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Original Article

Spatial Accessibility and Nodal Integration of the Road Network in Solapur District, Maharashtra

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Abstract

Connectivity indices describe how a road network is wired together, but they say little about how easy it actually is to reach places. This paper takes up that second question for Solapur district, using service area analysis, a shortest-path distance matrix, an origin–destination cost matrix, and an aggregate transport score that folds road density together with the standard graph indices. The picture that emerges is of a district organised around a small set of central connectors. Pandharpur, Mohol and Madha sit near the middle of the road system and reach their neighbours in short hops, while the twin urban tahsils of North and South Solapur are tightly bound to each other. Karmala and Akkalkot, by contrast, are genuinely peripheral, separated from most other tahsils by more than ninety kilometres of road. Service area analysis shows large tracts of the outer tahsils lying beyond twenty-five kilometres of any headquarters. On the aggregate score only Madha and Mohol rate as highly accessible; Malshiras, Sangola and Akkalkot fall to the bottom. The results confirm a core–periphery accessibility structure and point to the specific corridors where investment would close the gap.

Keywords: *accessibility, shortest path, origin–destination matrix, service area, nodal integration, Solapur district*

Introduction

There is a difference between a network that looks well connected on a topological map and one that is genuinely easy to move around in. A tahsil can have plenty of road links and still leave many of its villages a long drive from the nearest town, simply because those links are long and the settlements are scattered. Accessibility, in the sense used here, is about that lived experience of distance: how far people actually have to travel to reach an administrative centre, a market or a hospital, given the roads that exist. This paper looks at accessibility in Solapur district and treats it as a complement to the structural analysis of the same network. Where a graph-theoretic study asks how the links are arranged, an accessibility study asks what those links deliver. The two belong together. A companion paper measured the topology of the district's road network and found a mild gradient from a well-integrated core toward a thinner agrarian periphery.

The task here is to test whether that structural gradient shows up in functional terms, when we measure real travel distances and service coverage rather than counts of nodes and edges. Four tools are used, each answering a slightly different question. Service area analysis asks how much of a tahsil lies within convenient reach of its headquarters. The shortest-path matrix asks how far each tahsil is from every other. The origin–destination cost matrix asks what those journeys cost in practice along the existing alignments. And an aggregate transport score combines road density with the connectivity indices to rank the tahsils on a single accessibility scale. Read together, they give a fuller account than any one measure could. The idea of accessibility used here goes back to Hansen's classic formulation, in which the reach of a place depends on the opportunities around it and the ease of getting to them.

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Indian regional geographers have applied the aggregate transport score in this spirit for some years, from Sarkar's work in Kooch Bihar to Kaushik and Kumar's study of Haryana and Sangle and Gawande's analysis of rural Maharashtra, generally finding that areas with higher accessibility scores also show stronger economic activity and better service delivery.

This paper follows that tradition and applies the same family of measures to Solapur, where the interest lies less in the absolute scores than in the gap between the accessible centre and the poorly reached edges.

Study Area and Data

Solapur district, in south-eastern Maharashtra, has eleven tahsils and covers roughly 14,895 square kilometres. Its total road length in 2021 was about 21,090 kilometres, but that length is distributed unevenly. Road density ranges from just under one kilometre of road per square kilometre in Akkalkot to 1.76 in Madha, with a district average of 1.45. Measured against population rather than area, the spread is even wider, from 1.44 kilometres per thousand people in North Solapur to 8.50 in Mohol. Node and edge counts, road lengths, tahsil areas and headquarters locations were compiled for 2021 from topographic sheets and digitised road layers. Inter-tahsil distances were computed along the network rather than as straight lines, so they reflect the routes people would actually take.

Method

Service area analysis draws distance bands outward from each tahsil headquarters along the road network, in five-kilometre steps up to twenty-five kilometres, with a final band for everything beyond that. The area falling in each band shows how compact or how stretched a tahsil's catchment is. A tahsil with most of its land close to the headquarters is well served; one with a large share beyond twenty-five kilometres has a poorly reached hinterland.

The shortest-path matrix records the minimum road distance between every pair of headquarters. From it, a tahsil that reaches its neighbours in short distances is central; one whose distances run long is peripheral. The origin–destination cost matrix is built the same way but is read as the practical travel burden along real alignments, which can differ from the theoretical minimum. Finally, the aggregate transport score follows the approach used in several Indian regional studies, standardising road density and the Alpha, Beta and Gamma indices and combining them so that each tahsil receives one accessibility value. Tahsils scoring above 1.00 are classed as high, those near the district mean as moderate, and those clearly below as low.

Results and Discussion

1. Service coverage and its gaps

The service area results make the core–periphery split visible in terms of land. In the central tahsils of Barshi, Pandharpur and Mohol, the distance bands around the headquarters overlap and settlements sit close to the centre, so a large share of the land is reached within short distances. The outer tahsils behave differently. Karmala, Sangola, Malshiras and Akkalkot each carry a substantial area in the beyond-twenty-five-kilometre band, which means that sizeable populations live well away from their administrative centre. For a district where markets, higher schools and hospitals cluster in the headquarters towns, that distance translates directly into weaker access to services.

It is worth stressing that this is a coverage problem, not simply a road-length problem. A tahsil can have a respectable total road length and still leave its edges poorly served if the network fans out along a few long routes rather than filling in the spaces between them. The remedy that the service area maps suggest is not more radial roads reaching outward from the headquarters, but connecting roads that pull the outer settlements into shorter effective distances.

The district-level totals put the scale of the gap in perspective. Of the roughly 14,854 square kilometres covered by the service area analysis, only about 556 square kilometres, a little under four per cent, lie within five kilometres of a tahsil headquarters, while more than 7,394 square kilometres, close to half the district, fall beyond the twenty-five kilometre band. In other words, a very large share of Solapur's land, and a substantial part of its rural population, sits at a distance from administrative and service centres that would count as poor accessibility by any reasonable standard. This is not a failing peculiar to one or two tahsils; it is a district-wide condition that the peripheral tahsils simply express most acutely. Karmala carries about 950 square kilometres beyond twenty-five kilometres, Sangola about 929 and Malshiras about 860, and each of these is more than half the tahsil's area.

2. Central connectors and peripheral tahsils

The shortest-path matrix identifies a clear set of central connectors. Pandharpur is the most accessible node in the district, reaching Mangalwedha in about twenty-three kilometres, Sangola in thirty-two and Mohol in thirty-eight. Mohol and Madha act as intermediate hubs, tying together Barshi, Pandharpur and the Solapur towns. North and South Solapur are bound to each other in a little over sixteen kilometres, which reflects the compact urban fabric around Solapur city and its dominance of the eastern sector.

At the other extreme, Karmala and Akkalkot stand out as peripheral. Most of Karmala's shortest paths to other tahsils run beyond ninety kilometres, reaching about 121 kilometres to North Solapur and nearly 159 to Akkalkot. Akkalkot is similarly cut off, lying roughly ninety-two kilometres from Mangalwedha and over a hundred from most other tahsils, even though it sits close to the state border. These are not marginal differences. A tahsil whose nearest developed neighbours are two hours away by road is structurally disadvantaged in a way that no amount of internal road-building alone will fix; what it needs is a better trunk connection into the district core.

3. Travel cost and the shape of the network

The origin–destination cost matrix, which measures travel along actual alignments, tells the same story with slightly different numbers and adds a spatial reading. Central tahsils record the lowest inter-tahsil costs, often under forty kilometres. Pandharpur again connects efficiently to Mangalwedha, Sangola and Mohol, and Madha keeps short costs to Mohol and Barshi. North Solapur reaches South

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Solapur in under fifteen kilometres and lies close to Mangalwedha and Akkalkot. Plotted out, the cost matrix forms a web-like pattern in the centre, where central tahsils interlink densely at short distances, and long, thin lines to the outer tahsils. This is the visual signature of a core–periphery network, and it matches what the service area and shortest-path results already suggested.

4. The aggregate accessibility ranking

The aggregate transport score pulls these strands into a single ranking, set out in Table 1. Only Madha (1.05) and Mohol (1.01) qualify as highly accessible, combining good road density with efficient topology. A broad moderate group follows, including South Solapur, Mangalwedha, North Solapur, Karmala, Pandharpur and Barshi, all clustered between about 0.90 and 0.96. Malshiras (0.83), Sangola (0.84) and Akkalkot (0.81) sit at the bottom. The ranking largely tracks the accessibility measures above, which is a good sign that the different methods are pointing the same way.

One result in the table deserves comment because it looks paradoxical. North Solapur has the lowest road density per thousand people in the district, just 1.44 kilometres, yet it is urban and industrial and scores moderately well overall. The explanation is that its population is so concentrated that even a substantial road length spreads thinly on a per-capita basis. This is a reminder that accessibility has more than one denominator. Measured against area, North Solapur is served; measured against people, it is stretched. Mohol shows the opposite pattern, with a modest population and a dense network producing the highest per-capita figure in the district. Neither reading is wrong; they answer different questions, and a planner has to hold both in view.

It is worth setting this functional ranking against the structural one from the companion topology study, because the two do not line up neatly, and the mismatch is instructive. North Solapur tops the topological indices, with the most looping, redundant network in the district, yet it is only moderate on accessibility once population is taken into account. Mangalwedha and South Solapur, which post the highest length-based index values because their rural links are long, turn out to be central on the distance measures, sitting close to the district's connecting hubs. And the two tahsils that are weakest on topology, Malshiras and Sangola, are also weakest on the aggregate accessibility score, which is the one place the two analyses agree emphatically. The lesson is that structure and accessibility are related but not interchangeable. A tahsil can be well wired and still stretched, or loosely wired and still central, depending on where it sits and how its population is arranged. Judging a tahsil's connectivity from any single measure risks getting it wrong.

Table 1. Accessibility measures and aggregate transport score by tahsil, Solapur district, 2021

Tahsil	Road density (km/sq.km)	Density /1000 pop.	Theta (θ)	ATS	Class
Madha	1.76	7.53	5.35	1.05	High
Mohol	1.75	8.50	6.77	1.01	High
South Solapur	1.47	6.72	7.57	0.96	Moderate
Mangalwedha	1.40	7.25	8.05	0.95	Moderate
North Solapur	1.22	1.44	2.84	0.92	Moderate
Karmala	1.40	7.31	5.68	0.91	Moderate
Pandharpur	1.28	3.00	3.07	0.91	Moderate
Barshi	1.35	5.09	3.22	0.90	Moderate
Sangola	1.15	3.60	2.97	0.84	Low
Malshiras	1.16	2.93	2.76	0.83	Low
Akkalkot	0.99	4.65	5.42	0.81	Low

Source: *computed by the author. ATS after the aggregate transport score method used in Indian regional accessibility studies.*

5. What accessibility does not settle

These measures share a limitation worth naming. They are built on distance, and distance is only part of what makes a journey easy. A short link on a broken, single-lane road can take longer than a longer link on a highway, and none of the matrices used here capture road quality, traffic or seasonal flooding. The service area bands also assume travel radiates neatly from the headquarters, when in practice people often travel to the nearest town of any kind rather than their own administrative centre. The results are therefore best read as a distance-based skeleton of accessibility, reliable for ranking tahsils against one another but not a substitute for on-the-ground travel-time data. Even so, the ranking is stable across four different methods, which gives some confidence that the core–periphery pattern is real and not an artefact of any single technique.

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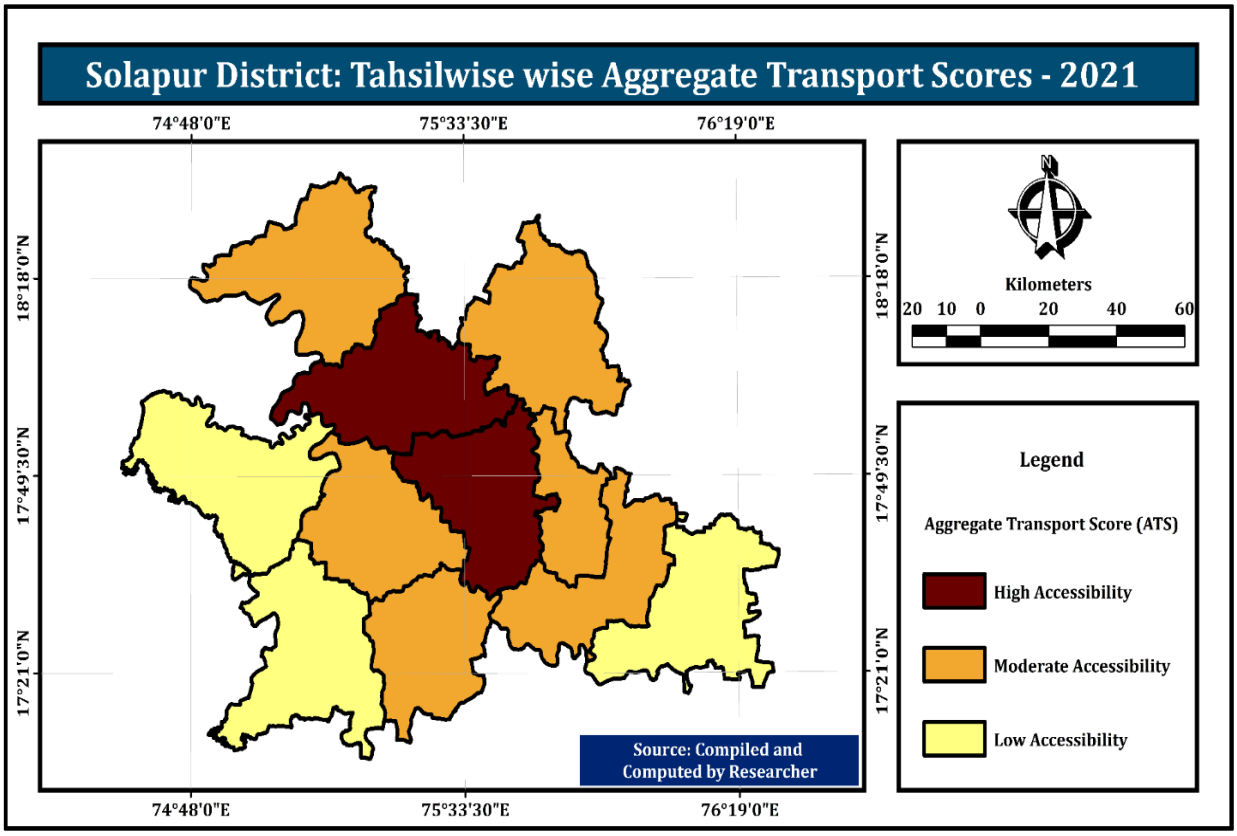

Fig. No. 4.1

Planning implications

The accessibility results translate fairly directly into priorities, and they differ by tahsil type. For the peripheral tahsils of Karmala and Akkalkot, the binding constraint is external. Both are internally passable but separated from the district core by long trunk distances, so the intervention with the highest return is an upgraded corridor connecting them to the central hubs of Mohol, Madha or the Solapur towns. Internal road-building in these tahsils, without a better trunk link, would improve local movement while leaving their isolation from district-level services largely intact.

For the tahsils with large under-served hinterlands, notably Sangola and Malshiras, the priority is the opposite: connecting and feeder roads that shrink the beyond-twenty-five-kilometre zone and bring dispersed settlements within reach of their own headquarters. For the urban core of North and South Solapur, the accessibility problem is neither external isolation nor sparse coverage but per-capita strain, where a dense population presses on a road length that has not kept pace. There the answer lies in capacity and traffic management rather than in extending the network. Matching the type of intervention to the type of accessibility deficit is the practical value of separating these measures out rather than collapsing them into a single score.

Conclusion

Measured in functional terms, Solapur district has a clear accessibility core and a clear periphery. Pandharpur, Mohol and Madha are the central connectors, reaching the rest of the district in short distances, and the two Solapur tahsils form a tightly linked urban pair. Karmala and Akkalkot are the outliers, separated from most of the district by long road distances and burdened by large under-served hinterlands. The aggregate score confirms the split, placing only Madha and Mohol in the top band and pushing Malshiras, Sangola and Akkalkot to the bottom.

The planning message follows directly from the geography. For the peripheral tahsils the priority is not internal road density, which several of them already have, but stronger trunk connections into the district core that would shorten their effective distance to services and markets. For the outer edges of the central tahsils, the priority is connecting roads that pull distant settlements into shorter service catchments. Accessibility and structure together give a more complete diagnosis than either alone, and the next step is to set both against the district's socio-economic indicators to see whether the accessible tahsils are also the developed ones.

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aggregate transport score to understand the accessibility structure of the district.
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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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