020-21	75,213
9	2021-22	62,290
10	2022-23	64,395
11	2023-24	52,221
12	2024-25	39,996
Total	604,765	

Key Fetuars of PMAY-G

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- Enhancement of unit assistance from Rs. 70,000 to Rs. 1,20,000 in plains and from Rs. 75,000 to Rs.1,30,000 in hilly States, difficult areas and IAP districts. The cost of unit (house) assistance is to be shared between Central and State governments in the ratio 60:40 in plain areas and 90:10 for north-eastern and hilly States.
- Identification of beneficiaries using SECC-2011 data. The identification and selection of the beneficiaries shall be done by the community through the Gram Sabha, from the SECC 2011 list, based on the housing deficiency and other social deprivation parameters.
- The beneficiaries of PMAY-G. in addition to being provided financial assistance. shall also be offered technical assistance in the construction of the house. If the beneficiary so chooses, he/she will be facilitated to avail loan from financial institutions for an amount of up to Rs. 70,000. A special module for orientation of beneficiaries for demystifying concepts of construction costs and process. All payments through DBT to beneficiary's Bank/Post office accounts registered in AwaasSoft MIS.
- Provision of toilets at Rs. 12.000 and 90/95 days of unskilled wage labour under MGNREGA over and above the unit cost.
- Use of effective convergence for provision of electricity, piped drinking water facility, rainwater harvesting, LPG gas connection under Ujjwala scheme, solar initiatives, backyard fruit plants, poultry, goatery, dairy shed, solid and liquid waste management, etc.
- Creating a menu of housing designs based on local typologies incorporating local materials, traditional knowledge and aesthetics. Specially designed mason training certificates proforma on-site to improve the quality of homes and enhance the skills of participants.

Various Housing Schemes of the Government of India

Sl.No	Housing Schemes	Launched Year
1	Integrated Subsidized Housing Scheme for Industrial workers and Economically Weaker Sections	1952
2	Low Income Group Housing Scheme	1954
3	Subsidized Housing Scheme for Plantation Workers	1956
4	Middle Income Group Housing Scheme	1959
5	Rental Housing Scheme for State Government Employees	1959
6	Slum Clearance and Improvement Scheme	1956
7	Village Housing Projects Scheme	1959
8	Land Acquisition and Development Scheme	1959
9	Provision of House Sites of Houseless Workers in Rural Areas	1971
10	Environmental Improvement of Urban Slums	1972
11	Sites and Services Schemes	1980
12	Indira Awas Yojana	1985
13	Night Shelter Scheme for Pavement Dwellers	1990
14	National Slum Development Programme	1996
15	2 million Housing Programme	1998
16	Valmiki Ambedkar Malin Basti Awas Yojana	2000
17	Pradhan Mantra Gramodaya Yojana	2001
18	Jawaharlal Nehru National Urban Renewal Mission	2005
19	Pradhan Mantri Adarsh Gram Yojana (2009-10)	2009
20	Rajiv Awas Yojana	2011
21	Pradhan Mantri Awas Yojana- Housing for all	2015

(Source: Various reports of Government of India, Ministry of Housing, Ministry of Urban Development and Poverty alleviation)

NSAP (pension)-

International social system program launched in 1995 is central sponsored in India providing social pensions to the elderly, video and disabledon below the probability line (BPL) research indicators the scheme significantly improves the financial stability. What is security at the and well being of beneficiaries, thought it faced challenges with lock coverage inadequate pension amount (Rs 200-500) and implementation days.

Impact-

1. Financial security-
   Buy providing steady monthly pension support NSAP has helped to to reduce the economic valunerability of widows, folder people and people with disabilities.
2. Complementary support-

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Bye encouraging States to create and executive Ocean plans the central plan has increased coverage and benefits over the bare minimum required by the federal government.

3. Targeted approach-
   Program acknowledges the increasing dangerous and disprivations faced by socially vulnerable groups and targets them individually
4. Expensive coverage-
   With nearly 4.65 crore beneficiariers annual leave NSAP extension reach across rural and urban areas in all states and UTS.
5. Foundation for social protection-
   NSAP studies law Nation world framework for social protection that can be expanded and improve upon.
   Havewer ,the relatively low pension amounts Rs 200-500per month) restricted transformative potential of Progress –

Financial Year	Total Funds Allocated to BBBP	Funds Allocated for Media/ advocacy
FY15	Rs. 34.87 crore (US$ 5.7 million)	Rs. 21.46 crore (US$ 3.5 million)
FY16	Rs. 59.37 crore (US$ 9.1 million)	Rs. 21.01 crore (US$ 3.2 million)
FY17	Rs. 28.66 crore (US$ 4.3 million)	Rs. 25.84 crore (US$ 3.9 million)
FY18	Rs. 169.1 crore (US$ 26.2 million)	Rs. 135.92 crore (US$ 21.1 million)
FY19	Rs. 244.73 crore (US$ 35.0 million)	Rs. 164.04 crore (US$ 23.5 million)
FY20	Rs. 85.78 crore (US$ 12.2 million)	Rs. 25.75 crore (US$ 3.7 million)
FY19	Rs. 244.73 crore (US$ 35.0 million)	Rs. 164.04 crore (US$ 23.5 million)
FY20	Rs. 85.78 crore (US$ 12.2 million)	Rs. 25.75 crore (US$ 3.7 million)
FY21	Rs. 60.57 crore (US$ 8.3 million)	Rs. 7.02 crore (US$ 0.96 million)
FY22	Rs. 57.13 crore (US$ 7.7 million)	-
FY23	Rs. 90.36 crore (US$ 11.5 million)	Rs. 0.21 crore (US$ 0.03 million)
Total	Rs. 830.57 crore (US$ 120 million)	Rs. 401.25 crore (US$ 59.9 million)

In the first 9 years of implementation the BBBP skin has been successful in improving key performance Matrix outlander in its targeted objectives. Tupatar boost success of the program the government plants to carry out of detailed a district level survey to evaluate progress and detect hurdles to implementation. Dasarve would be conducted by an independent agency in collaboration with me the IO the primary goals of the survey is to find raised to strengthen execution of the scheme in low performing States.

the especially inflation and rising living cost over the year since the amounts were fixed.

Beti bachao beti padhao employment (BBBP)

The Indian government introduced to death of Beti bachao beti padhao scheme to address concerns of gender discrimination and women empowerment in the country the scheme sims to educate citizen for gender bians improve efficacy of welfare services for girls it was launched with hand initial funding of rupees 100 crore.

Objectives-

1. Brother child sex ratio.
2. Ensure gender equality and women empowerment.
3. Prevent gender biased, sex select elimination.
4. Ensure survival and protection of the girl child.
5. Uncourage education and participation of the girl child.

sanitation-swachh Bharat abhiyan (SBM)-

Recognising the need for urgentaction sanitization front on 2 October 2014 the birth anniversary of Mahatma Gandhi prime minister Narendra Modi announcedure India swachh Bharat mission to enhance the *Broad- based engagement SBM set up to swachh Bharat kosh to encourage corporate social responsibility and accept contributions from private organisation individual and philanthropist.

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Table 1: Details of funds allocated and the funds released for SBM (2015-19)

Years	₹ (in Crore)		
	Funds Allocated	Funds Released	Fund Utilization (per cent)
2014-15	2850.0	2730.3	95.8
2015-16	6525.0	6363.0	97.51
2016-17	10513.0	10272.0	97.70
2017-18	16948.27	16610.9	98.0
2018-19 (RE) *	14478.1	12932.96	89.3

* (up to 31.03.2019)

Source: Ministry of Drinking Water and Sanitation

As a result of the efforts of the government has on date 98.9% of India has been covered the under SBM . Since October 2014 over 9.5 crore toilets have been build all over the country the total number of householder toilets construct constructed from 2014 till 2018 so jazz rapid progress over The Last of Us starting from less than 50 lakh householder toilet per year and reaching up to over 3 crore toilets per year a major focus of SBM has been on making village open defecation free (ODF).

Role of welfare schemes in inclusive growth

1 Poverty reduction

Growth elasticity studies show that economic growth reduces multimensional poverty significantly.

2. Employment generation-

Rural employment themes riddles distress migration.

3 Human development-

Improved excess to health and education.

4 . financial inclusion -

Jan dhan Yojana promote banking access.

5. Regional development-

Welfare schemes reduce reasonal disparities.

6. Impact Analysis-

Indicator	Impact of welfare schemes
Poverty.	Decline in multidimensional poverty
Employment.	Increasing rural employment
Health.	Improved healthcare access.
Education.	Higher enrolment rates.
Inequality.	Partial reduction

Studies indicate that social sector expenditure positively contribute to inclusive growth, thrown out all skins are equally effective.

*Challenge in achieving inclusive growth

1. Enequality-

Growth benefits are unevenly distributed.

2. Implementation issues

*LinkedIn corruption

*Poor tar geting

3. Reasonal disparities -

Some States lag behind.

4.fisal burden -

Excessive subsidies may affect long term growth.

Conclusion -

English growth in India represents not merely any economic objective but broader socio economic commitment to ensure that the benefits of development are equitably shared across all sections of society. The analysis of major welfare schemes such as MGNREGA,NFSA,RTE Act 2009 ,PM-JAY,P MAY,NSAP, Beti bachao beti padhao swachh Bharat mission clearly indicates that this initiative how playered a transformative poverty improving Human development indicators and enhancing social security. In conclusion, welfare schemes have laid strong foundation for inclusive growth in India, but they are success ultimately depends on effective implementation, continuous policy innovation and integration with broader economic , reforms achieving inclusive growth is not a one time on going process that require alternated action between the government provide sector and civil society only for such a comprehensive and inclusive approach can India ensure sustainable development that benefits of its citizens.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Interdisciplinary Horizons: Pathways to Innovation, Sustainability and Global Development – A Conceptual Review

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Abstract

The growing complexity of global concerns such as climate change, digital transformation, and socioeconomic inequality needs interdisciplinary methods that combine knowledge from several fields. This review study investigates how interdisciplinary integration stimulates creativity, which in turn promotes sustainability and contributes to global development. The study takes a conceptual approach, integrating previous material and presenting a structured framework that emphasizes the sequential relationship between interdisciplinary collaboration, innovation, sustainability, and global development. Furthermore, the role of moderating elements including policy, financial resources, and infrastructure is investigated. The findings underline the importance of interdisciplinary collaboration in promoting long-term innovation and inclusive global progress.

Keywords: *Interdisciplinary Integration, Innovation, Sustainability, Global Development, Moderation, Systems Thinking*

Introduction

The modern world has interrelated difficulties that extend beyond traditional disciplinary lines. Issues like environmental deterioration, technological disruption, and economic injustice necessitate integrated solutions that draw on expertise from other fields. Interdisciplinary research has developed as an effective strategy for addressing such complex difficulties by encouraging collaboration, information exchange, and innovation.Sustainability and global development are inextricably linked, and innovation plays an important role in bridging the two. However, obtaining sustainable outcomes necessitates not only technology breakthroughs, but also social and institutional transformation. This underscores the importance of a comprehensive framework that explains how interdisciplinary integration promotes creativity and sustainability, ultimately leading to global development.

Theoretical Background

Interdisciplinary study combines knowledge, methodologies, and viewpoints from other fields to approach complex problems. It encourages teamwork, systemic thinking, and innovation. Sustainability is described as addressing current demands without jeopardizing future generations. It includes environmental, social, and economic factors that are inextricably linked.

Innovation is critical to attaining sustainability since it allows for technological improvements, social transformation, and the development of new economic models such as eco-innovation and circular economies. The combination of interdisciplinary methods and innovation enables sustainable solutions in sectors such as energy, healthcare, and finance. Furthermore, systems thinking and interdisciplinary education improve the ability to confront global concerns by encouraging innovation, critical thinking, and collaborative problem solving.

Literature Review

1 Interdisciplinary Integration

Interdisciplinary integration has gained significant attention as a means of addressing complex global challenges that cannot be solved within the boundaries of a single discipline. According to Julie Thompson Klein, interdisciplinarity involves the integration

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of knowledge and methods from different disciplines to create a more comprehensive understanding of complex issues. Similarly, Allen F. Repko emphasizes that interdisciplinary research enhances problem-solving capacity by synthesizing diverse perspectives.

Studies suggest that interdisciplinary collaboration promotes innovation by enabling knowledge exchange and systems thinking. Helga Nowotny highlights that modern research increasingly operates in a "Mode 2" knowledge production system, where collaboration across disciplines is essential for addressing real-world problems.

2 Innovation as a Mediating Mechanism

Innovation plays a central role in transforming interdisciplinary knowledge into practical solutions. Joseph Schumpeter defines innovation as the process of creating new combinations of resources that drive economic development. In the context of sustainability, innovation extends beyond technological advancements to include social and organizational dimensions.

Henry Chesbrough introduced the concept of open innovation, emphasizing the importance of collaboration and knowledge sharing in fostering innovation. Furthermore, Clayton Christensen argues that innovation can transform industries and create new markets, highlighting its significance in addressing global challenges.

3 Sustainability Dimensions

Sustainability is a multidimensional concept encompassing environmental, social, and economic aspects. John Elkington introduced the "Triple Bottom Line" framework, which integrates these three dimensions of sustainability.

Environmental sustainability focuses on resource conservation and climate change mitigation, while social sustainability emphasizes equity, inclusion, and community well-being. Economic sustainability ensures long-term growth and stability. According to United Nations, sustainable development aims to balance these dimensions to meet present needs without compromising future generations.

4 Global Development

Global development refers to efforts aimed at improving living standards, reducing inequality, and promoting sustainable economic growth. The adoption of the Sustainable Development Goals (SDGs) by the United Nations provides a comprehensive framework for achieving global development.

Research indicates that innovation and sustainability are key drivers of global development. Jeffrey Sachs emphasizes that achieving the SDGs requires integrated approaches that combine economic, social, and environmental strategies.

5 Role of Moderating Factors

The effectiveness of interdisciplinary integration and innovation in achieving sustainability and global development is influenced by several external factors. Government policies play a critical role in providing regulatory support and incentives. Financial resources enable investment in innovation and sustainable practices, while infrastructure facilitates implementation.

According to Douglass North, institutions and governance structures significantly influence economic and social outcomes. Similarly, Daron Acemoglu highlights that strong institutions and policies are essential for sustainable development.

Research Gap

Despite the expanding literature on transdisciplinary research, numerous gaps remain:

1. Lack of Integrated Models: The majority of research focus on either innovation or sustainability individually. There is minimal research that combines interdisciplinary approaches, innovation, sustainability, and global development in a unified framework.
2. Limited empirical evidence: Many studies are conceptual or theoretical. Empirical validation through data-driven methodologies, such as SEM and regression models, is necessary.
3. Developing Country Perspective is Underexplored: The current literature is dominated by developed economies. There is little focus on developing countries such as India, where interdisciplinary techniques might have a substantial influence.
4. Weak Link Between Innovation and Sustainability Outcomes: There is a weak link between innovation and sustainability outcomes. Although innovation is extensively discussed, its direct measurable impact on sustainability characteristics is not well understood.
5. Lack of emphasis on moderating variables.: Few studies explore how policy support, infrastructure, and funding impact transdisciplinary collaboration and outcomes.
6. Sector-specific gaps: There is limited research in Integrated education systems for transdisciplinary learning.

- MSMEs are implementing sustainable innovation.
- Interdisciplinary techniques for rural development.

Research Methodology

1 Research Design

This study adopts a **qualitative review-based research design** to examine the role of interdisciplinary integration in driving innovation, sustainability, and global development. The paper is conceptual in nature and focuses on synthesizing existing literature to develop a comprehensive framework.

2 Data Sources

The study is based on **secondary data** collected from:

- Peer-reviewed journal articles
- Books and book chapters
- Reports from international organizations (e.g., UN, World Bank)
- Conference proceedings

Databases such as:

- Google Scholar
- Scopus-indexed journals
- Web of Science

were used to identify relevant literature.

3 Literature Selection Criteria

The selection of literature was guided by the following criteria:

- Relevance to interdisciplinary research, innovation, sustainability, or global development

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- Publications in peer-reviewed journals
- Studies published primarily between 2000 and 2025
- Highly cited and influential theoretical contributions

Irrelevant, duplicate, and non-scholarly sources were excluded to ensure quality and reliability.

4 Analytical Approach

The collected literature was analyzed using a thematic analysis approach, where key themes and patterns were identified and categorized under major constructs:

- Interdisciplinary Integration
- Innovation
- Sustainability
- Global Development
- Moderating Factors

This process enabled the identification of relationships among variables and the development of a structured conceptual framework.

5 Development of Conceptual Framework

Based on the synthesis of literature, a conceptual model was developed to illustrate the sequential relationships between interdisciplinary integration, innovation, sustainability, and global development. The framework also incorporates moderating variables such as policy, infrastructure, and financial resources.

6 Limitations of the Study

- The study is based on secondary data, which may limit empirical validation
- Potential selection bias in literature inclusion
- Findings are conceptual and require future empirical testing

Conceptual Framework

The proposed conceptual framework illustrates that interdisciplinary integration acts as the primary driver of innovation, which subsequently leads to sustainability outcomes, ultimately contributing to global development. The framework also incorporates moderating factors that influence key relationships within the model.

1 Core Constructs:

1. Interdisciplinary Integration (Independent Variable)

- Collaboration across disciplines (technology, economics, environment, social sciences)
- Knowledge sharing and systems thinking
- Cross-sector partnerships (academia–industry–government)

2. Innovation (Mediating Variable)

- Technological innovation (AI, IoT, digital platforms)
- Social innovation (inclusive models, community solutions)
- Business model innovation (circular economy, green finance)

3. Sustainability (Intermediate Outcome)

- Environmental sustainability (resource efficiency, climate action)
- Social sustainability (equity, inclusion)
- Economic sustainability (long-term growth)

4. Global Development (Dependent Variable)

- Achievement of SDGs
- Inclusive economic growth
- Global collaboration and resilience

5. Moderating Factors

- Government policies
- Financial resources
- Institutional support
- Digital infrastructure

The framework highlights that interdisciplinary integration is essential for fostering innovation. By combining knowledge from multiple disciplines, organizations and institutions can develop innovative solutions that address sustainability challenges.

Innovation acts as a critical mediator that transforms interdisciplinary knowledge into practical outcomes. These outcomes, when aligned with sustainability principles, contribute to balanced environmental, social, and economic development.

The role of moderating factors is particularly significant. Supportive policies, adequate financial resources, and strong infrastructure enhance the effectiveness of innovation and sustainability initiatives. Without these factors, even highly innovative solutions may fail to achieve desired outcomes.

Figure 1: Conceptual Framework Model

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Table 1: Components of the Conceptual Framework

Component	Construct	Description	Expected Outcome
Independent Variable	Interdisciplinary Integration	Collaboration across disciplines, systems thinking, and knowledge sharing	Strong knowledge base
First-Level Mediator	Innovation	Technological, social, and business innovation	Creative and practical solutions
Second-Level Mediator	Sustainability	Environmental, social, and economic sustainability	Balanced and sustainable outcomes
Dependent Variable	Global Development	Achievement of SDGs, inclusive growth, and global partnerships	Sustainable global progress
Moderating Variables	Policy, Infrastructure, Finance	External support systems influencing relationships between constructs	Strengthens or weakens relationships

Source: Author's conceptualization

Table 1 presents the key components of the proposed conceptual framework, outlining the roles of each construct in the model. Interdisciplinary integration is treated as the independent variable driving innovation, which in turn influences sustainability outcomes and ultimately leads to global development. The framework also incorporates moderating variables such as policy, infrastructure, and financial resources, which affect the strength and direction of relationships between the constructs.

Table 2: Structural Relationships in the Conceptual Model

From	To	Arrow Type	Effect
Interdisciplinary Integration	Innovation	Solid ↓	Enhances knowledge integration and creativity
Innovation	Sustainability	Solid ↓	Facilitates sustainable solutions
Sustainability	Global Development	Solid ↓	Drives inclusive global progress
Moderating Variables (Policy, Infrastructure, Finance)	Innovation → Sustainability	Dashed →	Strengthens or weakens the relationship
Moderating Variables (Policy, Infrastructure, Finance)	Sustainability → Global Development	Dashed →	Influences outcome effectiveness

Source: Author's conceptualization

Table 2 illustrates the structural relationships among the key constructs in the proposed conceptual model. The solid arrows indicate direct causal relationships, where interdisciplinary integration enhances innovation, innovation facilitates sustainability, and sustainability drives global development. The dashed arrows represent moderating effects, showing that policy support, financial resources, and infrastructure influence the strength and direction of the relationships between innovation and sustainability, as well as between sustainability and global development.

Practical Implications and Suggestions

1 Practical Implications

The proposed conceptual framework offers valuable implications for policymakers, industry practitioners, and academic institutions by highlighting how interdisciplinary integration can drive innovation and sustainability, ultimately contributing to global development.

1. Policy Implications

Governments should promote **interdisciplinary collaboration** through supportive policies, funding mechanisms, and institutional frameworks. Policies encouraging innovation ecosystems, green technologies, and sustainable practices can strengthen the link between innovation and sustainability outcomes.

2. Industry Implications

Organizations can adopt **interdisciplinary approaches** by integrating technological, environmental, and social perspectives into their business strategies. Firms focusing on eco-innovation, circular economy models, and digital transformation can enhance both sustainability and competitiveness.

3. Educational Implications

Educational institutions should design **interdisciplinary curricula** that foster critical thinking, creativity, and problem-solving skills. Integrating sustainability and innovation into academic programs can prepare students to address complex global challenges.

4. Infrastructure and Institutional Support

Strong infrastructure and institutional mechanisms are essential for translating innovation into sustainability outcomes. Investment in digital infrastructure, research facilities, and collaborative platforms can improve implementation efficiency.

2 Suggestions for Future Practice

Based on the proposed framework, the following suggestions are made:

1. Strengthening Interdisciplinary Collaboration

Encourage partnerships among academia, industry, and government to enhance knowledge sharing and innovation.

2. Promoting Sustainable Innovation

Focus on developing technologies and business models that address environmental and social challenges while ensuring economic viability.

3. Enhancing Policy Support

Governments should introduce incentives such as subsidies, tax benefits, and grants to promote sustainable innovation initiatives.

4. Leveraging Digital Technologies

Utilize emerging technologies like AI, IoT, and blockchain to improve sustainability outcomes across sectors.

5. Building Capacity and Awareness

Conduct training programs and awareness campaigns to promote interdisciplinary thinking and sustainable practices.

Future Research Directions

Future studies should focus on:

- Empirical validation using SEM or regression models
- Comparative studies across regions and sectors
- Integration of digital technologies in sustainability research
- Policy-oriented interdisciplinary frameworks
- Development of measurable indicators for each construct.

Conclusion

This review emphasizes the importance of interdisciplinary collaboration as a fundamental engine of innovation, sustainability, and global growth. By synthesizing insights from several domains, the study demonstrates how multidisciplinary collaboration improves the ability to produce innovative solutions capable of addressing difficult global issues. The proposed conceptual framework offers a clear sequential link in which innovation plays a critical mediating role in transforming transdisciplinary knowledge into sustainable outcomes, ultimately contributing to inclusive and resilient global development.

Furthermore, the study underlines the importance of moderating variables such as policy support, financial resources, and infrastructure in determining the strength and effectiveness of these linkages. Without proper institutional and structural support, the potential of innovation to drive sustainability may go untapped.

This review adds to the existing body of knowledge by merging interdisciplinary methods, innovation, and sustainability into a single framework. It improves theoretical understanding while providing practical insights to policymakers, industry practitioners, and academic institutions. The findings underline the importance of encouraging interdisciplinary collaboration, which is facilitated by enabling environments, in accomplishing sustainable development goals and ensuring long-term global success.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Impact of Service Quality on Customer Satisfaction Towards Purchase of Second-Hand Cars: A Review-Based Study

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Abstract

The second-hand car market has emerged as an important segment of the automobile industry due to increasing consumer preference for affordable mobility, rising prices of new vehicles, availability of vehicle finance, and the growth of organized used-car dealerships and digital automobile platforms. However, purchasing a second-hand car involves a higher level of perceived risk than purchasing a new car because customers are concerned about vehicle condition, accident history, mileage, ownership transfer, documentation, price fairness, warranty, and after-sales service. In such a context, service quality becomes a critical determinant of customer satisfaction. The present review-based research paper examines the impact of service quality on customer satisfaction towards the purchase of second-hand cars. The paper is based on the SERVQUAL framework developed by Parasuraman, Zeithaml, and Berry, which includes tangibility, reliability, responsiveness, assurance, and empathy. In addition to these traditional service quality dimensions, the paper also considers automobile-specific variables such as price transparency, vehicle condition, documentation support, after-sales service, dealer trust, and digital service quality. The review suggests that customer satisfaction in second-hand car purchase is influenced not only by the physical condition of the vehicle but also by the overall service experience before, during, and after purchase. The paper develops a conceptual framework and identifies key variables for future empirical research.

Keywords: *Service Quality, Customer Satisfaction, Second-Hand Cars, SERVQUAL, Dealer Trust, Price Transparency, Vehicle Condition, Review-Based Study*

Introduction

The automobile industry is one of the most dynamic sectors contributing to economic development, employment generation, personal mobility, and lifestyle transformation. In recent years, the second-hand car market has gained significant importance due to changing consumer preferences, affordability concerns, and the growing need for personal mobility. Earlier, the purchase of second-hand cars was often associated with financial limitations; however, this perception has changed considerably. Today, many consumers consider second-hand cars as a practical, economical, and value-based option.

The demand for second-hand cars has increased due to several factors such as rising prices of new vehicles, easy availability of finance, expansion of organized dealerships, growth of certified pre-owned car platforms, digital advertisements, shorter vehicle replacement cycles, and increasing consumer awareness. For many first-time car buyers, second-hand cars provide an opportunity to own a vehicle at a comparatively lower cost. For middle-class families, small business owners, professionals, and rural or semi-urban consumers, pre-owned cars offer convenience, affordability, and mobility.

However, purchasing a second-hand car is more complex than purchasing a new car. In the case of a new car, customers generally receive standardized product quality, manufacturer warranty, authorized service support, and formal documentation. In contrast, second-hand car buyers face uncertainty related to vehicle condition, previous ownership, accident history, engine performance, service record, insurance status, loan clearance, odometer reading, legal transfer, and future maintenance expenses. This situation creates information asymmetry between the seller and buyer,

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where the seller usually knows more about the product than the buyer. Akerlof (1970) explained this issue through the concept of "market for lemons," where quality uncertainty can create distrust in markets involving used products.

Service quality plays a vital role in reducing uncertainty and building customer confidence. In the second-hand car market, customers expect dealers to provide correct information, fair pricing, transparent communication, proper documentation support, technical guidance, test-drive facilities, and post-sale assistance. A customer may be satisfied not only because the vehicle is in good condition but also because the buying process is smooth, reliable, transparent, and trustworthy.

The concept of service quality has been widely discussed in marketing and service management literature. Parasuraman, Zeithaml, and Berry (1985) proposed a conceptual model of service quality, and later developed the SERVQUAL scale for measuring customer perceptions of service quality through five dimensions: tangibility, reliability, responsiveness, assurance, and empathy (Parasuraman et al., 1988). These dimensions are relevant in the second-hand car market because customers evaluate both the physical evidence of service and the behaviour of service providers.

The present paper is a review-based study that examines the impact of service quality on customer satisfaction towards the purchase of second-hand cars. The paper also identifies key service quality variables suitable for future empirical research. The topic is suitable for interdisciplinary academic discussion because it connects consumer behaviour, marketing, service management, automobile business, digital commerce, and sustainable consumption. The conference brochure also includes themes related to commerce, management, consumer behaviour, digital commerce, sustainability, and innovation.

Concept of Service Quality

Service quality refers to the customer's overall judgment about the excellence or superiority of a service. It is commonly understood as the difference between customer expectations and actual service performance. When the service received by the customer meets or exceeds expectations, service quality is perceived as high. When service performance is below expectations, customers perceive poor service quality (Parasuraman et al., 1985).

In service industries, quality is not always easy to measure because services are intangible, variable, and experience-based. Unlike physical products, services are produced and consumed simultaneously, and their quality often depends on human interaction, communication, reliability, and responsiveness. Grönroos (1984) explained that service quality is influenced by both technical quality, which refers to what the customer receives, and functional quality, which refers to how the service is delivered.

In the context of second-hand car purchase, service quality has a special meaning. The customer is purchasing a physical product, but the purchase decision depends greatly on the service process. A second-hand car buyer generally requires detailed information about vehicle condition, pricing, ownership, insurance, loan status, service history, accident record, and transfer procedure. Therefore, the dealer's ability to provide reliable and transparent service becomes very important.

The SERVQUAL model explains service quality through five major dimensions: tangibility, reliability, responsiveness, assurance, and empathy (Parasuraman et al., 1988). Although SERVQUAL provides a strong theoretical base, the second-hand car market requires additional service quality variables. Customers purchasing second-hand cars are highly concerned about price transparency, actual vehicle condition, documentation support, after-sales service, dealer trust, and digital service quality. These variables are directly related to customer satisfaction because the used-car market involves information asymmetry and perceived risk.

Table 1: SERVQUAL Dimensions in Second-Hand Car Purchase

Dimension	Meaning	Application in Second-Hand Car Purchase
Tangibility	Physical facilities and appearance	Showroom, vehicle display, cleanliness, staff appearance, inspection setup
Reliability	Ability to perform promised service accurately	Correct vehicle information, genuine documents, fulfilment of promises
Responsiveness	Willingness to help customers quickly	Quick response, test-drive support, finance guidance, document support
Assurance	Knowledge and courtesy that create trust	Technical explanation, legal clarity, confidence in vehicle quality
Empathy	Individual care and attention	Understanding budget, family need, usage pattern, and personal preferences

Source: Adapted from Parasuraman et al. (1988).

Concept of Customer Satisfaction

Customer satisfaction refers to the customer's emotional and cognitive response after comparing expectations with actual experience. Oliver (1980) explained satisfaction through the expectation-confirmation theory, where satisfaction occurs when actual performance confirms or exceeds prior expectations. If the actual experience is below expectations, dissatisfaction occurs.

In the second-hand car market, customer satisfaction is influenced by both product-related and service-related factors. Product-related factors include car model, age of vehicle, engine condition, mileage, physical appearance, fuel efficiency, brand image, maintenance cost, and resale value. Service-related factors include dealer behaviour, honesty, responsiveness, pricing clarity, document support, warranty, complaint handling, and after-sales support.

The purchase of a second-hand car is a high-involvement decision. Customers usually spend considerable time comparing options, checking vehicle condition, negotiating price, arranging finance, and verifying documents. Since the

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customer may not possess complete technical knowledge, satisfaction depends greatly on the dealer's support and service quality. According to Zeithaml et al. (1996), superior service quality can lead to favourable behavioural intentions such as loyalty, repeat purchase, and positive word-of-mouth. In the second-hand car market, satisfied customers are more likely to recommend the dealer, provide positive feedback, and develop trust in organized used-car platforms.

Review of Literature

Parasuraman et al. (1985) developed a conceptual model of service quality and identified gaps between customer expectations and service delivery. Their model became the foundation for later studies on service quality. Parasuraman et al. (1988) later developed the SERVQUAL scale to measure consumer perceptions of service quality using five dimensions: tangibility, reliability, responsiveness, assurance, and empathy. This model has been widely applied in banking, insurance, education, hospitality, healthcare, retail, and automobile service settings.

Oliver (1980) proposed the expectation-confirmation model of satisfaction. The model explains that customers compare actual performance with prior expectations. When performance meets or exceeds expectations, customers experience satisfaction. This theory is highly relevant to second-hand car purchase because buyers enter the market with expectations regarding car condition, fair price, legal documents, dealer honesty, and after-sales support.

Cronin and Taylor (1992) proposed the SERVPERF model and argued that service performance is a strong predictor of customer satisfaction. Their study emphasized that actual service performance should be measured directly. In the second-hand car market, actual service performance includes accurate vehicle information, timely response, transparent pricing, proper documentation, and post-sale support.

Zeithaml et al. (1996) examined the behavioural consequences of service quality and argued that high service quality leads to positive outcomes such as loyalty, recommendation, and willingness to pay more. In the used-car market, better service quality can encourage customers to recommend the dealer or online platform to friends and relatives.

Grönroos (1984) presented a service quality model based on technical quality and functional quality. Technical quality refers to what the customer receives, while functional quality refers to how the service is delivered. This distinction is highly applicable to second-hand car purchase. The technical quality may include the actual condition of the car, while functional quality includes dealer communication, transparency, courtesy, and support.

Akerlof (1970) highlighted the issue of information asymmetry in markets for used goods. His study showed that when buyers cannot distinguish between good-quality and poor-quality used products, market trust may decline. This concept is especially relevant to the second-hand car market because customers may not have full information about accident history, hidden defects, service records, or legal issues.

Anderson and Sullivan (1993) studied the antecedents and consequences of customer satisfaction and found that satisfaction influences repurchase intention and customer loyalty. In the second-hand car market, customer satisfaction may result in repeat purchase, referral, and trust in the dealer.

Reichheld and Sasser (1990) emphasized that customer retention and service quality are closely connected. They argued that reducing customer dissatisfaction can improve loyalty and profitability. For second-hand car dealers, retaining customers and generating positive word-of-mouth depend heavily on transparent service and reliable support.

Sweeney et al. (1999) discussed the role of perceived value in customer purchase decisions. In the second-hand car market, perceived value is highly important because customers evaluate whether the price paid is justified by the quality, service, documentation, and after-sales support received.

Gefen et al. (2003) examined the role of trust in online shopping and found that trust is an important factor in customer acceptance of online transactions. This is relevant because many second-hand car customers now begin their search through digital platforms. Trust in online information, dealer reputation, customer reviews, and platform reliability can influence customer satisfaction.

Ladhari (2009) reviewed the SERVQUAL model and noted that it remains one of the most widely used tools for measuring service quality, although researchers often adapt it according to sector-specific requirements. This supports the need to extend SERVQUAL with automobile-specific variables such as price transparency, vehicle condition, documentation support, and after-sales service.

The literature shows that service quality and customer satisfaction have been widely studied in several sectors. However, there is limited research specifically focusing on second-hand car purchase. The second-hand car market has unique characteristics such as hidden defects, document risk, pricing uncertainty, dealer trust, and post-sale support. Therefore, this review paper proposes a service quality framework suitable for the second-hand car market.

Variables of the Study

The present review-based study identifies the following variables for examining the impact of service quality on customer satisfaction towards the purchase of second-hand cars.

5.1 Independent Variables

No.	Variable	Description
1	Tangibility	Physical appearance of showroom, vehicle display, staff appearance, facilities, and inspection setup
2	Reliability	Ability of dealer to provide correct, dependable, and honest information
3	Responsiveness	Speed and willingness of dealer or staff to help customers
4	Assurance	Knowledge, courtesy, confidence, and trust created by dealer or staff
5	Empathy	Personal attention and understanding of customer needs

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6	Price Transparency	Clear explanation of price, charges, commission, and additional costs
7	Vehicle Condition	Mechanical and physical quality of the second-hand car
8	Documentation Support	Assistance in RC transfer, insurance, loan clearance, and legal formalities
9	After-Sales Service	Support provided after purchase, including warranty and complaint handling
10	Dealer Trust	Customer belief in the honesty, reputation, and ethical behaviour of dealer
11	Digital Service Quality	Accuracy of online listings, digital communication, reviews, and online support

2 Dependent Variable

Variable	Description
Customer Satisfaction	Overall satisfaction of customers towards their second-hand car purchase experience

3 Demographic Variables

No.	Demographic Variable
1	Age
2	Gender
3	Education
4	Occupation
5	Monthly Income
6	Area of Residence
7	Type of Car Purchased
8	Budget of Purchase
9	First-time or Repeat Buyer
10	Source of Purchase: Dealer, Broker, Online Platform, or Individual Seller

Explanation of Major Variables with Literature Support

1 Tangibility

Tangibility refers to the physical evidence of service quality, such as infrastructure, equipment, staff appearance, and service environment. Parasuraman et al. (1988) considered tangibility as one of the core dimensions of service quality. In second-hand car purchase, tangibility includes showroom infrastructure, cleanliness, vehicle arrangement, staff appearance, seating arrangement, availability of inspection tools, and overall professional environment. A well-maintained showroom creates a positive first impression and helps customers feel confident about the dealer.

2 Reliability

Reliability refers to the ability to perform promised services dependably and accurately. It is considered one of the most important SERVQUAL dimensions (Parasuraman et al., 1988). In second-hand car purchase, reliability is crucial because customers expect correct information about mileage, ownership, accident history, engine condition, service record, insurance status, and loan clearance. Since information asymmetry is common in used-product markets, reliability helps reduce customer uncertainty (Akerlof, 1970).

3 Responsiveness

Responsiveness refers to the willingness and ability of the service provider to help customers quickly. Parasuraman et al. (1988) emphasized responsiveness as a key element of service quality. In second-hand car purchase, customers may ask several questions about price, model, vehicle condition, finance options, insurance, test drive, service history, and documentation. Quick response through phone, WhatsApp, online platforms, or personal visits improves the customer experience and reduces purchase hesitation.

4 Assurance

Assurance refers to the knowledge, courtesy, and ability of employees to create trust and confidence among customers (Parasuraman et al., 1988). In the second-hand car market, customers may not have technical knowledge about cars. They expect the dealer to explain vehicle condition, engine performance, legal documents, insurance, loan status, and future maintenance. Assurance reduces perceived risk and increases purchase confidence.

5 Empathy

Empathy means providing individual care and personal attention to customers. According to Parasuraman et al. (1988), empathy reflects the service provider's ability to understand specific customer needs. Each second-hand car buyer may have different requirements, such as low budget, family use, business use, fuel efficiency, low maintenance, or resale value. When the dealer understands customer requirements and suggests suitable options, the customer feels valued and satisfied.

6 Price Transparency

Price transparency refers to clear communication of price, charges, commission, documentation cost, insurance cost, and other expenses. In second-hand car purchase, price transparency is critical because customers often fear hidden charges, unfair valuation, and overpricing. Perceived value plays an important role in customer purchase decisions, and customers evaluate whether the benefits received are worth the price paid (Sweeney et al., 1999). Therefore, transparent pricing can increase perceived value and satisfaction.

7 Vehicle Condition

Vehicle condition is a core factor influencing customer satisfaction in second-hand car purchase. Customers are concerned about engine performance, tyre condition, body condition, battery, air-conditioning, interior quality, accident history, mileage, service record, and future repair expenses. From the perspective of Grönroos (1984), vehicle condition represents technical quality, or what the customer actually receives. If the actual condition of the vehicle matches the dealer's claim, customer satisfaction increases.

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8 Documentation Support

Documentation support includes assistance in ownership transfer, registration certificate transfer, insurance transfer, pollution certificate, loan closure, hypothecation removal, tax records, and RTO formalities. In second-hand car purchase, proper documentation reduces legal risk and customer stress. Since satisfaction depends on the total purchase experience, documentation support becomes an important service component (Oliver, 1980).

9 After-Sales Service

After-sales service refers to support provided after the vehicle is purchased. It may include warranty, free inspection, service reminders, complaint handling, repair support, technical guidance, and assistance in resolving post-purchase issues. Zeithaml et al. (1996) argued that better service quality influences favourable behavioural intentions. In second-hand car markets, after-sales service can increase satisfaction, customer loyalty, and positive word-of-mouth.

10 Dealer Trust

Dealer trust refers to the customer's belief that the dealer is honest, reliable, ethical, and customer-oriented. Trust is highly important in second-hand car purchase because buyers often have less information than sellers. Gefen et al. (2003) found that trust plays a major role in customer acceptance and satisfaction in online transactions. Similarly, in second-hand car purchase, trust reduces perceived risk and increases customer confidence.

11 Digital Service Quality

Digital service quality has become increasingly important due to the growth of online automobile platforms. Many customers search for second-hand cars online before visiting dealers. Digital service quality includes accurate online listings, real photographs, vehicle details, price information, customer reviews, quick online response, online booking, and digital payment options. Trust in digital information and platform reliability can influence customer satisfaction, especially when customers begin the purchase journey online (Gefen et al., 2003).

Research Gap

The review of literature shows that service quality and customer satisfaction have been widely studied in several sectors, including banking, insurance, retail, education, hospitality, healthcare, and automobile after-sales service. However, comparatively limited research has focused on service quality in the second-hand car purchase process.

Most automobile-related studies focus on new-car buyers, brand satisfaction, service centres, or after-sales service. The second-hand car market has unique characteristics such as information asymmetry, hidden defects, uncertain vehicle history, price negotiation, document transfer, and lack of standardized warranty. Akerlof's (1970) theory of information asymmetry is particularly relevant in this context because buyers may not be able to judge the actual quality of a used vehicle before purchase.

Further, many studies use traditional SERVQUAL dimensions, but the second-hand car market requires additional variables such as price transparency, vehicle condition, documentation support, dealer trust, digital service quality, and after-sales service. These variables are highly relevant because they directly influence customer confidence and satisfaction.

Thus, this review identifies the need for an empirical study that examines the impact of both SERVQUAL and automobile-specific variables on customer satisfaction towards the purchase of second-hand cars.

Discussion

The review clearly indicates that service quality is an important determinant of customer satisfaction in the second-hand car market. Since second-hand car purchase involves higher risk than new-car purchase, customers depend heavily on the quality of service provided by dealers, brokers, and digital platforms.

The SERVQUAL dimensions provide a useful foundation for understanding customer expectations. Tangibility creates the first impression of professionalism. Reliability ensures that customers receive correct and dependable information. Responsiveness improves customer convenience and reduces waiting time. Assurance builds confidence through knowledge and courtesy. Empathy provides personal attention and improves customer experience (Parasuraman et al., 1988).

However, second-hand car purchase also requires additional variables beyond SERVQUAL. Price transparency is necessary because customers are highly concerned about hidden charges and unfair valuation. Vehicle condition directly affects satisfaction because the customer's main expectation is to receive a usable and reliable car. Documentation support is essential because legal transfer and insurance formalities can be complicated. After-sales service reduces customer anxiety after purchase. Dealer trust reduces perceived risk and encourages positive word-of-mouth. Digital service quality is increasingly important because many customers begin their purchase journey online.

The review also shows that customer satisfaction in this market depends on both rational and emotional factors. Rational factors include price, vehicle condition, documents, warranty, and finance. Emotional factors include trust, confidence, comfort, and personal attention. Oliver's (1980) satisfaction theory supports the idea that customer satisfaction is formed when actual experience meets or exceeds expectations. Similarly, Zeithaml et al. (1996) support the view that better service quality leads to favourable behavioural outcomes such as loyalty and recommendation.

Suggestions

Second-hand car dealers should provide accurate and complete information about vehicle condition, ownership history, mileage, accident record, insurance status, and service history. Misrepresentation should be avoided because it damages customer trust and satisfaction.

Dealers should improve price transparency by clearly explaining the total cost of purchase. The customer should be informed about vehicle price, transfer charges, insurance charges, service charges, finance charges, and any additional cost.

Vehicle inspection should be made more systematic. Dealers should provide inspection reports covering engine condition, body condition, tyre condition, battery, air-

conditioning, accident history, and service record. This will help customers make informed decisions.

Documentation support should be strengthened. Dealers should assist customers in RC transfer, insurance transfer, loan clearance, hypothecation removal, and RTO formalities. Proper documentation can reduce legal risk and improve satisfaction.

After-sales service should be improved through warranty, free check-up, repair assistance, service reminders, and complaint-handling mechanisms. Even limited post-sale support can improve customer confidence.

Sales staff should be trained in technical knowledge, ethical selling, communication skills, and customer handling. They should understand customer needs and suggest suitable vehicles according to budget, usage, family size, and preferences.

Digital platforms should ensure that online listings are accurate and updated. Photographs, price, ownership details, vehicle condition, and inspection reports should be clearly displayed. Quick online communication and customer reviews can also improve trust.

Conclusion

The second-hand car market has become an important part of the automobile industry due to affordability, increasing mobility needs, digital platforms, and growing consumer acceptance. However, the purchase of a second-hand car involves higher perceived risk because customers may not have complete information about vehicle history, condition, documents, and future maintenance costs.

This review-based research paper concludes that service quality has a significant conceptual impact on customer satisfaction towards the purchase of second-hand cars. The SERVQUAL dimensions—tangibility, reliability, responsiveness, assurance, and empathy—provide a strong theoretical foundation for understanding service quality. However, in the second-hand car market, additional variables such as price transparency, vehicle condition, documentation support, after-sales service, dealer trust, and digital service quality are equally important.

The proposed conceptual framework can be used for future empirical research. The study is useful for dealers, brokers, online platforms, automobile marketers, and researchers. By improving service quality, second-hand car dealers can reduce customer risk, build trust, enhance satisfaction, encourage positive word-of-mouth, and contribute to the sustainable growth of the used-car market.

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Original Article

Automatic traffic light system design and violation detection

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Abstract

Automatic traffic light system is an automated system for controlling and managing traffic using electronic systems. The technology used is a network of digital cameras connected to the information center of the responsible authorities and traffic regulators, which in turn check the violation technically and then request the owner's information from the database and then issue violations related to speed and signal cutting in order to improve traffic safety.

This paper designed with the title Automatic traffic light system design and violation detection, we made automatic traffic lights using the Arduino application, and we put a flash lamp that blinks when the traffic light is cut off, and it was verified.

Finally, the paper can be developed to be used by applying a digital camera that records violations and saves them in the allocated memory, and the speed system can also be applied to traffic lights.

Key Words: *traffic light, violation technically, digital camera, allocated memory.*

Introduction

1 Traffic signals

Traffic signals are designed to ensure an orderly flow of traffic, provide an opportunity for pedestrians or vehicles to cross an intersection and help reduce the number of conflicts between vehicles entering intersections from different directions.

Traffic signals control vehicle and pedestrian traffic by assigning priorities to various traffic movements to influence traffic flow.

2 Advantages of traffic signals

Properly designed, located and maintained traffic signals have one or more of these advantages:

- Provide for orderly movement of traffic.
- Increase traffic-handling capacity of an intersection.
- Reduce frequency and severity of certain types of crashes, especially right-angle collisions.
- Provide for continuous movement of traffic at a definite speed along a given route.
- Interrupt heavy traffic at intervals to permit other vehicles or pedestrians to cross.

3 Disadvantages of traffic signals

Traffic signals are not a solution for all traffic problems at intersections, and unwarranted signals can adversely affect the safety and efficiency of traffic by causing one or more of the following:

- Excessive delay.
- Increased traffic congestion, air pollution and gasoline consumption.
- Disobedience of signals.
- Increased use of less-adequate streets to avoid traffic signals.
- Increased frequency of crashes, especially rear-end collisions.

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Figure 1.1 shows traffic signals.

Figure 1.1: Traffic signals.

4 Traffic signals' principle of work

Fixed-time signals follow a predetermined sequence of signal operation, always providing the same amount of time to each traffic movement, whether traffic is present or not. Actuated signals change the lights according to the amount of traffic in each direction. They use various types of sensors to detect vehicles, and adjust the length of the green time to allow as many vehicles as possible through the intersection before responding to the presence of vehicles on another approach.

Traffic lights follow a universal color code which alternates the right of way accorded to users with a sequence of illuminating lamps or LEDs of three standard colors:

- **Green light:**
  Allows traffic to proceed in the direction denoted, if it is safe to do so and there is room on the other side of the intersection. The green light was traditionally green in color (hence its name) though modern LED green lights are turquoise.
- **Red light:**
  Prohibits any traffic from proceeding. A flashing red indication requires traffic to stop and then proceed when safe (equivalent to a stop sign).
- **Yellow light:**
  Warns that the signal is about to change to red, with some jurisdictions requiring drivers to stop if it is safe to do so, and others allowing drivers to go through the intersection if safe to do so. In some European countries (such as the UK), red and Yellow is displayed together, indicating that the signal is about to change to green.

1. **The Arduino**

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Netmedia's BX-24, Phidgets, MIT's Handyboard, and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy-to-use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, students, and interested amateurs over other systems:

- **Inexpensive -** Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less than $50
- **Cross-platform -** The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.
- **Simple**, clear programming environment - The Arduino Software (IDE) is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with how the Arduino IDE works.
- **Open source and extensible software -** The Arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, you can add AVR-C code directly into your Arduino programs if you want to.
- **Open source and extensible hardware -** The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module in order to understand how it works and save money.

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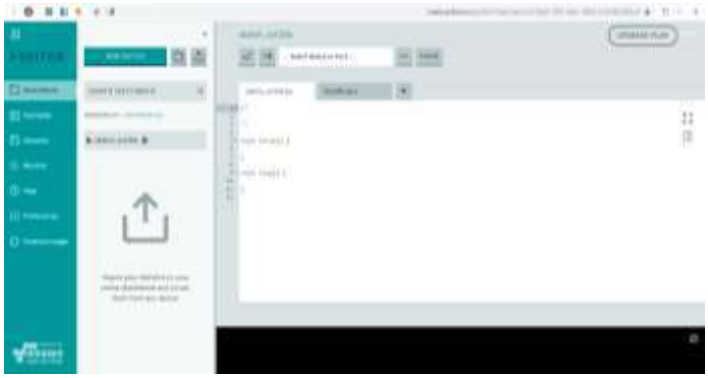
Arduino = Two Things

Software for programing

ARDUINO EDITOR
Two ways to editor :
1-arduino web editor



2-arduino application editor

Our papers used Arduino uno.

2. Structure

In this paper, we are implementing an Arduino traffic light circuit using Arduino UNO. Figure 3.1 shows the general view of the project.

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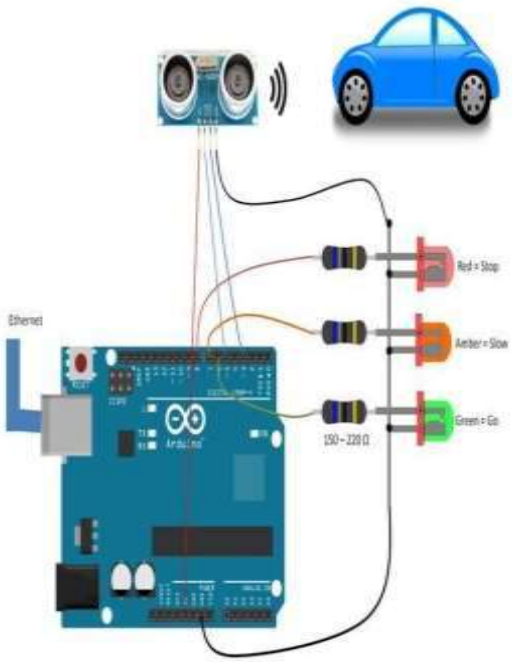

Figure2.1: General view of the project.

From the above schematic we notice that there are three leds and three resistors. The leds are connected to some pins in the Arduino. The Three leds are for traffic signals and the ultrasonic sensor is to detect illegal crossing of a car. The three resistors are used to limit leds' current.

2 Components

- 5mm red led.
- 5mm green led.
- 5mm yellow led.
- 5mm white led.
- Resistor 220 ohm *3.

To provide power to the Arduino we use a USB power cable after building the circuit. The cable provides a steady 5v to the Arduino. If we use another power source, there is a chance the voltage might be too high, which might overload the components.

3 Code

```
#define  LED_RED      2
#define  LED_GREEN    3
#define  LED_YELLOW   4
#define  LED_FLASH    5
#define trigPin A1
#define echoPin A0
void SonarSensor(int trigPin,int echoPin);
unsigned long Time=0;
long duration, distance, FIRSTSensor;
int Flag=0;
void setup() {
pinMode(LED_RED,OUTPUT);
pinMode(LED_GREEN,OUTPUT);
pinMode(LED_YELLOW,OUTPUT);
pinMode(LED_FLASH,OUTPUT);
pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT);
Time =millis();}
void loop() {
digitalWrite(LED_RED,HIGH);
if ((millis()-Time)>=35000){
digitalWrite(LED_RED,LOW);
digitalWrite(LED_GREEN,HIGH);
delay(35000);
digitalWrite(LED_GREEN,LOW);
digitalWrite(LED_YELLOW,HIGH);
delay(5000);
digitalWrite(LED_YELLOW,LOW);
Time =millis();
}else{
 SonarSensor(trigPin,echoPin);
   FIRSTSensor = distance;
   delay(5);
   if ((FIRSTSensor<=0)||(FIRSTSensor>=8)){
    digitalWrite(LED_FLASH,LOW);
   }else{
     digitalWrite(LED_FLASH,HIGH);
     delay(2000);
     digitalWrite(LED_FLASH,LOW);   } }}
void SonarSensor(int trigPin,int echoPin){
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);
distance = (duration/2) / 29.1;}
```

3. Practical implementation

In this paper we have implemented the circuit shown in figure 3.1, and programmed the Arduino with programs.

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Figure 3.4 shows the practical implementation of the paper.

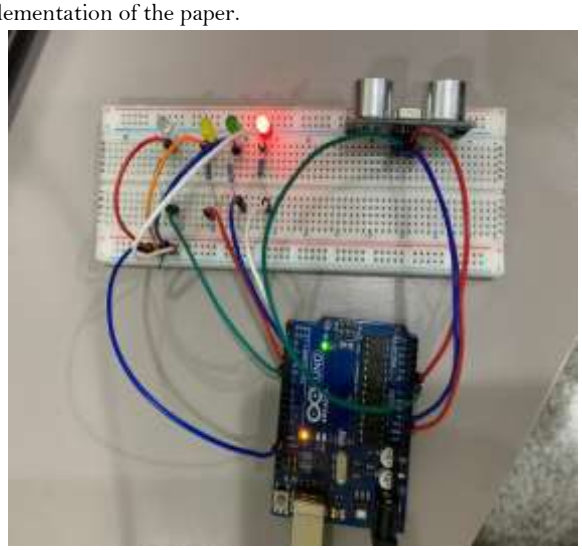

Figure 3.2: Practical implementation of the paper.

Recommendation

Traffic is frequently contemplated as a type of fluid flow network, just like an electrical circuit. Nevertheless, what is different about the fluid network is that the flow is alternating, halting at Red lights, and begin again at Green lights. It is the aim of the traffic engineer to make perfect or upgrade the traffic flow within a given road network. The benefits of this proposed work are:

- Learning Arduino programming.
- Learning basics about electric circuits.
- Learn pull up and pull-down resistors.
- Learning about some signal systems of traffic around the world.
- Lear how to deal with ultrasonic sensors.

Conclusion

In this project, we have implemented a traffic light system using Arduino. A set of traffic light situations were applied as in Figure 5.1 and the results were obtained in Table 5.1. We learned Arduino programming and some basics of electrical circuits. We also learned about ultrasonic sensors and how they can be used to detect motion.

Input	Output
Stays as green for 5 Second	Green light is on
Stays as yellow for 2 Second	Yellow light is on
Stays as red for 5 Second	Red light is on

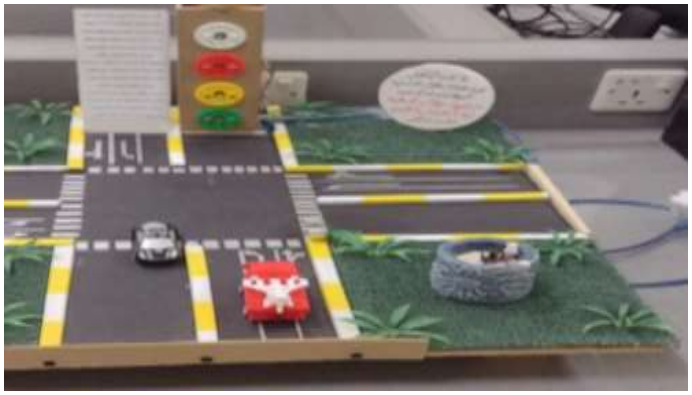

Figure 3.1: Design idea and results.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Impact of Fundamental Awareness and Risk Management on Ease of Use of Fintech Investment Applications: The Mediating Role of Trading Competence

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Abstract

The rapid growth of FinTech investment applications has transformed retail investors participation in financial markets, yet investors differ significantly in how they perceive the ease of using these platforms. While prior research predominantly emphasizes technology adoption intention, limited attention has been given to understanding how financial capability translates into platform usability perception. Addressing this gap, the present study examines the impact of Fundamental Awareness and Risk Management on Ease of Use, with Trading Competence serving as a mediating construct in the context of FinTech investment applications. The study adopts a quantitative research design using primary data collected through a structured questionnaire administered using purposive sampling method. The proposed hypotheses were tested using SPSS and SmartPLS. Exploratory Factor Analysis (EFA) was conducted to identify underlying constructs, followed by Partial Least Squares Structural Equation Modelling (PLS-SEM) to examine direct and indirect relationships, including mediation effects. The findings reveal that Fundamental Awareness and Risk Management do not directly influence Ease of Use; however, both significantly enhance Trading Competence, which in turn positively affects perceived Ease of Use. The mediation analysis confirms that Trading Competence plays a central role, with significant mediation effects observed. The results indicate that financial knowledge and risk-handling practices improve usability perception only when they translate into practical trading capability. The study contributes to FinTech adoption literature by integrating financial literacy constructs within a mediation framework and offers practical insights for enhancing investor capability in digital investment ecosystems.

Keywords: *FinTech Investment Applications, Fundamental Awareness, Risk Management, Trading Competence, Ease of Use.*

Introduction

The rapid digital transformation of financial services has significantly reshaped the way retail investors participate in capital markets. FinTech investment applications have simplified trading processes, reduced transaction costs, and expanded market access to a broader segment of the population. In emerging economies particularly, these platforms have transformed investment opportunities by enabling individuals to engage in stock market activities through user-friendly mobile interfaces. However, despite the technological advancement and increased accessibility, investors differ considerably in how they perceive the Ease of Use of such applications.

Existing research on FinTech adoption has largely concentrated on behavioural intention and technology acceptance using established frameworks such as the Technology Acceptance Model and UTAUT. While these studies highlight the importance of, Fintech literacy, performance expectancy, and perceived risk, they often overlook the internal capabilities of investors that shape their usability perceptions. Financial knowledge alone may not automatically contribute to effective platform usage unless it enhances user's ability to interpret data, manage risk, and execute trades confidently. This gap is particularly critical in investment contexts, where decision-making involves financial consequences and risk exposure.

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In this regard, the present study becomes highly significant as it moves beyond traditional adoption models and investigates the structural mechanism through which Fundamental Awareness and Risk Management influence perceived Ease of Use through Trading Competence. By identifying Trading Competence as a central mediating construct, the study provides deeper insight into how investor capability transforms financial knowledge into practical usability outcomes. This perspective is crucial for FinTech service providers, regulators, and financial educators seeking to promote responsible and sustainable digital investment participation.

Thus, the study offers both theoretical advancement and practical relevance by integrating financial literacy constructs within a mediation framework, contributing to a more comprehensive understanding of investor behaviour in FinTech investment platforms.

Literature Survey

Prior research highlights financial literacy and technological competence as key drivers of FinTech adoption. Kishan and Venugopal (2024) found that financial literacy and technical readiness significantly influence mobile trading app usage among Indian investors, suggesting that awareness enhances engagement with digital investment platforms. Similarly, Johri et al. (2023) reported that financial literacy and risk-related perceptions significantly shape adoption behaviour in stock trading applications, emphasizing the importance of knowledge and risk evaluation. From a theoretical perspective, the Technology Acceptance Model (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (Chan et al., 2022) indicate that effort expectancy, perceived risk, and performance expectations influence technology acceptance. Further, studies grounded in Social Cognitive Theory (Bandura, 1986) and Technology Self-Efficacy Theory (Compeau & Higgins, 1995) demonstrate that competence enhances confidence and reduces perceived complexity. Joo et al. (2014) also confirmed that self-efficacy significantly influences usage behaviour. Although existing studies establish the role of financial literacy and risk perception in technology adoption, limited research has examined how Fundamental Awareness and Risk Management translate into perceived Ease of Use through Trading Competence in FinTech investment applications. The present study addresses this gap using a mediation framework.

Research Problem

The rapid expansion of FinTech investment platforms has increased retail investor participation; however, differences remain in how investors perceive the Ease of Use of these applications. Existing studies, largely grounded in the Technology Acceptance Model (Davis, 1989) and UTAUT-based frameworks (Chan et al., 2022), primarily focus on adoption intention rather than examining the structural factors that shape usability perceptions within investment contexts. Prior research confirms that financial literacy and risk awareness significantly influence adoption behaviour (Kishan & Venugopal, 2024; Johri et al., 2023), and theories such as Social Cognitive Theory (Bandura, 1986) suggest that knowledge enhances competence and confidence. Nevertheless, limited empirical evidence explains how Fundamental Awareness and Risk Management translate into perceived Ease of Use through Trading Competence in FinTech investment applications. Therefore, the key research problem is to determine whether Trading Competence acts as a mediating mechanism through which financial awareness and risk management practices influence investors' perception of Ease of Use in FinTech platforms.

Objectives of the Study

- To examine the impact of Fundamental Awareness, Risk Management, and Trading Competence on Ease of Use of FinTech investment applications.
- To analyse the mediating role of Trading Competence in the relationship between Fundamental Awareness, Risk Management, and Ease of Use.

Research Methodology

The present study is based on a quantitative research design. The data were collected from respondents using FinTech investment applications. To conduct the analysis, a sample of 303 respondents was collected from the state of Goa. The data were collected through a well-designed structured questionnaire using the purposive sampling method. The period of survey was from January 2025 to March 2025.

The following hypotheses have been framed to examine the relationships among Fundamental Awareness (FA), Risk Management (RM), Trading Competence (TC), and Ease of Use (EU). The following hypotheses were tested:

- **H1:** Fundamental Awareness significantly influence Ease of Use, Risk Management, and Trading Competence.
- **H2:** Risk Management significantly influence Ease of Use and Trading Competence.
- **H3:** Trading Competence significantly influence Ease of Use.
- **H4:** There is a Serial mediation from Fundamental Awareness to Ease of Use through Risk Management and Trading Competence.
- **H5:** There is a significant indirect effect of Fundamental Awareness on Trading Competence through Risk Management.
- **H6:** There is a significant indirect effect of Fundamental Awareness on Ease of Use of FinTech investment apps through Trading Competence.
- **H7:** There is a significant indirect effect of Fundamental Awareness on Ease of Use of FinTech investment apps through Risk Management.
- **H8:** There is a significant indirect effect of Risk Management on Ease of Use of FinTech investment apps through Trading Competence.

The above hypotheses were tested using SPSS and SmartPLS software. The statistical tools used for analysis were Exploratory Factor Analysis (EFA), Partial Least Squares Structural Equation Modelling (PLS-SEM) and mediation analysis.

Significance of the Study:

This study contributes to the growing field of FinTech adoption literature by examining how Fundamental Awareness and Risk Management influence

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investors' perception of Ease of Use through Trading Competence. Unlike prior studies that primarily focus on behavioural intention, the present research identifies Trading Competence as a key mediating mechanism that translates financial knowledge and risk-handling practices into usability perception. The findings provide practical insights for FinTech service providers, policymakers, and investor educators by emphasizing that improving financial awareness alone is insufficient unless it enhances user competence. By integrating financial literacy constructs with a structural mediation framework using PLS-SEM, the study offers both theoretical advancement and managerial relevance in understanding investor interaction with digital investment platforms.

Limitations of the Study:

The study is limited by its use of purposive sampling, which may restrict the generalizability of the findings to the broader investor population. The data were collected within a specific time frame (January 2025 to March 2025), capturing perceptions at a single point in time; therefore, the results may not reflect changes in behaviour over longer periods. Additionally, the study focuses only on selected constructs—Fundamental Awareness, Risk Management, Trading Competence, and Ease of Use—while other potential determinants such as trust, perceived usefulness, or behavioural intention were not included in the model. Future research may adopt longitudinal designs and incorporate additional variables to provide a more comprehensive understanding of FinTech platform usage.

Discussion:

This section discusses the empirical findings of the study by interpreting the structural relationships among Fundamental Awareness, Risk Management, Trading Competence, and Ease of Use within FinTech investment platforms. Drawing upon established theoretical foundations such as the Technology Acceptance Model and Social Cognitive Theory, the analysis explains how financial knowledge and risk-handling mechanisms translate into user perceptions of platform simplicity. The results are examined in light of both direct and mediating effects to understand the underlying behavioural mechanisms that influence perceived ease of use. By doing so, this section highlights the cognitive and competence-based pathways through which users engage with FinTech applications.

Identification of Key Factors Influencing Investors' Ability to Use FinTech Investment Apps

To identify the underlying dimensions influencing investors' ability to use FinTech investment applications, Exploratory Factor Analysis (EFA) was employed. This technique helps in reducing multiple observed variables into meaningful latent constructs by examining their interrelationships. The analysis aims to uncover the core competency-based and awareness-driven factors that shape investors' interaction with digital investment platforms.

Exploratory Factor Analysis was conducted on 12 observed variables to identify the underlying factor structure. The results revealed three distinct factors explaining 60.087% of the total variance. The Kaiser–Meyer–Olkin (KMO) value of 88.5% indicates meritorious sampling adequacy, confirming the suitability of the data for factor analysis. All three factors reported eigenvalues greater than 1, satisfying Kaiser's criterion. The extracted constructs were labelled as Trading Competence, Fundamental Awareness, and Risk Management based on the conceptual meaning of the respective items.

Trading Competence reflects investor's confidence and capability in executing trades, supported by a strong Cronbach's Alpha of 82.8%. Fundamental Awareness captures essential investment knowledge such as goal setting and familiarity with investment options, with an acceptable reliability of 70%. The third construct, Risk Management, represents awareness of risk-control mechanisms such as investment limit settings, circuit breaker options, and performance tracking before investment. This factor reported a Cronbach's Alpha of 66.2%, which is acceptable in exploratory research contexts (Hair et al., 2019).

Subsequently, the extracted factors were incorporated into the structural model and regressed against the dependent variable, ease of use of fintech apps, using Partial Least Squares Structural Equation Modelling (PLS-SEM). The use of PLS-SEM is appropriate

as the study adopts a predictive approach and examines relationships among newly developed constructs within a moderate sample size framework.

Table No. 1: Factors Highlighting Investors ability to use FinTech Investment Apps.

Determinants	Trading Competence	Fundamental Awareness	Risk Management
Real-time market data usage	0.78		
Technical and financial knowledge	0.749		
Confidence in making a portfolio	0.717		
Buying and selling process awareness	0.651		
Security protocols awareness	0.594		
Risk management features	0.505		
Customization of investment notifications		0.794	
Financial goals setting		0.7	
Familiarity with investment options		0.616	
Investment limit settings			0.754
Awareness of circuit breaker options			0.716
Performance tracking before investment			0.655

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Total Eigen values	**3.023**	**2.105**	**2.082**
Percentage of Variance	25.193	17.541	17.353
Cumulative Variance	25.193	42.734	**60.087**
Cronbach Alpha	82.80%	70%	66.20%
KMO	**88.50%**		

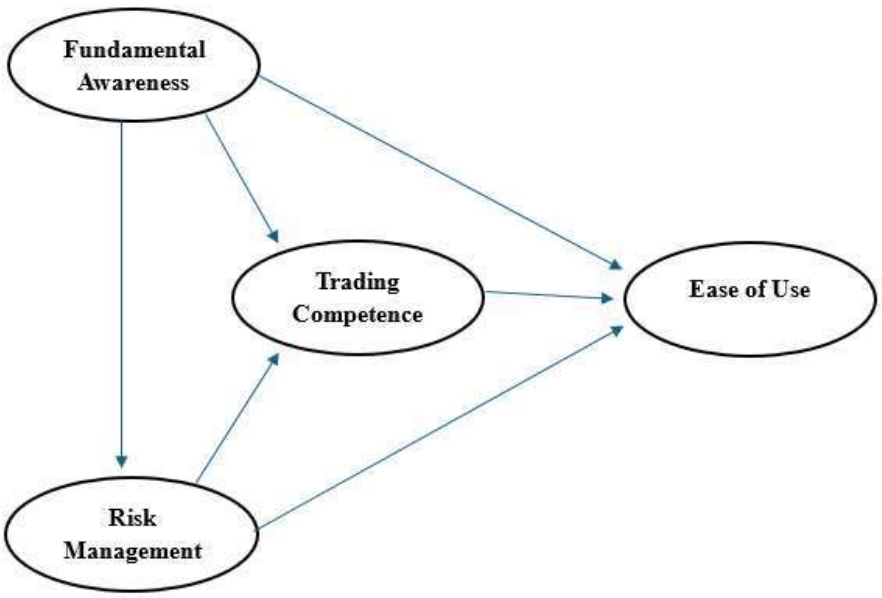
Source: Primary Data

Impact of Fundamental Awareness and Risk Management on Ease of Use Through Trading Competence in Fintech Platforms

In order to analyse the model with multiple relationship, the PLS-SEM has been used to analyse the factors influencing the Ease of Use. It has been found that the values of kurtosis and skewness is ranging from -2 to +2 indicating a normal distribution of data. This confirms that the data is well suited for structural equation modelling. The three construct that is Fundamental Awareness, Risk Management and Trading Competence have been derived through EFA. Whereas the scale item for the construct "Ease of Use" has been adapted from Singh et.al 2020, Akinwale and Kyari 2020, Humbani and Wiese 2018. These constructs provide a strong theoretical foundation for analysing the factors influencing the adoption and continued use of FinTech investment apps.

Further, the model also considers the mediating effect of the construct. Following is the proposed conceptual framework.

Figure No. 1: Conceptual Framework



Source: Designed by Researcher

Partial Least Squares Structural Equation Modelling (PLS SEM) was employed in this study due to its suitability for handling complex models with relatively small sample sizes (María Francisca Blasco Lopez et al., 2017). The model considers construct "Ease of Use" which is based on validated scales from previous research. Bootstrapping of 5000 samples have been used in the analysis to propose standard errors and t-values.

Table No. 2: Measurement Model

Construct	Item	Variable
Fundamental Awareness (FA)	**FA1**	Customization of investment notifications
	FA2	Financial goals setting
	FA3	Familiarity with investment options
Risk Management (RM)	**RM1**	Investment limit settings
	RM2	Awareness of circuit breaker options
	RM3	Performance tracking before investment

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Trading Competence (TC)	**TC1**	Real-time market data usage
	TC2	Technical and financial knowledge
	TC3	Confidence in making a portfolio
	TC4	Buying and selling process awareness
	TC5	Security protocols awareness
Ease of Use (EU)	**EU1**	Fintech apps are easy to learn.
	EU2	Fintech apps are easy to browse.
	EU3	Easier to learn and use without going through the service manual.
	EU4	Easier to download Fintech applications from the internet.
	EU5	Easy to become skilful in using Fintech apps.
	EU6	Fintech apps have an attractive layout and appearance.

Source: EFA & Literature Survey

To assess the reliability and validity of the measurement model, Cronbach's alpha and Composite Reliability (CR) were examined. Cronbach's alpha exceeded 0.70 for all the variables, confirming good internal consistency.

However, for Risk Management, the Cronbach's alpha is "0.667". While slightly below the conventional threshold, still these values are considered acceptable as per the prior studies (Nunnally & Bernstein 1994, Singh Apar and Malhotra Meenakshi 2016). CR values exceeded 0.75, aligning with the recommended minimum of 0.60 (Bagozzi & Yi, 1988) (see table no. 2).

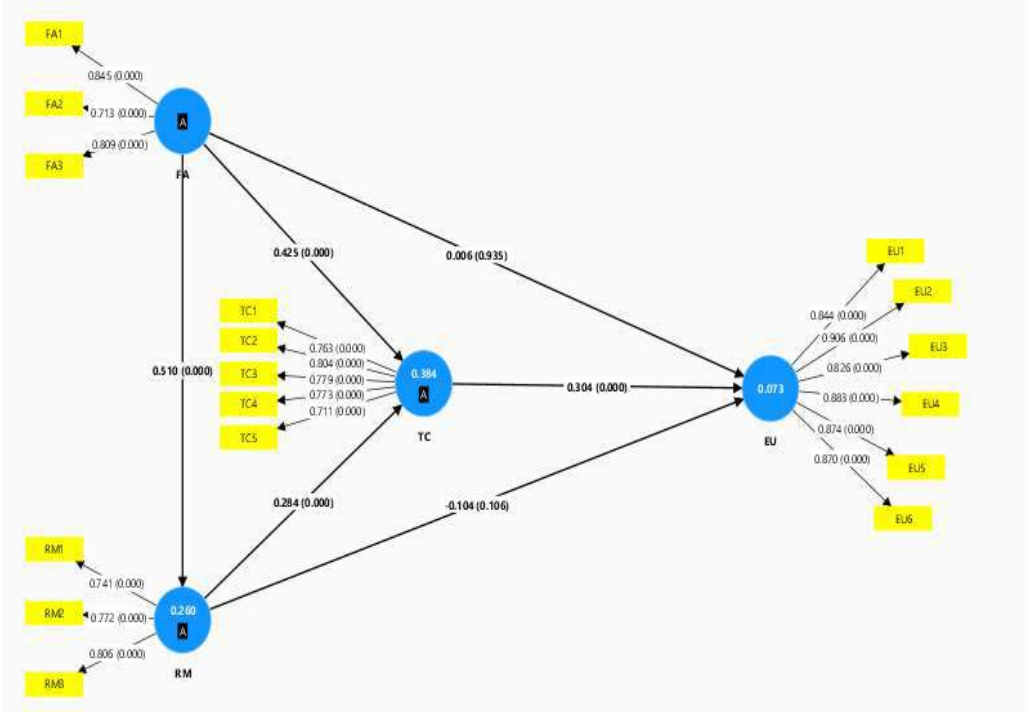

Figure No. 2: Computed through PLS SEM

Source: Drawn from Primary data

The above model has been computed using PLS-SEM for which following Convergent validity has been obtained:

Table No. 3: Measurement Model Reliability and Convergent Validity

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Factor	Item	Standardized Loadings	t-value (bootstrapped)	CA	CR	AVE	R^2
Ease of Use (EU)	EU1	0.844	39.625	0.934	0.948	0.753	0.073
	EU2	0.906	69.572				
	EU3	0.826	29.801				
	EU4	0.883	50.688				
	EU5	0.874	53.431				
	EU6	0.87	45.489				
Fundamental Awareness (FA)	FA1	0.845	45.482	0.701	0.833	0.626	-
	FA2	0.713	16.544				
	FA3	0.809	37.431				
Risk Management (RM)	RM1	0.741	18.979	0.667	0.817	0.598	0.26
	RM2	0.772	20.978				
	RM3	0.806	19.911				
Trading Competence (TC)	TC1	0.763	23.682	0.824	0.877	0.588	0.384
	TC2	0.804	31.959				
	TC3	0.779	32.443				
	TC4	0.773	32.556				
	TC5	0.711	16.863				

Source: Primary Data

Table No. 4: Measurement Model Discriminant Validity using HTMT Criterion

	EU	FA	RM	TC
EU				
FA	0.154			
RM	0.132	0.716		
TC	0.288	0.753	0.673	

Source: Primary Data

Table No. 5: Measurement Model Discriminant Validity using Fornell Larcker Criterion

	EU	FA	RM	TC
EU	0.868			
FA	0.127	0.791		
RM	0.051	0.51	0.774	
TC	0.256	0.569	0.5	0.767

Source: Primary Data

The above table represents the assessment of convergent validity using Average Variance Extracted (AVE). All constructs reported AVE values above the recommended threshold of 0.50, indicating that the latent constructs explain more than half of the variance of their respective indicators (Fornell & Larcker, 1981). All standardized factor loadings exceeded 0.70, confirming indicator reliability. Furthermore, the bootstrapped t-statistics were well above the critical value of 1.96, demonstrating the statistical significance of the outer loadings. These results collectively establish adequate convergent validity and internal consistency of the measurement model.

Discriminant validity was assessed using both the Fornell–Larcker criterion and the Heterotrait–Monotrait (HTMT) ratio. The HTMT values were below the conservative threshold of 0.90, with all values below 0.80, indicating strong discriminant validity (Guillermo

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Calahorra et al., 2024). Additionally, the square root of AVE for each construct exceeded its inter-construct correlations, satisfying the Fornell–Larcker criterion (Fornell & Larcker, 1981). Cross-loading examination further supported construct distinctiveness. Overall, the results confirm that the measurement model demonstrates satisfactory reliability and validity, supporting further structural model analysis.

Table No. 6: Direct Path Analysis

Hypotheses		*β*	STDEV	T statistics	P values	Inference
H1	**FA -> EU**	0.006	0.078	0.081	0.935	Not Supported
	FA -> RM	0.51	0.046	11.006	**0.000*****	Supported
	FA -> TC	0.425	0.056	7.539	**0.000*****	Supported
H2	**RM -> EU**	-0.104	0.064	1.618	0.106	Not Supported
	RM -> TC	0.284	0.059	4.774	**0.000*****	Supported
H3	**TC -> EU**	0.304	0.065	4.686	**0.000*****	Supported

Source: Primary Data

To begin with, the study examined whether Fundamental Awareness (FA) and Risk Management (RM) directly influence user's perception of Ease of Use (EU) in FinTech applications. The results indicate that Fundamental Awareness does not significantly affect Ease of Use ($p = 0.935$). This suggests that possessing basic financial knowledge alone does not directly enhance users' perception of platform simplicity. This finding contrasts with the Technology Acceptance Model (TAM) proposed by Davis (1989), which suggests that perceived knowledge positively influences ease of technology use. In this context, awareness may need to be complemented by applied skills or platform familiarity to improve perceived ease.

However, Fundamental Awareness significantly influences Risk Management ($\beta = 0.510$, $p < 0.001$), indicating that financial knowledge serves as a foundation for developing informed risk-management strategies within FinTech investment applications. This finding aligns with Risk Perception Theory (Slovic, 1987), which argues that individuals with higher domain knowledge are better equipped to recognize and mitigate financial risks. Furthermore, Fundamental Awareness has a significant positive effect on Trading Competence ($\beta = 0.425$, $p < 0.001$), implying that financially aware users demonstrate greater confidence and skill in trading decisions. This supports Social Cognitive Theory (Bandura, 1986), which emphasizes that awareness and learning enhance self-efficacy in task performance.

Although Risk Management significantly improves Trading Competence ($\beta = 0.284$, $p < 0.001$), it does not directly influence Ease of Use ($\beta = -0.104$, $p = 0.106$). This suggests that risk-handling activities may be perceived as complex or cognitively demanding and therefore do not directly enhance perceived simplicity. This observation is consistent with Cognitive Load Theory (Sweller, 1988), which explains how effort-intensive processes can increase perceived complexity. Finally, Trading Competence positively influences Ease of Use ($\beta = 0.304$, $p < 0.001$), indicating that competent users perceive FinTech applications as easier to navigate. This finding is supported by Technology Self-Efficacy Theory (Compeau & Higgins, 1995), which suggests that higher competence reduces perceived system complexity.

Table No. 7: Mediation Analysis through Trading Competence

Hypotheses		*β*	STDEV	T statistics	P values	Type of Mediation
H1$_4$	**FA -> RM -> TC -> EU**	0.044	0.014	3.16	**0.002*****	Serial Mediation
H1$_5$	**FA -> RM -> TC**	0.145	0.033	4.348	**0.000*****	Partial Mediation
H1$_6$	**FA -> TC -> EU**	0.129	0.034	3.857	**0.000*****	**Full Mediation**
H1$_7$	**FA -> RM -> EU**	-0.053	0.034	1.579	0.114	No Mediation
H1$_8$	**RM -> TC -> EU**	0.086	0.026	3.372	**0.001*****	**Full Mediation**

Source: Primary Data

The study further examined the mediating role of Trading Competence (TC) in the relationships among Fundamental Awareness (FA), Risk Management (RM), and Ease of Use (EU). The results indicate a significant full serial mediation effect in the path FA → RM → TC → EU ($\beta = 0.044$, $p = 0.002$). Since the direct relationship between FA and EU was not significant, this finding confirms that financial awareness enhances perceived ease of use only through its sequential influence on risk management and trading competence. This progression from awareness to control and execution is consistent with the cognitive evaluation process described in Cognitive Appraisal Theory (Lazarus, 1991).

Further analysis reveals that Risk Management partially mediates the relationship between Fundamental Awareness and Trading Competence (FA → RM → TC; $\beta = 0.145$, $p < 0.001$), as both the indirect and direct paths remain significant. In contrast, Trading Competence demonstrates a full mediation effect in the relationship between Fundamental Awareness and Ease of Use (FA →

TC → EU; β = 0.129, p < 0.001), given the absence of a significant direct FA → EU path. Similarly, a full mediation effect is observed in RM → TC → EU (β = 0.086, p = 0.001), as Risk Management does not directly influence Ease of Use but operates entirely through Trading Competence. The indirect path FA → RM → EU was not significant (β = −0.053, p = 0.114), indicating no mediation in this route. Collectively, these findings establish Trading Competence as the central explanatory mechanism through which financial awareness and risk-management practices translate into enhanced perceptions of ease of use in FinTech investment platforms.

Conclusion

The present study examined the impact of Fundamental Awareness and Risk Management on investor's perception of Ease of Use in FinTech investment applications, with Trading Competence acting as a mediating construct. The findings reveal that while Fundamental Awareness and Risk Management do not directly influence Ease of Use, they significantly enhance Trading Competence, which in turn positively affects perceived Ease of Use. This indicates that financial knowledge and risk-handling practices alone are insufficient to improve usability perception unless they translate into practical trading capability.

The structural model confirms that Trading Competence serves as a central mechanism linking awareness and risk management to platform usability. The results further establish significant indirect effects, including serial mediation from Fundamental Awareness to Ease of Use through Risk Management and Trading Competence. Notably, full mediation was observed in the relationship between Risk Management and Ease of Use through Trading Competence, reinforcing the importance of investor capability in digital investment environments.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

A Study on Impact of Delivery Speed on Customer Satisfaction in Quick Commerce

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Abstract

Over the past few years, quick commerce has transformed the shopping for household goods experience through fast delivery services using mobile application and online platforms. As people are spending longer time at work or home, and have less time to shop, they are increasingly looking for fast and easy delivery for groceries, drugs and household products. Delivery speed is one of most critical aspects of service quality, which in turn, influence customer satisfaction and repurchase behaviour. This research focuses on investigating the delivery speed for quick commerce services and its influence on customer satisfaction, customer expectations and re-purchase behaviour. The study primarily uses primary data sourced from a questionnaire of quick commerce customers. Literature-based secondary sources such as journals, research articles, and internet sources are also used. The research design is descriptive and the sampling method is convenience sampling, and the sample size is scientifically determined referring to past studies. Descriptive analysis through percentage, frequency distribution, tables and charts, and statistical analysis like Chi-Square test is employed for data analysis to test the hypotheses. The research will reveal that quick delivery enhances customer satisfaction, trust and leads to frequent use of quick commerce services. In conclusion, the study gives valuable insights on the impact of delivery speed on customer experience, and for quick commerce firms, how to enhance service quality and customer loyalty.

Keywords: *Quick Commerce, Delivery Speed, Customer Satisfaction, Customer Expectations, Repeat Usage Behaviour, Online Shopping, Logistics, E-Commerce Services*

Introduction

With the alarming rise of online and mobile services, shopping for groceries has indeed become a thing of the past in recent years. With the rise of busy work schedules and urbanisation, and reduced time for visiting brick and mortar stores, consumers now demand quicker and more efficient shopping experiences. The prevalence of mobile devices and internet penetration has also contributed to this trend. Thus, the notion of quick commerce has been established whereby essential products like groceries, medicines, desktop items, and cleaning products can be delivered within a short period (10-30 minutes). Brands that operate in the industry primarily deal with speed, convenience and quality to satisfy customers. In this regard, speed has become one of the critical factors in satisfying customers.

Quick commerce is thought to be the next and faster form of e-commerce because it offers extremely fast delivery via local stockrooms or dark stores near where customers live. Instead of waiting for a day or two for their products to arrive, as with traditional e-commerce, customers expect near instant delivery with quick commerce platforms. It has become a popular business model, particularly in urban and semi-urban areas, where customers are looking for fast delivery and easy availability. Consumers are now demanding fast responses and instant gratification. To be successful in quick commerce, it is essential that the websites deliver products quickly and accurately to customers. As the quick commerce market becomes more crowded, businesses need to continually enhance their delivery times to keep up with customer expectations.

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Quick delivery is essential to delivering a positive customer experience in quick commerce. Customers tend to use quick commerce services when there is an urgent need for products like groceries, food or medicines. In these cases, any delay in receiving the product can be frustrating. If their orders are not delivered on or before the expected time, then customers may feel unsatisfied or even disgruntled. But if the shipping is quick, customers feel that they can rely on the service. Hence, delivery time is not only an operational consideration but also a factor impacting customer satisfaction, loyalty, and repeat visits to quick commerce platforms.

Customer satisfaction is the level of satisfaction or contentment customers feel post-usage of a service. For quick commerce, customer satisfaction is based on (1) timeliness of delivery, (2) order accuracy, (3) product availability, (4) ease of use of the mobile app and (5) customer support. But the most observable and influential aspect is the speed of delivery, as it disrupts the customer's daily activities and fulfills their immediate needs. If orders are delivered on time or sooner, customers are satisfied with the experience, leading to increased loyalty. That enhances the likelihood of their return and loyalty to the service. In contrast, inconsistent delivery delays may drive customers to try out other platforms that offer quicker delivery.

Quick commerce is a crowded market with several platforms competing on similar product ranges, prices and discounts. Among the key factors that set these companies apart is the speed of delivery. Knowing the impact of delivery speed on customer satisfaction is crucial for companies to enhance service quality and ensure customer loyalty. Despite the rapid development of quick commerce in recent years, there is a lack of empirical evidence based on primary data that focuses on the link between delivery speed and customer satisfaction specifically from customers' perspective. This leaves a gap in the literature to be filled. The current research seeks to address this issue by gathering and examining primary data from quick commerce users.

The study will be based on primary and secondary data. The primary data will be gathered from customers of quick commerce service providers via a questionnaire. Secondary data will be obtained from sources including research publications and journals, company reports, web pages and articles on quick commerce and customer satisfaction. The research will aim to discover customers' expectations, perceptions and level of satisfaction with delivery speed. Through the analysis of customer feedback and secondary data, the study will be able to determine if quicker delivery plays an important role in customer satisfaction and loyalty.

This research will assist in better understanding customer attitudes and preferences in the quick commerce industry and will also assist companies to enhance their delivery operations and overall efficiency.

This study will help quick commerce firms to enhance their order-to-delivery process. Knowing customers' expectations about time to delivery will help companies build more efficient logistics and ensure quality of service. The research will also help marketers and operational managers in their decision making. Lastly, the study will contribute to the existing body of knowledge by contributing with the feedback from real customers.

Literature Review

A number of authors have examined customer satisfaction in e-commerce and quick commerce, particularly relating to delivery speed and quality of service. According to Vikrant Singh Teotia (2025), delivery speed is one of the very important factors affecting customer satisfaction in quick commerce. The research found quick delivery enhances satisfaction, whereas delayed delivery causes dissatisfaction, and fewer re-orders. This is a clear indication showing that speed is a key factor in why customers choose quick commerce.

Likewise, L. Santosh and Raviraj Shetty (2025) have researched last-mile delivery efficiency and discovered that quick delivery, real-time visibility and notification enhance the customer experience. They found a significant correlation between delivery efficiency and satisfaction which implies that logistics efficiency improve customer satisfaction. This is crucial for quick commerce which requires very fast service.

Sushama J. Gandal and Jalindar R. Gandal (2025) also examined the logistics functions in e-commerce and found that a timely delivery, accurate order and effective communication enhance customer trust and loyalty. Customers who receive timely and accurate orders are more satisfied with the e-commerce website. We see that efficient logistics is key to customer satisfaction.

Ayush Tyagi (2021) investigated the factors that affect customer satisfaction in online retail and concluded that timely delivery, price, product availability and security are crucial. While the study was conducted for Myntra, the insights are applicable for quick commerce also as customers in online shopping expect timely deliveries, affordable prices, and payment security.

Mohamed Dawood Shamout et al. (2024) studied the last-mile delivery of Amazon and discovered that fast and accurate delivery contributes to customer satisfaction. It also found that customer expectations are very different depending on their characteristics and usage patterns. Therefore, fast and effective delivery systems play a critical role in enhancing the e-commerce experience.

Ha Nam Khanh Giao (2020) highlighted that trust and customer service are the main factors impacting customer satisfaction on e-commerce platforms. This research found that customer satisfaction increases when the consumers trust the platform and get satisfactory service quality. This means trust and service alongside speed of delivery are crucial in virtual platforms.

In another study, Sanskriti Soni (2025) examined the factors driving purchase intention in quick commerce and showed that fast speed of delivery is a key factor. But it also showed that product availability and price are also critical for consumer behaviour. As such, consumers want platforms that are quick, convenient, and cheap.

Sreekumar Unni, Vishnu S. Nair, and Sangeetha Gunasekar (2015) examined the effect of delivery time in Indian cities and discovered that if customers were satisfied with the delivery time, they were likely to be satisfied with the service. They demonstrate that the quicker service affects positively on customer satisfaction and loyalty.

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Vipin Vihari Ram Tripathi et al. (2024) noted that good logistics performance has a positive impact on customer behaviour, satisfaction and re-purchase. Likewise, Vijoleta Vrhovac et al. (2024) noted the importance of speed, trust, price, and communication in last-mile delivery service that affects user satisfaction. This research shows that customer satisfaction is measured by not a single factor but various elements of service quality.

Other research like P. Venkatesh et al. (2025) and T. Krishnaveni and P. Devi (2024) that compared food platforms found that speed and user-friendliness of the mobile app are major factors for customer satisfaction. Similarly, Mohammad Hassan and Enikő Lencsés (2024) found that logistics service quality positively affects customer satisfaction and loyalty. In general, the existing studies reveal that food delivery, logistics service quality, trust, service quality and technology are important factors in customer satisfaction and loyalty in e-commerce and quick commerce studies.

Research Gap

While a lot of research has clarified that delivery speed is quite significant for determining customer satisfaction in quick commerce, there are a few research gaps. Many studies have been conducted on e-commerce websites in general and not on quick commerce sites specifically, which offer super-fast delivery in minutes. Moreover, researchers have mostly studied delivery speed in isolation, but very few have considered the relationship between delivery speed and other aspects such as price, product availability and user interface in a quick commerce scenario. Furthermore, there is a need for more research based on particular regions or cities, particularly in the Indian market as customer expectations and preferences may vary. And many studies have relied on secondary data (or general surveys) and it requires more primary data to reflect real customer experiences. So, this research seeks to address the gaps by looking at the impact of the speed of delivery in quick commerce, in the context of a specific market rather than a broad one.

Objective Of the Study

The main objectives of the study are:

- To analyze the impact of delivery speed on customer satisfaction in quick commerce.
- To understand customer expectations regarding delivery time in quick commerce platforms.
- To examine the relationship between delivery speed and repeat usage behavior of customers.

Statement Of the Problem

Customers in today's rapidly evolving quick commerce industry expect not only very short delivery times (often minutes), but also high service quality. But many delivery platforms face challenges meeting these demands, such as traffic congestion, demand and supply imbalance, inefficient logistics, and operational problems. This impacts customer satisfaction and likelihood of repeat order, affecting loyalty and customer lifetime value. While customers believe speed is an important factor, it is not known how speed affects customer satisfaction relative to other factors such as pricing, product availability and mobile app usage. And there is little work on the study of customers of quick commerce in local urban contexts in particular and in Indian cities.

Research Methodology

Research Design

The study adopts a descriptive research design to explore the significance of delivery speed in quick commerce services and how it affects customer satisfaction and repurchase intentions. This type of research is appropriate for this study as it helps to explain customer perceptions, expectations and experiences of delivery speed based on customer experiences of using quick commerce platforms.

Nature and Source of Data

This research is primarily based on primary data. Primary data comes directly from quick commerce customers who are receiving fast delivery services. Secondary data is gathered from books, online journals, journals, research papers, reports and online articles about quick commerce, delivery, logistics and customer satisfaction to provide a theoretical foundation for the study.

Data Collection Method

Primary data is obtained using a questionnaire. The questionnaire is developed with simple and close-ended questions on delivery speed, customer satisfaction, customer expectation, and reusing the riders. The questionnaire is administered online and offline to customers who use quick commerce services.

Target Population

The population of the study is quick commerce customers who use platforms like Blinkit, Zepto, Swiggy Instamart and BigBasket for placing quick orders for grocery, food and other essential items along with delivery within a short time.

Sampling Technique

Convenience sampling technique is used for this study. This technique involves choosing participants who are easily available to participate in the study. This sampling technique is useful, cheap, and feasible for students with little time and resources to conduct research.

Sample Size Determination

The required sample size for this study is around 109.

Sampling Unit

The sampling unit consists of customers using quick commerce platforms with experience of using delivery service and online ordering.

Tools for Data Analysis

Data will be analysed using basic statistical methods. The data would be analysed through percentage analysis and frequency distribution in order to determine the customers' expectations, satisfaction, and return or repeat usage behaviours towards delivery speed. The data will be represented using pie charts, bar charts, and other similar diagrams.

To test the hypotheses, Chi-Square test will be conducted to identify whether there is an association between delivery speed, customer expectations, customer satisfaction and re-purchasing intentions in quick commerce platforms since the data obtained from the questionnaire is in the form of categories.

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Limitations of the Study

The study is based on a sample of respondents and the outcome is based on the feedback obtained from the respondents.

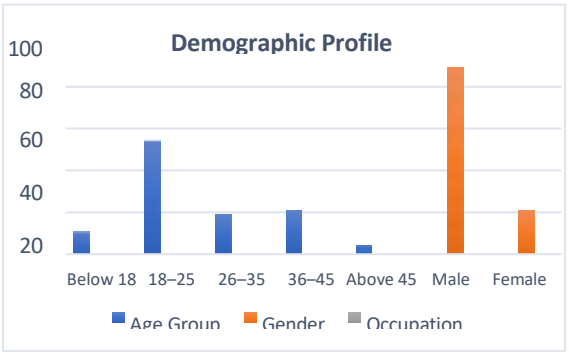
The study is conducted using convenience sampling, so the responses are specific to those who participants. The information is based on self-reports and is susceptible to bias and/or recent events.

The research is limited to some factors (such as speed and satisfaction) without considering other factors such as price and availability. In addition to this, the data is taken at a specific time, and therefore does not reflect patterns in customer behaviour over time.

Data Analysis and Interpretation

A. Demographic Profile

Variable	Category	Frequency	ercent (%)	Cumulative Percent (%)
Age Group	Below 18	11	10.0	10.0
	18–25	55	50.0	60.0
	26–35	19	17.3	77.3
	36–45	21	19.1	96.4
	Above 45	4	3.6	100.0
	Total	**110**	**100.0**	
Gender	Male	89	80.9	80.9
	Female	21	19.1	100.0
	Total	**110**	**100.0**	



Graph 1 Demographic Profile of the Respondents

Interpretation

From the above table, it is evident that most of the respondents are from 18-25 years of age (50%), which means young people are the primary users of quick commerce service. The next significant group is 36–45 years (19.1%), followed by 26–35 years (17.3%). Next, the number of respondents aged less than 18 and more than 45 is very low so it can be concluded that young people and old people are using quick commerce less.

Looking at the gender of the respondents, the statistics reveal there are more males (80.9%) than females (19.1%). This suggests that in our research, the usage of quick commerce by males is higher than females.

Therefore, it can be identified that, in this study, the main users of quick commerce platforms are young males.

B. Usage Pattern of Quick Commerce

Variable	Category	Frequency	Percent (%)	Cumulative Percent (%)
Usage Frequency	Daily	17	15.5	15.5
	3 times a week	51	46.4	61.8
	Once a week	20	18.2	80.0
	Occasionally	17	15.5	95.5
	Rarely	5	4.5	100.0
	Total	**110**	**100.0**	
Most Used Platform	Blinkit	23	20.9	20.9
	Zepto	17	15.5	36.4
	Swiggy Instamart	28	25.5	61.8
	BigBasket	18	16.4	78.2
	Others	24	21.8	100.0
	Total	**110**	**100.0**	

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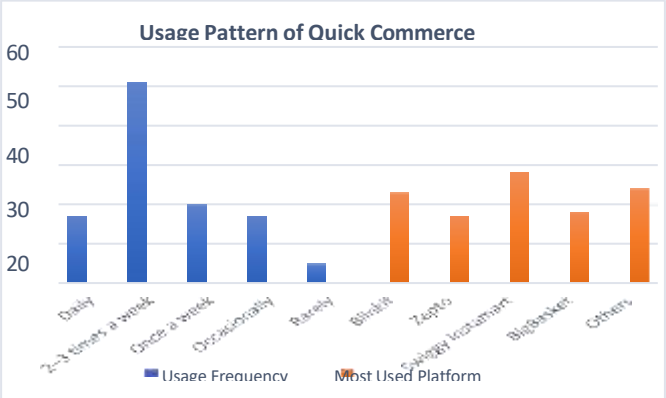


Graph 2 Usage Pattern of Quick Commerce

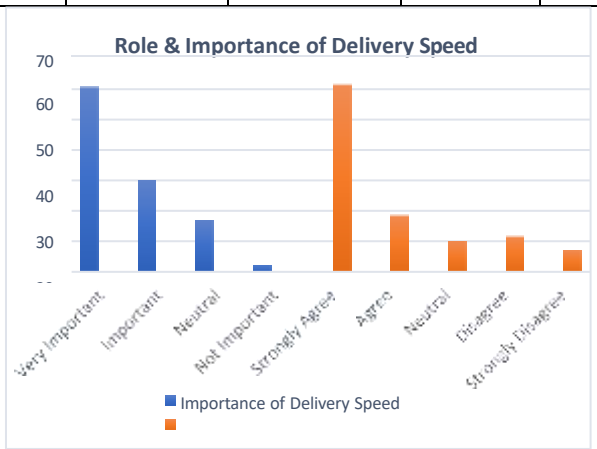
Interpretation

Our findings reveal that most of our respondents use quick commerce 2-3 times a week (46.4%), which shows it is used frequently but not necessarily every day. Some (approximately 18.2%) use it weekly and some (around 15.5%) use it daily, which suggests many use these services regularly. Very few respondents use it rarely.

Out of all of these, Swiggy Instamart (25.5%) is the most popular, followed by Blinkit (20.9%) and Others (21.8%). Zepto and BigBasket are slightly less used.This shows that people are gradually incorporating fast commerce into their lives, and have multiple options.

C. Role & Importance of Delivery Speed

Variable	Category	Frequency	ercent (%)	Cumulative Percent (%)
Importance of Delivery Speed	Very Important	61	55.5	55.5
	Important	30	27.3	82.7
	Neutral	17	15.5	98.2
	Not Important	2	1.8	100.0
	Total	**110**	**100.0**	
Delivery Speed Influences Decision	trongly Agree	62	56.4	56.4
	Agree	19	17.3	73.6
	Neutral	10	9.1	82.7
	Disagree	12	10.9	93.6
	Strongly Disagree	7	6.4	100.0
	Total	**110**	**100.0**	



Graph 3 Role & Importance of Delivery Speed

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Interpretation

It is clear from the data that customers consider delivery speed as very important because 55.5% of the respondents have put a rating of "very important" and 27.3% have put a rating of "important". Very few believe it is not important.

Similarly, 56.4% strongly agree and 17.3% agree that it is important for them when deciding to order. So, the majority of customers keep in mind the delivery speed while making their decision.

In general, it can be concluded that customers consider delivery speed very important, and it's a crucial element in the quick commerce model.

D. Customer Expectations Regarding Delivery Time

EXPECTED_DELIVERY_TIME					
		reque ncy	erce nt	Valid Percent	umulat ive Percent
Valid	. Within 10 minutes	50	45.5	45.5	45.5
	B. 10–20 minutes	12	10.9	10.9	56.4
	C. 20–30 minutes	25	22.7	22.7	79.1
	D. 30–45 minutes	18	16.4	16.4	95.5
	E. More than 45 minutes	5	4.5	4.5	100.0
	Total	110	100.0	100.0	

Graph 4 Customer Expectations Regarding Delivery Time

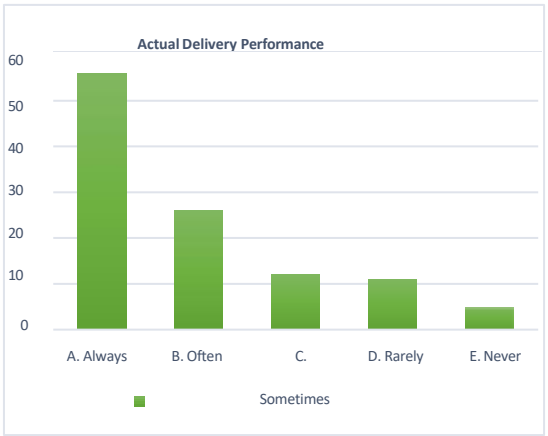
Interpretation

As the graph above indicates, 45.5% of the respondents expect delivery of products within 10 minutes, which is very fast. Some 22.7% expect delivery in 20-30 minutes, while others are more willing to wait a longer time.

This shows that customers expect relatively quick delivery, so quick commerce businesses should adapt to this, to keep customers happy.

In general, customers expect fast delivery, with preferences for 10-20 minute delivery times.

E. Actual Delivery Performance



Graph 5 Actual Delivery Performance

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Interpretation

According to the graph, 50.9% of the respondents reported that the platforms consistently deliver goods within the agreed time, and 23.6% often. This suggests that the majority of platforms seem to be doing well with regard to timely delivery.

But some customers said "sometimes" or "rarely", which suggests that there are limited deliveries that are delayed.

In summary, it is possible to draw the conclusion that quick commerce platforms generally fulfil delivery promises, but can do better.

Customer Satisfaction

Variable	Category	Frequency	Percent (%)	Cumulative Percent (%)
Satisfaction with Delivery Speed	Strongly Agree	63	57.3	57.3
	Agree	23	20.9	78.2
	Neutral	21	19.1	97.3
	Disagree	2	1.8	99.1
	Strongly Disagree	1	0.9	100.0
	Total	**110**	**100.0**	
Delivery Delay Impact	Strongly Agree	61	55.5	55.5
	Agree	31	28.2	83.6
	Neutral	15	13.6	97.3
	Disagree	2	1.8	99.1
	Strongly Disagree	1	0.9	100.0
	Total	**110**	**100.0**	
Overall Customer Satisfaction	Highly Satisfied	75	68.2	68.2
	Satisfied	20	18.2	86.4
	Neutral	13	11.8	98.2
	Dissatisfied	2	1.8	100.0
	Total	**110**	**100.0**	
Delivery Speed Increases Satisfaction	Strongly Agree	58	52.7	52.7
	Agree	27	24.5	77.3
	Neutral	19	17.3	94.5
	Disagree	3	2.7	97.3
	Strongly Disagree	3	2.7	100.0
	Total	**110**	**100.0**	

DELIVERY_WITHIN_PROMISED_TIME					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A. Always	56	50.9	50.9	50.9
	B. Often	26	23.6	23.6	74.5
	C. Sometimes	12	10.9	10.9	85.5
	D. Rarely	11	10.0	10.0	95.5
	E. Never	5	4.5	4.5	100.0
	Total	110	100.0	100.0	

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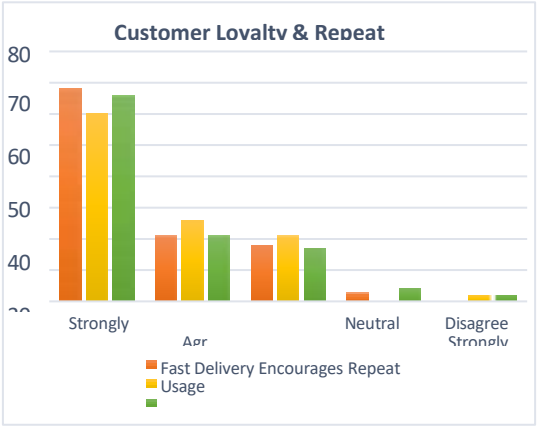

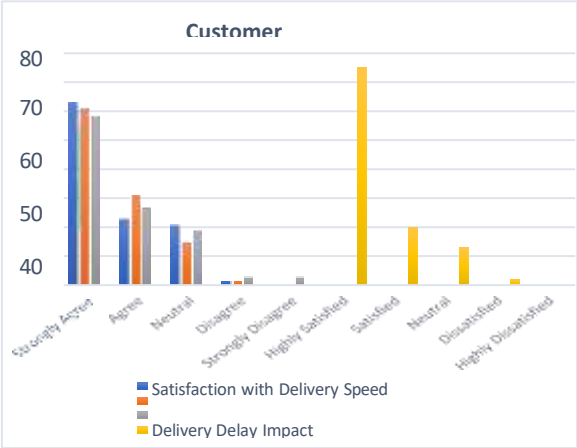

Graph 6 Customer Satisfaction

Interpretation

The results indicate that many customers are happy with quick enough delivery times as 57.3% strongly agree and 20.9% agree. This shows that they are very satisfied.

Furthermore, 55.5% respondents strongly agree that delays prevent them from being satisfied, which indicates that delay affects satisfaction.

In terms of overall customer satisfaction, 68.2% are satisfied and very few are dissatisfied. This demonstrates the overall satisfaction with quick commerce among customers.

Also, most of the respondents feel that a quickly delivered product makes the experience more satisfactory - showing that speed is a critical element of satisfaction.

F. Customer Loyalty & Repeat Usage

Variable	Category	Frequency	Percent (%)	Cumulative Percent (%)
Fast Delivery Encourages Repeat Usage	Strongly Agree	68	61.8	61.8
	Agree	21	19.1	80.9
	Neutral	18	16.4	97.3
	Disagree	3	2.7	100.0
	Total	**110**	**100.0**	
Switch App if Delivery is Slow	Strongly Agree	60	54.5	54.5
	Agree	26	23.6	78.2
	Neutral	21	19.1	97.3
	Disagree	1	0.9	98.2
	Strongly Disagree	2	1.8	100.0

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	Total	**110**	**100.0**	
Recommend Due to Fast Delivery	Strongly Agree	66	60.0	60.0
	Agree	21	19.1	79.1
	Neutral	17	15.5	94.5
	Disagree	4	3.6	98.2
	Strongly Disagree	2	1.8	100.0
	Total	**110**	**100.0**	

Graph 7 Customer Loyalty & Repeat Usage

Interpretation

This graph reveals 61.8% strongly agree that quick delivery leads to repeat usage. So, speed of delivery impacts on reuse.

Likewise, 54.5% strongly agree they will change to a different platform if the delivery is slow. This suggests users are quite sensitive to slow delivery and may be likely to switch service providers.

Also, 60% strongly agree they would recommend quick commerce apps for quick delivery. This demonstrates that fast delivery results in satisfaction and word-of-mouth.

In conclusion, it can be said that delivery speed significantly affects customer loyalty, usage and referral.

Hypothesis Testing

Hypothesis 1

H_0: Delivery speed does not have a significant impact on customer satisfaction.

H_1: Delivery speed has a significant impact on customer satisfaction.

Correlations			
		DELIVERY_ SPEED	CUSTOMER _ SATISFACTION
DELIVERY_SPEED	Pearson Correlation	1	.338**
	Sig. (2-tailed)		<.001
	N	110	110
STOMER_SATISFACTION	Pearson Correlation	.338**	1
	Sig. (2-tailed)	<.001	
	N	110	110
**. Correlation is significant at the 0.01 level (2-tailed).			

Interpretation

The table above shows the Pearson correlation of delivery speed and customer satisfaction. The value of the correlation coefficient, r (r = 0.338), shows there is a strong positive correlation between the variables. The p-value (p = 0.000) is less than 0.05, so the correlation is significant.

This suggests that as delivery speed increases, so does customer satisfaction.

Result

The p-value is less than 0.05 therefore we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_1). So delivery speed plays a crucial role in customer satisfaction in quick commerce.

Hypothesis 2

H_0: Delivery speed does not significantly influence repeat usage behaviour.

H_1: Delivery speed significantly influences repeat usage behaviour.

Correlations			
		ELIVERY _ SPEED	REPEAT_ US AGE_BE HA VIOUR
DELIVERY_SPEED	Pearson Correlation	1	.296**
	Sig. (2-tailed)		.002
	N	110	110

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PEAT_USAGE_BE HAVIOUR	Pearson Correlation	.296**	1
	Sig. (2-tailed)	.002	
	N	110	110
**. Correlation is significant at the 0.01 level (2-tailed).			

Interpretation

According to the table, the Pearson correlation coefficient (r) between delivery speed and repeat usage behaviour is 0.296, which is a positive correlation between the two. This value is statistically significant (p-value = 0.002 < 0.05).

So, quicker delivery leads to repeat use and creates customer loyalty.

Result

Since the p-value is smaller than 0.05, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) accepted. So, delivery speed has a significant impact on re-patronage intentions.

Hypothesis 3

H_0: Delivery speed does not significantly affect customer expectations.

H_1: Delivery speed significantly affects customer expectations.

Correlations

		ELIVERY_SPEED	PECTATION
DELIVERY_SPEED	Pearson Correlation	1	.303**
	Sig. (2-tailed)		.001
	N	110	110
EXPECTATION	Pearson Correlation	.303**	1
	Sig. (2-tailed)	.001	
	N	110	110
**. Correlation is significant at the 0.01 level (2-tailed).			

Interpretation

The correlation between delivery speed and customer expectations using the Pearson correlation coefficient is r = 0.303 and is significant at the 0.05 level. The p-value (p = 0.001) is lower than 0.05, meaning that this correlation is significant.

Hence, delivery speed has a significant influence on customer expectations about quick commerce delivery.

Result

The p-value being lower than 0.05 means that the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) accepted. So, delivery time does have an impact on customer experience.

Findings

Our study results reveal that quick commerce platforms are widely being adopted by young people, particularly 18-25 years. This means that young people are more technologically savvy and like to enjoy quick and convenient services. The number of male users is larger than that of females in this study, which indicates that men are more engaged users of quick commerce services. The demographic information shows that quick commerce is more prominent among young tech-savvy people.

The frequency of use shows that customers are not completely addicted to these platforms but are frequent users. Many of the respondents use quick commerce 2-3 days a week, which indicates that the platforms are becoming a part of everyday life. People use different platforms such as Blinkit, Zepto and Swiggy Instamart with no platform dominating the market. This suggests a competitive environment and reveals that customers are willing to switch platforms depending on their experience and preference.

A key insight of this research is the importance of delivery speed. The survey responses indicate that delivery speed plays an important role in the customers' choices. A majority of people rate it as very important and many strongly agreed that delivery speed is a reason to choose a platform. This makes it essential for fast commerce businesses to consider delivery speed to win and retain customers. Speedy delivery is not longer a luxury, but an expectation for customers.

This is also supported by our hypothesis testing. The findings of hypothesis 1 indicate that delivery speed is moderately positively and significantly related with customer satisfaction (r = 0.338, p < 0.05). This suggests that quick delivery also enhances customer satisfaction. So, faster delivery is not only critical for retaining customers but also for making them happy with their experience.

Another finding of the study is that customers' expectations in terms of delivery speed are high. Many customers in this study expect a delivery time of 10-20 minutes, and this places pressure on companies to offer incredibly fast delivery services. The outcomes of

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Hypothesis 3 show that delivery speed significantly affects customer expectations ($r = 0.303$, $p < 0.05$). So, the faster that companies become, the higher customers' expectations become and that requires platforms to continue to increase speed and efficiency.

The level of customer satisfaction is high, meaning that customers' expectations are for the most part being satisfied by quick commerce. But the study also finds that even minor delays can have a negative impact on customer experience. This suggests that customer satisfaction is very time sensitive. Quick delivery makes customers happy and delays can make them unhappy. The statistical results of Hypothesis 1 also support this conclusion by suggesting a strong association between delivery speed and satisfaction.

Lastly, the findings clearly demonstrate a relationship between delivery speed and loyalty. The majority of customers believe that fast delivery makes them more likely to experience a repeat usage, referral behaviour and loyalty. The findings from Hypothesis 2 support this view, showing delivery speed is positively related to customer retention ($r = 0.296$, $p < 0.05$). It suggests faster delivery leads to higher customer convenience and better customer retention, which increases website usage and stickiness.

However, customers are also willing to change their platform if the delivery time is slow. This demonstrates that loyalty towards quick commerce is largely determined by quality delivery services. In conclusion, the results of the three hypotheses clearly demonstrate that delivery speed is very important in determining the level of customer satisfaction, as well as the level of expectations and repeat purchase decision making.

Suggestions

Looking at the results of the study, it can be seen that delivery speed is a very important aspect when it comes to customer satisfaction, but companies must focus on making it better in an efficient manner. Firstly, companies offering quick commerce services need to focus on improving delivery efficiency through improved route optimisation, increased fleet size, and technology. This will ensure on-time delivery of 10-20 minutes as desired by the customers. Customers are not forgiving of even small delays in delivery so firms need to be consistent with their service.

Secondly, firms should not only focus on time alone but overall quality of services. It's important for products to be in stock, the right order to be delivered, and the product is well packaged. If products are damaged or incorrect, even fast delivery won't give a high-quality experience. Therefore, companies should ensure better stock management and quality control to provide a seamless experience to their customers.

Secondly, it is recommended that companies should set the right expectations. As shorter deliveries lead to higher expectations, companies should provide accurate delivery times. They can also offer reliable tracking and updates to customers to enhance trust and satisfaction.

Finally, quick commerce businesses should retain their customers. This could involve discounts, rewards or loyalty programs for frequent users. As customers are likely to use a different platform if it takes too long to deliver, companies need to constantly improve their service to retain customers. Overall, quick commerce must find the right balance between speed of service, quality of service and customer satisfaction to sustain.

Conclusion

This research concludes that delivery speed is a key service attribute of quick commerce and directly affects customer satisfaction, service expectation and loyalty. The results suggest that the majority of the customers, particularly Gen Z, anticipate a very quick delivery, ranging between 10 and 20 minutes and regard it as a determining factor during platform selection. The tests for hypotheses reveal that delivery speed indeed has a statistically significant positive impact on customer satisfaction, with quicker delivery causing an increase in satisfaction. The findings also indicate that customer satisfaction is highly price sensitive to delivery speed, in which meeting delivery expectations increases satisfaction while any delays can have a negative impact.

Moreover, the research shows that delivery speed is highly critical in driving customer loyalty and what happens next after the delivery. Faster delivery is shown to increase the probability of reusing an e-commerce platform and more likely to be recommended to others. In addition, the speed of delivery also influences customer expectations: faster delivery sets a higher bar. In a competitive environment, customers will leave the platform if they experience slow delivery, so it plays a significant role in customer retention. Thus, delivery speed stands out as a critical factor for the success of quick commerce platforms, ensuring customer satisfaction, the desired customer experience and sustainable growth.

Acknowledgement

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Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Psychological Safety and its Role in Reducing Operational Errors

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Abstract:

In today's supply chain and operations landscape, we usually define efficiency through the lens of speed, volume, and technical precision. However, this research suggests that the most critical factor for operational accuracy might actually be the psychological state of the workforce specifically, their level of "psychological safety." In high-pressure environments like modern warehouses, strict quotas and constant monitoring often backfire by creating a "culture of fear." This pressure triggers a dangerous phenomenon known as "Workplace Silence," where employees feel forced to hide small errors or ignore process flaws just to avoid getting in trouble. Unfortunately, these hidden mistakes don't stay small; they eventually snowball into major financial losses and supply chain disruptions that could have been easily avoided through open communication. This paper examines how chronic stress wears down a worker's mental energy, directly leading to more physical accidents and errors. The study demonstrates that when a company chooses to prioritize mental well-being and builds a "learning culture" instead of a "blame culture," employees feel safe enough to report problems in real-time. This shift does more than just lower turnover and save on hiring costs; it fundamentally strengthens the entire system's resilience. Ultimately, this paper concludes that psychological safety isn't just a "soft" HR topic it is a strategic operational tool. Investing in the mental health and autonomy of the team is essential for building a lean, error-resistant supply chain that can actually survive under pressure.

Key Words: *Occupational Stress, Psychological Safety, Workplace Silence, Error Management Theory, Operational Excellence*

Introduction

If you look at how most modern supply chains are run today, they look like perfectly oiled machines. We've become obsessed with speed, volume, and tracking everything down to the second. In an era where everyone wants their package delivered yesterday, the pressure on companies to perform has never been more intense. To keep up, managers have leaned heavily on automation and strict performance metrics. But there's a massive problem that the spreadsheets aren't catching: the human cost of all this pressure. In many warehouses and logistics hubs, the atmosphere isn't one of teamwork; it's one of survival. When you're being tracked by a scanner every ten seconds and know that one slow moment could get you flagged, you stop caring about doing the job "right" and start focusing on just looking fast. This creates a "culture of fear." When people are scared, they don't report problems; they hide them. This is what psychologists call "Workplace Silence," and it is the silent killer of supply chain accuracy. A worker might see a damaged box or a mislabeled pallet, but if speaking up means slowing down their "score," they'll just let it pass. This research paper is built on the idea that "Psychological Safety" the simple feeling that you won't be fired for pointing out a mistake is actually a business necessity. We often think of mental health as a "soft" HR topic, but in a high-stakes operation, it's as vital as the conveyor belt. When workers feel safe, the information flows freely. When they're stressed and anxious, the brain's "bandwidth" shrinks, and that's exactly when expensive mistakes happen. By using the Job Demands-Resources (JD-R) model, I want to show that pushing people to their breaking point doesn't actually make a company more efficient it just makes the errors harder to find until it's too late. To build a supply chain that actually lasts, we have to stop treating people like robots and start building a culture where it's safe to be human. Ultimately, a resilient business isn't just about fast trucks; it's about a workforce that feels safe enough to tell the truth.

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Literature Review

When we look at the existing research, there is a glaring contradiction between traditional operations management and modern workplace psychology. For decades, the dominant academic view in supply chain research has been rooted in "Lean" principles and "Six Sigma" methodologies, where success is defined by the total elimination of waste and the maximization of speed. Scholars in this field often argue that real-time monitoring and high-visibility tracking are the gold standards for a competitive warehouse. However, this technical focus often ignores the "Human Factor." On the other side of the fence, psychologists like Amy Edmondson have spent years proving that in high-stakes environments, the most successful teams aren't the ones who never make mistakes, but the ones who feel "psychologically safe" enough to talk about them. This is where the Job Demands-Resources (JD-R) model becomes essential; it suggests that when the physical and mental demands of a job like impossible shipping quotas outpace the support resources provided to the worker, the result isn't just burnout, it's a total breakdown in operational accuracy. While the operations world focuses on the "machine," and the psychology world focuses on the "mind," there is a significant gap in research regarding how fear-driven management specifically creates the "Workplace Silence" that leads to catastrophic supply chain errors. My research aims to bridge this gap, arguing that we cannot have a truly efficient supply chain without first securing the psychological safety of the people running it.

Research Gap

While the world of operations management has mastered the art of tracking physical assets, it has largely ignored the psychological assets of the people moving them. Current research is filled with studies on how to optimize a conveyor belt or a delivery route, but there is a significant gap in understanding how the stress of constant surveillance creates a culture of 'Workplace Silence.' We simply don't have enough data on how many supply chain disasters begin with a worker who saw a problem but was too afraid to speak up. My research addresses this by connecting the dots between employee anxiety and operational failure, proving that you cannot have a lean supply chain if your workers are too scared to be honest.

Objective

1. To determine how high-pressure monitoring creates anxiety and "Workplace Silence" among supply chain employees.
2. To prove that increasing psychological safety reduces hidden errors and improves overall operational performance.

Hypothesis

H1: High levels of managerial pressure and digital monitoring lead to increased "Workplace Silence," causing employees to hide operational errors.

H2: Teams with higher "Psychological Safety" will report errors more frequently in real-time, resulting in a significantly lower rate of long-term supply chain disruptions.

Research Methodology

Research Design

This study uses a **mixed-method approach**, combining quantitative data (to measure stress, errors, and safety) and qualitative insights (to understand employee behaviour).

Research Approach

It follows a **descriptive approach** to study current conditions and an **explanatory approach** to identify relationships between variables.

Theoretical Framework

Based on the **Job Demands-Resources (JD-R) Model**, which explains that high job demands increase stress, while proper support improves performance.

Data Collection

Primary Data: Questionnaires (Likert scale) and interviews
Secondary Data: Journals, articles, and reports

Sampling Design

Population: Supply chain/warehouse employees
Method: Convenience or purposive sampling
Sample Size: 100–150 respondents

Variables

Independent: Psychological safety, job demands
Dependent: Errors, performance
Mediating: Stress, workplace silence

Data Analysis

Quantitative: Percentage, correlation, regression
Qualitative: Thematic analysis Ethics & Limitations
Confidentiality and voluntary participation were ensured. The study is limited by small sample size and possible response bias.

Data Analysis and Interpretation

- Most employees are young and less experienced, making them more affected by pressure.
- **Psychological safety is low**: Around 60–65% employees feel unsafe reporting mistakes. This creates fear in the workplace.
- **Workplace silence is high**: About 70% avoid reporting errors due to fear of punishment. Small issues remain hidden and grow bigger.
- **Stress levels are high**: Nearly 75% face heavy workload and strict targets.
  Stress reduces focus and increases mistakes.
- **Operational errors**: Over 50% admitted making errors under pressure.
- Based on the **Job Demands-Resources (JD-R) Model**:

o High job demands → more stress → more errors
o Psychological safety → fewer errors

Findings

1. Psychological safety is low, making employees afraid to report mistakes or issues.
2. Workplace silence is common, leading to hidden errors that grow into bigger problems.
3. High job pressure and workload create stress, reducing focus and efficiency.
4. Stress and lack of communication increase operational errors and accidents.

5. As per the **Job Demands-Resources (JD-R) Model**, high job demands increase stress, while supportive environments improve performance and reduce errors

Suggestion

To improve supply chain performance, companies need to focus more on creating a supportive work environment where employees feel safe to speak up about mistakes without fear of punishment. When workers are comfortable sharing issues, small problems can be solved early instead of turning into major disruptions. Organizations should encourage open communication and move away from a blame culture, treating mistakes as opportunities to learn and improve. It is also important to reduce excessive workload and unrealistic targets, as high stress directly affects employee performance and increases errors. Managers should be approachable and supportive so that employees feel confident in sharing their concerns. Following the **Job Demands-Resources (JD-R) Model**, balancing job pressure with proper support, guidance, and flexibility can help improve both employee well-being and operational efficiency, ultimately leading to a more reliable and resilient supply chain.

Conclusion

In conclusion, this study shows that supply chain efficiency is not just about speed or technology, but also about how employees feel at work. When people are stressed and afraid to speak up, they tend to hide mistakes, which can later turn into bigger problems. On the other hand, when the workplace is supportive and employees feel comfortable sharing issues, problems can be solved early and work becomes smoother. Based on the **Job Demands Resources (JD-R) Model**, it is clear that balancing work pressure with proper support is important. Overall, creating a positive and open work environment helps reduce errors and makes the supply chain more efficient and reliable.

Acknowledgement

I would like to express my sincere gratitude to my teacher for providing me with the opportunity to complete this project on **"Psychological Safety and Its Role in Reducing Operational Errors."** Their valuable guidance, constant encouragement, and insightful suggestions were instrumental in the successful completion of this project.

I am also thankful to my school for providing the necessary resources and a supportive learning environment. I extend my heartfelt gratitude to my parents, friends, and classmates for their continuous support, motivation, and cooperation throughout the preparation of this project.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Artificial Intelligence (AI) as a catalyst for achieving Sustainable Development Goal (SDG) 4

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Abstract

This paper examines the transformative role of artificial intelligence (AI) in education, particularly with respect to the United Nations' Sustainable Development Goal 4 (SDG 4), which aims to ensure inclusive and equitable quality education for all by 2030. It highlights the potential of AI to dismantle barriers that inhibit access to quality education due to economic, geographic, and social disparities. By utilizing advanced technologies, such as natural language processing and machine learning, AI enhances personalized learning experiences and improves educational accessibility for diverse student groups. Furthermore, the study analyzes the implications of AI-driven educational innovations, addressing both the opportunities and challenges they present in achieving SDG 4. This exploration underscores the necessity of integrating AI in educational frameworks to foster an inclusive learning environment that promotes equity and quality in education worldwide.

Introduction

Education is a tool that liberates the intellectual and imagination process. Accessibility to Education is a factor for economic development as it enables everyone to make positive contribution to a healthy and functioning economy. It also provides wealth of knowledge and greater opportunities for success. With the advancement of artificial intelligence there is a breakthrough transformation in education system. Traditional systems of education are being replaced by modern and integrated systems of education. Artificial Intelligence has led to a major disruption in the education system. It has paved way for more individualized and adaptable learning by enhancing the accessibility of education across various student groups with diverse needs. AI has opened the doors for opportunities and challenges and has the potential to completely transform our education system. Hence there is a scope to examine the role of artificial intelligence towards achievement of sustainable Development Goal 4 of UNESCO.

The main purpose of SDG 4 i.e., Sustainable Development Goal of the United Nations is to ensure inclusive and equitable quality education for all by 2030. Education is one of the global fundamental rights, yet millions of students lack access to quality education due to disparities in economy, location, gender, disabilities etc. This paper analyses the role played by AI in shaping the education system especially with reference to Sustainable Development Goal 4.

Artificial Intelligence and Sustainable Development Goal 4

Artificial intelligence (AI) refers to the development of computer systems capable of performing tasks that typically require human intelligence. These tasks include: Learning and problem-solving, Visual perception and speech recognition, Decision-making and language translation, Reasoning and planning. AI systems use algorithms, machine learning, and deep learning techniques to process large amounts of data, identify patterns, and make predictions or decisions. The field of AI encompasses various subfields, such as: Machine Learning: Algorithms that improve their performance through experience, Natural Language Processing: Enabling computers to understand and generate human language, Computer Vision: Allowing machines to interpret and analyze visual information, Robotics: Designing and programming machines to perform physical tasks.

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AI applications are increasingly prevalent in various industries, including healthcare, finance, transportation, and entertainment. As the technology continues to advance, it has the potential to revolutionize many aspects of human life and work.

Sustainable Development Goal (SDG) 4 aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all by 2030.This goal emphasizes the importance of providing equal access to education for all, particularly marginalized groups, to foster a more inclusive society. Achieving SDG 4 requires concerted efforts at both international and national levels to address barriers and create inclusive educational environments for all learners, especially those from vulnerable populations. To effectively implement SDG 4, it is crucial to recognize that inclusive education extends beyond mere access; it also encompasses the quality of educational experiences provided to all students. This involves not only adapting curricula to meet diverse learning needs but also ensuring that teaching methods are inclusive and supportive of students with disabilities and other vulnerabilities. For instance, recent research highlights the importance of utilizing technology and innovative pedagogical strategies to create accessible learning environments that foster engagement and participation among all learners, particularly those facing health challenges(Argyriadi, et.,al 2024) (Ceresnova et.al., 2017) Furthermore, systematic evaluations of existing educational policies are necessary to identify gaps and barriers that persist, thereby facilitating targeted interventions that can enhance educational equity and promote lifelong learning in accordance with the aspirations outlined in SDG 4 (Vindigni, 2024).

Role of Artificial Intelligence as a catalyst for achieving Sustainable Development Goal 4

AI applications help advance SDG 4 by addressing key challenges in education:

1. Personalized Learning: AI-powered systems can analyze a student's learning patterns, strengths, and weaknesses to create a customized curriculum. This allows students to progress at their own pace, ensuring they fully grasp concepts before moving on. This is especially beneficial for students who may fall behind in a traditional classroom setting.
2. Enhanced Accessibility and Equity: AI can help bridge the gap in education by providing access to high-quality resources for students in remote or underserved areas. AI tools can offer multimodal language support, like real-time translation and transcription, making content more accessible for students with diverse linguistic backgrounds or disabilities.
3. Teacher Support and Efficiency: AI can automate time-consuming administrative tasks, such as grading quizzes and managing student records. This frees up teachers to focus on more meaningful interactions, providing personalized guidance and fostering deeper engagement with students.
4. Data-Driven Insights: AI can analyze educational data to identify students at risk of falling behind or dropping out. This allows educators to intervene with timely and targeted support, improving student outcomes and reducing inequalities.
5. Lifelong Learning and Skill Development: AI platforms can provide flexible, on-demand learning opportunities for adults and professionals, offering courses and resources to help them acquire new skills and adapt to a changing job market.

Challenges and Ethical Considerations

1. While AI offers immense potential, its implementation in education also comes with challenges that must be addressed to ensure its sustainable and equitable use:
2. The Digital Divide: Without adequate investment in digital infrastructure and resources, particularly in developing regions, AI-driven education could exacerbate existing inequalities. Students without access to reliable internet, devices, and digital literacy training will be left behind.
3. Bias in Algorithms: AI models are trained on data, and if that data is biased, the algorithms can perpetuate or even amplify existing social and cultural biases. This can lead to unfair or discriminatory outcomes, such as reinforcing stereotypes or providing inadequate support to certain student groups.
4. Data Privacy and Security: The use of AI in education involves collecting vast amounts of student data, raising significant concerns about privacy and security. Robust policies and safeguards are essential to protect sensitive information from misuse or breaches.
5. Over-reliance and Dehumanization: Over-reliance on AI could diminish critical thinking and problem-solving skills in students. It could also lead to a more isolated learning experience, as the technology cannot replicate the empathy and personal connection provided by human educators.

Conclusion

In conclusion, the integration of artificial intelligence in education holds significant promise for advancing the United Nations' Sustainable Development Goal 4 by enhancing accessibility, personalizing learning experiences, and supporting educators. However, to fully realize this potential, it is imperative to address the accompanying challenges, such as the digital divide and algorithmic bias, ensuring that AI serves as a tool for equity and inclusion in education for all.

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Human Resources Innovation: Transforming People Management in the Digital Era

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Abstract

The contemporary business environment demands that human resources (HR) functions transcend traditional administrative roles and assume strategic, data-informed identities. This paper investigates the landscape of HR innovation, examining the adoption of artificial intelligence (AI), talent analytics, agile methodologies, and human-centered experience design within people management practices. Drawing on a synthesis of empirical studies, conceptual frameworks, and organizational case evidence, the paper identifies five principal dimensions of HR innovation: technology integration, talent analytics, employee experience design, agile HR practices, and remote work enablement. The review further evaluates the comparative benefits of innovation-driven HR against traditional approaches across key functions including recruitment, performance management, learning and development, employee well-being, and workforce planning. Challenges to adoption—spanning technological, cultural, ethical, and organizational domains are examined alongside mitigation strategies. The paper concludes by proposing a conceptual model for sustainable HR innovation and offering directions for future research. Findings suggest that organizations embedding innovation within HR strategy report measurable gains in efficiency, engagement, and workforce agility, underscoring the business imperative of HR transformation.

Keywords: *human resources innovation, artificial intelligence in HR, talent analytics, employee experience, agile HR, digital transformation*

Introduction

The function of human resources management (HRM) has undergone a profound metamorphosis over the past two decades. Where HR once operated primarily as an administrative unit responsible for payroll, compliance, and personnel records, it is now increasingly positioned as a strategic engine of organizational performance (Ulrich et al., 2017). This shift has been catalyzed by technological advancement, changing workforce demographics, intensifying global competition, and the disruptive effects of the COVID-19 pandemic, which forced organizations to rethink how people are recruited, managed, developed, and retained (Lund et al., 2021).

HR innovation encompasses a broad spectrum of practices, tools, and philosophies that fundamentally alter how people management is conceptualized and executed. Scholars have defined HR innovation as the intentional introduction of new or significantly improved practices, processes, or products within the HR function that create value for individuals and organizations (Shipton et al., 2017). This definition acknowledges that innovation in HR is not limited to technology adoption but also includes structural, cultural, and philosophical shifts in how organizations relate to their employees.

The significance of HR innovation extends beyond operational efficiency. Research has consistently demonstrated that organizations with innovative HR practices outperform their peers on key metrics including employee engagement, talent retention, innovation output, and financial performance (Huselid, 1995; Pfeffer, 1998). More recently, the integration of AI, machine learning, and people analytics has opened new frontiers for evidence-based decision-making in HR, enabling organizations to move from reactive to predictive people strategies (Tambe et al., 2019).

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Despite the growing body of literature on HR innovation, several gaps remain. Empirical research on the organizational conditions that enable or hinder HR innovation is still nascent (Shipton et al., 2017). The ethical dimensions of AI-driven HR, including concerns about algorithmic bias, data privacy, and employee surveillance, have received increasing but still insufficient scholarly attention (Tambe et al., 2019). Furthermore, the intersection of remote work trends and HR innovation presents new and largely unexplored territory.

This paper aims to address these gaps by synthesizing current knowledge on HR innovation, evaluating its dimensions and outcomes, and identifying challenges and future research directions. The paper is structured as follows: Section 2 presents the theoretical framework. Section 3 reviews key dimensions of HR innovation. Section 4 compares traditional and innovative HR approaches. Section 5 examines challenges to adoption. Section 6 proposes a conceptual model, and Section 7 concludes with implications and future directions.

Theoretical Framework

Several theoretical lenses illuminate the phenomenon of HR innovation. The resource-based view (RBV) of the firm, originally articulated by Barney (1991), posits that sustainable competitive advantage derives from resources that are valuable, rare, inimitable, and non-substitutable. Human capital—encompassing the knowledge, skills, and capabilities of employees—represents one of the most potent sources of competitive advantage available to organizations. HR innovation, in this frame, is the mechanism through which organizations develop, deploy, and sustain superior human capital (Barney & Wright, 1998).

Complementing the RBV, institutional theory suggests that organizations adopt innovative HR practices not only because of their intrinsic economic value but also due to isomorphic pressures from industry peers, regulatory bodies, and professional networks (DiMaggio & Powell, 1983). This perspective helps explain the diffusion of HR innovations such as people analytics dashboards and AI-powered recruitment tools across industries, as organizations seek legitimacy by conforming to emerging norms of practice.

A third relevant framework is dynamic capabilities theory (Teece et al., 1997), which conceptualizes organizational competitiveness as contingent on the ability to sense, seize, and reconfigure resources in response to environmental change. HR innovation, from this standpoint, reflects the organization's dynamic capability to continuously adapt its people management systems to evolving internal and external conditions—a capability that has proven especially critical during periods of rapid technological and socioeconomic disruption (Teece, 2007).

Finally, self-determination theory (SDT; Deci & Ryan, 2000) provides a psychological foundation for understanding why certain HR innovations enhance employee motivation and engagement. SDT posits that human motivation is sustained when three fundamental needs are met: autonomy, competence, and relatedness. Innovations in employee experience design, flexible work arrangements, and personalized learning and development directly target these needs, suggesting that well-designed HR innovation can enhance intrinsic motivation alongside organizational efficiency.

Dimensions of HR Innovation

HR innovation manifests across five interconnected dimensions, as summarized in Table 1. These dimensions are not mutually exclusive; rather, they operate synergistically, with advances in one area enabling and accelerating innovation in others (Shipton et al., 2017).

Table 1

Dimensions of Human Resources Innovation and Their Applications

Dimension	Description	Example Application
Technology Integration	Adoption of AI, ML, and automation tools in HR workflows to enhance efficiency and reduce manual effort	AI-powered resume screening (Upadhyay & Khandelwal, 2018)
Talent Analytics	Use of data-driven approaches to forecast workforce needs, track performance, and reduce attrition	Predictive attrition modeling (Tursunbayeva et al., 2018)
Employee Experience Design	Human-centered design of workplace processes to improve engagement, well-being, and productivity	Journey mapping and digital onboarding (Plaskoff, 2017)
Agile HR Practices	Application of agile principles to HR functions including iterative policy development and cross-functional HR teams	Sprint-based performance reviews (Cappelli & Tavis, 2018)
Remote Work Enablement	Policies and technologies supporting distributed, hybrid, and asynchronous work models	Virtual collaboration platforms and digital HR portals (Lund et al., 2021)

Note. Data synthesized from Upadhyay and Khandelwal (2018), Tursunbayeva et al. (2018), Plaskoff (2017), Cappelli and Tavis (2018), and Lund et al. (2021).

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Technology Integration

The infusion of technology into HR processes represents perhaps the most visible dimension of HR innovation. Artificial intelligence, in particular, has transformed recruitment through automated resume parsing, natural language processing-based chatbots for candidate engagement, and predictive algorithms that identify high-potential candidates from large applicant pools (Upadhyay & Khandelwal, 2018). Machine learning models are also applied to performance prediction, succession planning, and compensation benchmarking, enabling HR professionals to make decisions informed by pattern recognition across large datasets rather than subjective intuition alone.

Robotic process automation (RPA) has further streamlined administrative HR tasks such as benefits enrollment, payroll processing, and compliance reporting, freeing HR professionals to focus on higher-value strategic activities (Stone et al., 2015). The integration of blockchain technology in credentialing and background verification represents an emerging frontier, promising to eliminate fraud and reduce the cost of candidate screening (Treiblmaier, 2019).

Talent Analytics

People analytics—the use of statistical and data science methods to derive insights from workforce data—has emerged as a cornerstone of modern HR strategy (Tursunbayeva et al., 2018). Organizations deploying mature analytics capabilities are able to predict employee attrition with remarkable accuracy, identify the antecedents of high performance, and quantify the return on investment of HR interventions such as training programs and wellness initiatives.

The evolution of analytics in HR follows a maturity continuum from descriptive (what happened) to diagnostic (why it happened), predictive (what will happen), and prescriptive (what should we do about it) analytics (Boudreau & Ramstad, 2007). Most organizations remain at the descriptive stage, with only a minority having reached prescriptive capability. This gap represents both a challenge and an opportunity: organizations that invest in advancing their analytics maturity gain significant informational asymmetries over competitors.

Employee Experience Design

Drawing on principles from user experience (UX) design and service design, employee experience (EX) innovation reconceptualizes the employee as a customer of the HR function (Plaskoff, 2017). This shift entails mapping employee journeys from pre-hire attraction through offboarding, identifying pain points, and designing interventions that enhance satisfaction, engagement, and productivity at each touchpoint. Digital onboarding platforms, mobile-first HR service portals, and personalized career development tools exemplify EX innovation in practice.

Research by Dery et al. (2017) found that organizations investing in employee experience design report significantly higher levels of innovation output and customer satisfaction, suggesting that EX innovation creates external as well as internal value. The COVID-19 pandemic accelerated EX innovation as organizations scrambled to replicate the social and emotional dimensions of in-person work in virtual environments.

Agile HR Practices

The application of agile principles—originally developed in software engineering—to HR functions has gained considerable momentum as organizations seek greater adaptability (Cappelli & Tavis, 2018). Agile HR involves replacing rigid annual performance cycles with continuous feedback loops, deploying cross-functional HR squads to address specific business challenges, and iterating on HR policies through experimentation and rapid prototyping.

The abandonment of traditional annual performance reviews in favor of ongoing check-ins and real-time feedback platforms represents one of the most widely cited examples of agile HR adoption. Companies such as Adobe, Deloitte, and Microsoft have publicly reported improvements in employee engagement and manager-employee relationship quality following this transition (Cappelli & Tavis, 2018).

Remote Work Enablement

The pandemic-induced shift to remote and hybrid work has compelled HR functions to innovate rapidly in the domain of distributed workforce management. This includes developing remote onboarding protocols, virtual engagement strategies, asynchronous communication norms, and digital performance management frameworks adapted to contexts in which face-to-face interaction is limited or absent (Lund et al., 2021).

Research by McKinsey suggests that hybrid work models, when effectively managed, can maintain or even enhance productivity while broadening talent pools geographically and improving work-life integration for employees (Lund et al., 2021). However, remote work enablement also introduces new challenges around social cohesion, managerial oversight, and the maintenance of organizational culture that HR innovation must address.

Comparative Analysis: Traditional Versus Innovation-Driven HR

Table 2 presents a systematic comparison of traditional and innovation-driven approaches across five core HR functions, drawing on empirical evidence from the literature.

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Table 2

Comparison of Traditional and Innovation-Driven HR Approaches Across Key Functions

HR Function	Traditional Approach	Innovation-Driven Approach	Reported Improvement
Recruitment	Manual CV review, in-person interviews	AI screening, video analytics, gamified assessments	Up to 70% reduction in time-to-hire (Upadhyay & Khandelwal, 2018)
Performance Management	Annual appraisals, top-down ratings	Continuous feedback, OKRs, real-time dashboards	30% increase in engagement (Cappelli & Tavis, 2018)
Learning & Development	Classroom-based, scheduled training	Microlearning, AI-personalized paths, VR simulations	40% higher retention of skills (Noe et al., 2020)
Employee Well-being	EAP programs, annual surveys	Sentiment analytics, mental health apps, pulse surveys	25% reduction in burnout (Moss, 2021)
Workforce Planning	Historical headcount analysis	Predictive analytics, scenario modelling, skill gap AI	50% improvement in forecast accuracy (Tursunbayeva et al., 2018)

Note. Reported improvement figures are approximate ranges drawn from the cited empirical literature and should be interpreted with methodological caution given variation in organizational contexts and measurement approaches.

The evidence presented in Table 2 reveals a consistent pattern: innovation-driven HR approaches outperform traditional approaches across all five functions examined. However, it is important to note that the reported improvements reflect outcomes under favorable implementation conditions. The realization of these benefits is contingent upon organizational readiness, leadership commitment, and the quality of change management (Kotter, 1996).

Recruitment transformation offers perhaps the most dramatic efficiency gains, with AI-powered tools dramatically compressing time-to-hire and enabling more objective initial screening. However, concerns about algorithmic bias in automated recruitment systems—where historical data reflecting past discrimination can be encoded into predictive models—have prompted calls for rigorous fairness auditing (Tambe et al., 2019). Amazon's much-publicized abandonment of an AI recruitment tool that disadvantaged female applicants serves as a cautionary reminder that technological innovation must be accompanied by ethical governance (Dastin, 2018).

Performance management innovation illustrates the potential of agile approaches to transform employee-manager relationships. The shift from annual to continuous feedback, enabled by digital platforms, has been associated with improvements in both performance outcomes and psychological safety (Cappelli & Tavis, 2018). Similarly, learning and development innovation—particularly the adoption of microlearning, adaptive platforms, and virtual reality simulations—has demonstrated superior knowledge retention compared to traditional instructor-led formats (Noe et al., 2020).

Challenges to HR Innovation Adoption

Despite the compelling evidence for the benefits of HR innovation, adoption remains uneven across organizations and industries. Table 3 presents a taxonomy of barriers to HR innovation adoption alongside recommended mitigation strategies.

Table 3

Challenges to HR Innovation Adoption and Recommended Mitigation Strategies

Challenge Category	Specific Barrier	Mitigation Strategy
Technological	Legacy system incompatibility; data silos	Phased modernization; API integration (Stone et al., 2015)
Human & Cultural	Resistance to change; digital skill gaps	Change management programs; upskilling initiatives (Kotter, 1996)
Ethical & Legal	Algorithmic bias; GDPR/data privacy	Fairness audits; transparent AI

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	compliance	governance (Tambe et al., 2019)
Organizational	Short-term ROI pressure; misaligned leadership	HR-C-suite alignment; long-term KPI frameworks (Boudreau & Ramstad, 2007)

Note. Categories adapted from Stone et al. (2015), Tambe et al. (2019), and Kotter (1996).

Technological Barriers

Many organizations, particularly those in mature industries, operate on legacy HR information systems that lack the flexibility and interoperability required to support advanced analytics or AI integration (Stone et al., 2015). Data silos—where employee information is fragmented across incompatible systems—undermine the data quality necessary for meaningful analytics. The financial and operational costs of system modernization can be prohibitive for smaller organizations, creating a technology gap between large enterprises and SMEs in HR innovation capability.

Human and Cultural Barriers

Resistance to change is a perennial challenge in HR innovation initiatives. HR professionals who have developed expertise in traditional practices may perceive innovation as a threat to their professional identity and job security (Kotter, 1996). Digital literacy gaps among HR staff can impede the effective use of new tools, while line managers may resist changes to established performance management or recruitment processes. Organizational cultures characterized by risk aversion and hierarchical decision-making create particularly inhospitable environments for HR innovation.

Ethical and Legal Barriers

The deployment of AI and data analytics in HR raises profound ethical questions that remain only partially resolved by current frameworks (Tambe et al., 2019). Algorithmic bias—where predictive models perpetuate or amplify existing inequalities—poses risks both to individual employees and to organizational reputation. Data privacy regulations, including the General Data Protection Regulation (GDPR) in Europe and the California Consumer Privacy Act (CCPA) in the United States, impose significant compliance obligations on organizations collecting and processing employee data. The tension between the data hunger of advanced analytics and employees' reasonable expectations of privacy represents an ongoing ethical challenge that requires deliberate governance frameworks.

Organizational Barriers

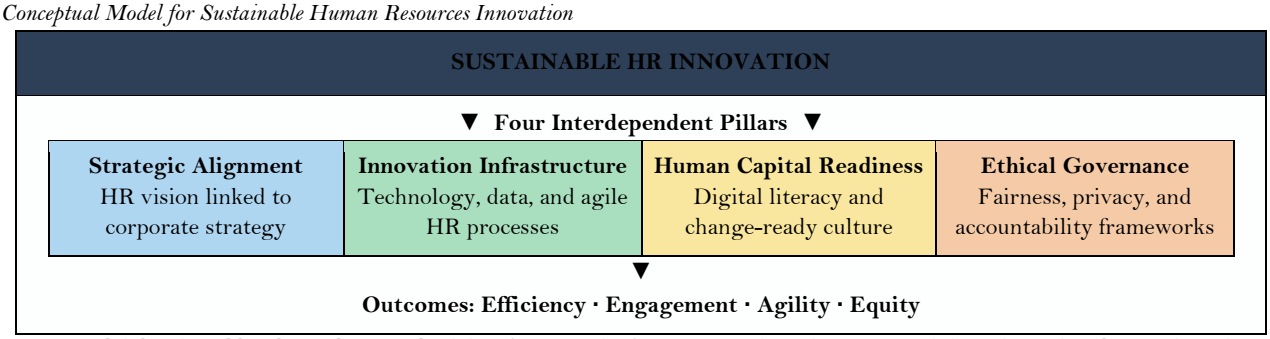
HR innovation initiatives frequently founder on organizational factors unrelated to technology or culture. Short-term performance pressures can divert resources away from transformational HR investments whose benefits materialize over longer time horizons (Boudreau & Ramstad, 2007). Misalignment between HR and senior leadership on the strategic importance of people management impedes the investment and sponsorship necessary for sustained innovation. In many organizations, HR still lacks a seat at the strategic table, limiting its ability to champion and resource innovation initiatives.

A Conceptual Model for Sustainable HR Innovation

Drawing on the theoretical frameworks and empirical evidence reviewed above, this paper proposes a conceptual model for sustainable HR innovation (Figure 1). The model identifies four interdependent components that organizations must develop in concert to achieve and sustain HR innovation: strategic alignment, innovation infrastructure, human capital readiness, and ethical governance.

Figure 1

Conceptual Model for Sustainable Human Resources Innovation



Note. Model developed by the author synthesizing frameworks from Barney (1991), Teece et al. (1997), Deci and Ryan (2000), and Tambe et al. (2019).

Strategic alignment requires that HR innovation be explicitly anchored to organizational strategy, with HR leadership having the authority and resources to drive transformation. Innovation infrastructure encompasses the technological platforms, data ecosystems, and organizational processes that enable agile, evidence-based HR practice. Human capital readiness addresses the capabilities and cultural dispositions of HR professionals and line managers that determine the effective adoption of innovative practices. Ethical governance, the fourth pillar, ensures that innovation serves human dignity and equity alongside organizational efficiency.

The model conceptualizes these four pillars as mutually reinforcing: strategic alignment without infrastructure yields vision without execution; infrastructure without readiness creates technological

capability that sits unused; readiness without governance generates innovation that may harm as much as it helps; and governance without alignment lacks the organizational backing to be sustained. Only when all four pillars are developed in concert does sustainable HR innovation emerge.

Future Research Directions

The literature on HR innovation is dynamic and rapidly expanding, yet several important areas warrant deeper investigation. First, longitudinal studies tracking the organizational outcomes of specific HR innovations over extended periods are needed to supplement the cross-sectional and case-study evidence that currently dominates the field. Understanding how the benefits and challenges of HR innovation evolve as implementations mature would provide valuable guidance for practitioners.

Second, the intersection of HR innovation and equity, diversity, and inclusion (EDI) merits sustained attention. While AI and analytics offer tools for identifying and addressing systemic bias, they also introduce new risks of discrimination. Research examining the conditions under which HR technology advances versus undermines EDI objectives would be practically and theoretically valuable.

Third, comparative international research on HR innovation is underdeveloped. Much of the existing empirical evidence is drawn from North American and Western European contexts, limiting its generalizability to organizations operating in different institutional, cultural, and regulatory environments. Studies examining HR innovation in emerging economies—where leapfrogging of legacy systems may accelerate adoption—represent a particularly promising frontier.

Fourth, the role of HR innovation in supporting organizational resilience deserves greater attention in the post-pandemic literature. The pandemic demonstrated that organizations with more digitally mature and agile HR functions adapted more rapidly to crisis conditions. Research identifying the specific HR innovation capabilities that contribute to organizational resilience would add significant value to both theory and practice.

Conclusion

This paper has examined the landscape of HR innovation through multiple theoretical lenses and synthesized empirical evidence on its dimensions, outcomes, and challenges. The evidence is compelling: innovation-driven HR approaches consistently outperform traditional practices across recruitment, performance management, learning and development, employee well-being, and workforce planning. The five dimensions of HR innovation—technology integration, talent analytics, employee experience design, agile HR practices, and remote work enablement—operate synergistically to transform people management from an administrative function into a strategic capability.

Yet the path to sustainable HR innovation is not without obstacles. Technological, human, ethical, and organizational barriers create real friction that organizations must deliberately manage. The conceptual model proposed in this paper offers a framework for navigating these challenges by developing four interdependent pillars—strategic alignment, innovation infrastructure, human capital readiness, and ethical governance—in concert.

The central argument of this paper is that HR innovation is not a luxury for large, resource-rich organizations but a strategic imperative for any organization seeking to attract, develop, and retain talent in an era defined by rapid change and heightened workforce expectations. As artificial intelligence, analytics, and digital work technologies continue to mature, the organizations that invest thoughtfully in HR innovation will be positioned to build human capital advantages that are genuinely difficult for competitors to replicate—realizing, in full, the promise of the resource-based view of the firm.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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Original Article

Recent Income Tax Changes and Economic Growth: An Analytical Study with Special Reference to India

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Abstract:

Taxation is a fundamental instrument of fiscal policy that influences economic growth through its impact on consumption, savings, investment, employment, and government revenue. In recent years, India has undertaken several significant income tax reforms aimed at simplifying tax administration, enhancing compliance, encouraging investment, and stimulating economic growth. Major reforms include the introduction of the optional new personal income tax regime, reduction in corporate tax rates, faceless assessments, digitization of tax administration, and measures to broaden the tax base. These reforms have transformed India's direct tax system and contributed to improving the ease of doing business. The present study examines the impact of recent income tax changes on economic growth in India. The study concludes that a balanced and efficient income tax system is essential for promoting sustainable economic growth and achieving long-term fiscal stability.

Keywords: *Income Tax Reforms, Economic Growth, Direct Taxes, Corporate Tax, New Tax Regime, Fiscal Policy, Tax Administration, India.*

Introduction:

Taxation serves as one of the most important instruments available to governments for mobilizing financial resources and influencing economic activities. Income tax, in particular, contributes significantly to government revenue and plays a crucial role in fiscal policy implementation. Through appropriate tax policies, governments can encourage investment, stimulate consumption, reduce income inequality, and support economic development.

India has witnessed significant changes in its income tax system during the last decade. These reforms have been introduced to improve tax compliance, simplify procedures, promote transparency, and enhance economic competitiveness. Recent measures such as the reduction in corporate tax rates in 2019, introduction of the optional new personal income tax regime in 2020, faceless assessment systems, digital tax administration, and expanded use of information technology have fundamentally transformed the tax landscape.

These reforms are expected to influence economic growth by affecting business investment decisions, household spending patterns, savings behavior, and government revenue generation. Therefore, understanding the relationship between recent income tax changes and economic growth has become increasingly important for policymakers, researchers, and stakeholders.

Review of Literature

Theoretical Relationship between Taxation and Economic Growth

Classical economists emphasized that taxation should be efficient, equitable, and minimally distortive. According to endogenous growth theory, taxation influences economic growth through its effects on capital formation, labor supply, innovation, and productivity.

Barro (1990) argued that productive government expenditure financed through taxation contributes positively to long-term economic growth. Conversely, excessive taxation may discourage investment and entrepreneurship.

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Income Tax Reforms and Economic Performance

Engen and Skinner (1996) found that lower marginal tax rates encourage economic activity by increasing incentives for work, savings, and investment. Several studies indicate that tax simplification improves compliance and reduces administrative costs.

Corporate Tax Reduction and Investment

Research suggests that reductions in corporate tax rates improve business profitability, attract foreign direct investment, and stimulate capital formation. Studies conducted after India's 2019 corporate tax reform reported improved investor confidence and enhanced business competitiveness.

Research Gap:

Existing literature largely focuses on broad taxation policies or individual tax reforms such as GST. Limited studies have comprehensively examined the impact of recent income tax reforms implemented after 2019 on economic growth in India. Furthermore, there is insufficient integration of corporate tax reforms, personal income tax changes, digital tax administration, and compliance measures within a single analytical framework. This study seeks to address this gap by providing a holistic assessment of recent income tax changes and their economic implications.

Objectives of the Study:

The study aims:

1. To examine recent income tax reforms introduced in India.
2. To analyze the relationship between income tax changes and economic growth.
3. To evaluate the impact of tax reforms on investment, savings, and employment.
4. To suggest policy measures for strengthening the growth-enhancing role of income taxation.

Research Methodology:

Research Design

The study adopts a descriptive and analytical research design. In the study period of 2019–2025.

Sources of Data

The research is based entirely on secondary data collected from:

- Ministry of Finance Reports
- CBDT Annual Reports
- RBI Publications
- Economic Survey of India
- Union Budget Documents
- NITI Aayog Reports
- IMF and World Bank Publications
- Research Journals and Academic Databases

Recent Income Tax Reforms in India:

Corporate Tax Rate Reduction (2019): The Government of India reduced the corporate tax rate from 30 percent to 22 percent for existing domestic companies and to 15 percent for new manufacturing companies. The objective was to enhance investment, attract foreign capital, and improve global competitiveness.

New Personal Income Tax Regime (2020): The optional tax regime introduced lower tax rates with reduced exemptions and deductions. This reform aimed to simplify tax compliance and provide greater flexibility to taxpayers.

Faceless Assessment and Appeals: The implementation of faceless assessment systems reduced direct interaction between taxpayers and tax officials, thereby improving transparency and reducing corruption.

Impact of Recent Income Tax Changes on Economic Growth:

- **Investment Growth:** Lower corporate tax rates have improved business profitability and encouraged capital investment.
- **Employment Generation:** Increased investment activity contributes to job creation and industrial expansion.
- **Enhanced Consumption:** Personal income tax relief increases disposable income and stimulates consumer spending.
- **Improved Compliance:** Digitalization and simplification have expanded the taxpayer base and improved voluntary compliance.
- **Revenue Mobilization:** Although tax rates were reduced, improved compliance and economic expansion have supported revenue growth.
- **Ease of Doing Business:** Tax reforms have improved India's business environment and international competitiveness.

Discussion

The findings indicate that recent income tax reforms have positively influenced economic growth by encouraging investment, improving compliance, and enhancing taxpayer confidence. Corporate tax reductions have strengthened India's competitiveness as an investment destination, while digital tax administration has modernized governance mechanisms.

However, the effectiveness of tax reforms depends on complementary factors such as regulatory stability, infrastructure development, financial inclusion, and overall macroeconomic conditions. Sustainable growth requires balancing revenue generation objectives with incentives for economic activity. Furthermore, continuous modernization of tax administration and broadening of the tax base are essential to ensure long-term fiscal sustainability.

10. Findings of the Study

The study reveals that:

1. Recent income tax reforms have improved transparency and efficiency.
2. Corporate tax reductions have encouraged investment.
3. The new tax regime has simplified personal taxation.
4. Digital tax administration has enhanced compliance.
5. Faceless assessment has reduced administrative inefficiencies.
6. Taxpayer confidence has improved due to modernization initiatives.
7. Revenue collection efficiency has increased despite lower tax rates.
8. Investment and business sentiment have strengthened.
9. Tax evasion remains a significant challenge.

10. Continuous reforms are necessary to support sustained economic growth.

Conclusion

Recent income tax reforms have played an important role in shaping India's economic development strategy. Measures such as corporate tax reductions, the new personal tax regime, faceless assessments, and digital tax administration have enhanced efficiency, transparency, and taxpayer confidence. These reforms have contributed positively to investment, compliance, and economic activity. Nevertheless, challenges such as tax evasion, informal economic activity, and fiscal constraints continue to require policy attention. A well-balanced income tax system that promotes growth, equity, and revenue generation remains essential for achieving sustainable economic development in India. Continued modernization and simplification of tax administration will be crucial for maximizing the long-term benefits of income tax reforms.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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