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Graph Theory Based Assessment of State Road Transportation Network among the Tehsil Towns of Ahmednagar District, Maharashtra

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Abstract: Road transport is essential to achieving most Sustainable Development Goals (UN, 2017&2020) of UN's 2030 Agenda. Road Transport is a critical infrastructure for the economic development of a country (GoI MRT&H, 2021) . The transportation network is a crucial to ease of movement of resources, people and goods to accelerate the economic development and social prosperity. Road transport network provided door to door service hence growing continuously. Road safety can achieve through improving the road network and quality of roads. International Road Federation (IRF) encourages and promotes development and maintenance of better, safe and sustainable road network (UN, 2017). It is true that too road network contribute in conservation of natural resources and minimize environmental losses. Hence, systematic and geometrically optimum network need of all regions toward sustainable development. Often assessment of structural properties of road network such as network connectivity and nodal accessibility is essential for future modification and development. The Graph Theory is a mathematical tool to assess the network considering network as dimension less graph having line and node as real road and settlements respectively. In present attempt of study, major road network among the tehsil headquarters of Ahmednagar district has been assessed with focus on connectivity and accessibility using Graph theory.

Key Words: Transportation, Road Network, Connectivity, Accessibility, Graph Theory

1. Introduction:

Roads are initial, oldest and popular mode of transport. As per traffic share and contribution to the national economy, road transport is dominant mode of transport in India (GoI MRT&H, 2021). Road network plays a crucial role in socio-economic development of any nation. The world's total length of road networks has reached 64 million km and motor vehicles has grown to 1.78 billion (UN ESCAP, 2016). The Indian road network is second largest in the world with 62, 15,797 Km length on 31st March 2018. The Maharashtra is first rank state having total length of 626491 km (11.79%) road network followed by Uttar Pradesh (8.21%), Madhya Pradesh (6.85%). The Ahmednagar district is largest district of Maharashtra having 20742.76km

length of road network which is 6.15% to state total. Assessment of major road network of tehsil nodes has been accomplished in present attempt.

2. Road Network of India:

Indian road network (62, 15,797 km) is second largest in the world after the United State of America (66, 45,709 km) (GoI MRTHTRW, 2021). As per Basic Road Statistics of India 2017-18 share of rural road is largest (71%) in total road network subsequently district road (10%), urban road (9%), project road (5%), state highways (3%) and national highways (2%).

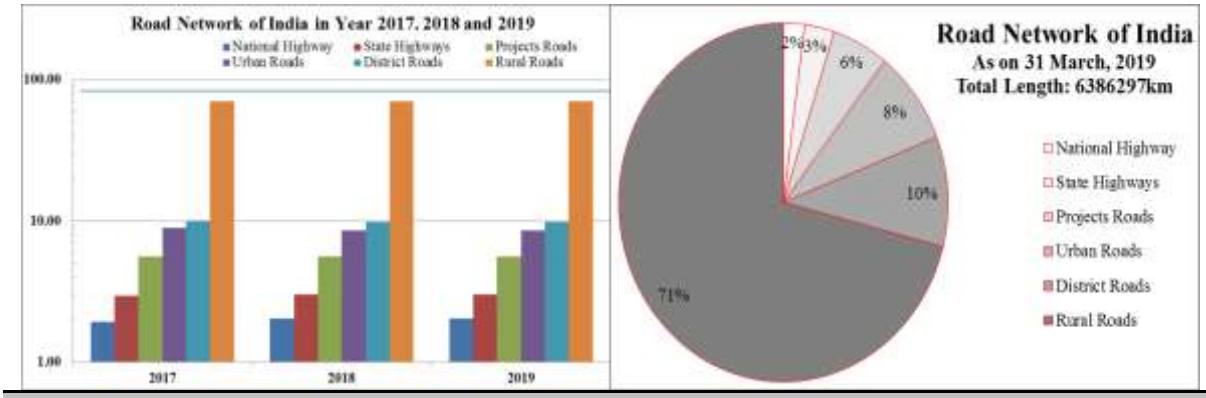


Fig.1: Road Transportation Network of India in years 2017, 2018 and 2019

Types of Road	Category wise Road Network Length of India (Length in km) On 31st March, 2017, 20181 2019					
	2017		2018		2019	
	(km)	%	(km)	%	(km)	%
National Highway	114158	1.94	126350	2.03	132500	2.07
State Highways	175036	2.97	186908	3.01	186528	2.92
Projects Roads	328897	5.58	347547	5.59	354921	5.56
Urban Roads	526483	8.93	534142	8.59	544683	8.53
District Roads	586181	9.94	611268	9.83	632154	9.90
Rural Roads	4166916	70.65	4409582	70.94	4535511	71.02
	5897671	100.0	6215797	99.99	6386297	100.00

Table-1: Road network length in India. Source: (GoI MRTHTRW, 2021)

3. Road Network of Maharashtra and Ahmednagar District:

Table-2 reveals total road network of Ahmednagar district having length of 20742.46km whereas Maharashtra state has a road network of 336182.56 km. The Ahmednagar district network is only 6.15% compare to state road network. The Fig.2 shows comparison of road

Types of Road	Road Category wise Length (km)				% to State Total
	Ahmednagar Dist.	%	Maharashtra	%	
National Highway	210.70	1.02	4509.09	1.34	4.67
Major Stale Highway	347.58	1.68	7035.04	2.09	4.94
State Highway	1899.27	9.16	35754.68	10.64	5.31
Main District Road	2606.98	12.57	51993.71	15.47	5.01
Other District Roads	5395.25	26.01	61158.56	18.19	8.82
Rural Routes	10282.68	49.57	175731.48	52.27	5.85
Total Routes	20742.46	100.00	336182.56	100.00	6.15

Table-2: Road Network Length of Maharashtra and Ahmednagar district. Source: (District Survey Report for Ahmednagar District Part-A for Sand Mining or River bed Mining, 2020)

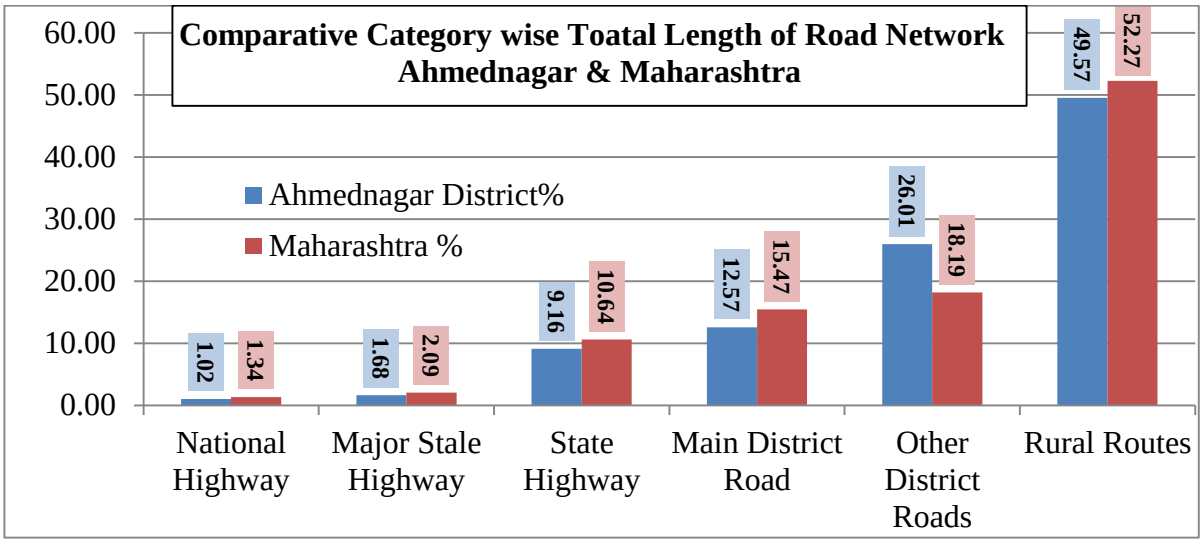


Fig.2 Category wise road network of Maharashtra and Ahmednagar district

Road network of district is plays a significant role in the development of agriculture, tourism, industry and trade sectors of district economy. Rural roads are larger in the length compare to national and major state highway roads. In the present study focus on the assessment of major state and state highway road network connectivity and accessibility assessment with respect to tehsil centers.

4. Transport Geography, Graph Theory and Transport Network Analysis

Transport geography is the branch of geography which belongs to economic geography falls under human geography, systematic branch of geography. Transport geography is a concern about the mobility of people, freight and information (Rodrigue , Comtois, & Slack, 2016). It is study of geographical pattern of transport network (Vaidya, 2003). An assessment transport network is fundamental one to understand the efficiency network. The graph theory (GT) is very reliable and widely accepted mathematical tool for the study of spatial structural properties of transport network to understand efficiency of network in region.

The Graph-theoretical ideas (Graph Theory) can be traced back to 1735, (Jonathan L Gross, J. Y., 2003). The Swiss mathematician L. Euler called the father of graph theory (Foulds, 1992). It extensively applied to road network in 1960s and 1970s (Sybil Derrible, 2009). (Edward J Taaffe, 1996) mentioned that Graph theory is branch of topology deals with abstract configurations of points and lines, or nodes and linkages.

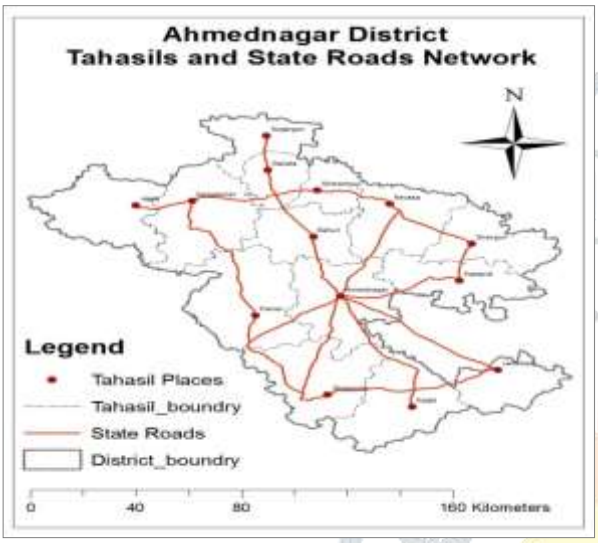
The transport geographer William L Garrison (1960), introduced elementary and descriptive use of graph theory to evaluate effects of changes in transportation network (Garrison, 1960). (Kansky, 1963) Has studied transportation network with applications of graph theory and established ratio and non-ration indices i.e. Alpha (α), Beta (β), Gamma (λ) & Cyclomatic number (μ), network diameter (d) respectively. He has introduced associated number, degree of connectivity, dispersion, accessibility, degree of circuit as indicators to measure accessibility. (Haggett & Chorley, 1969) has studied network structure and graph theory. Hence the transport network analysis to understand structural properties using graph theory is a pivotal topic of transport geography.

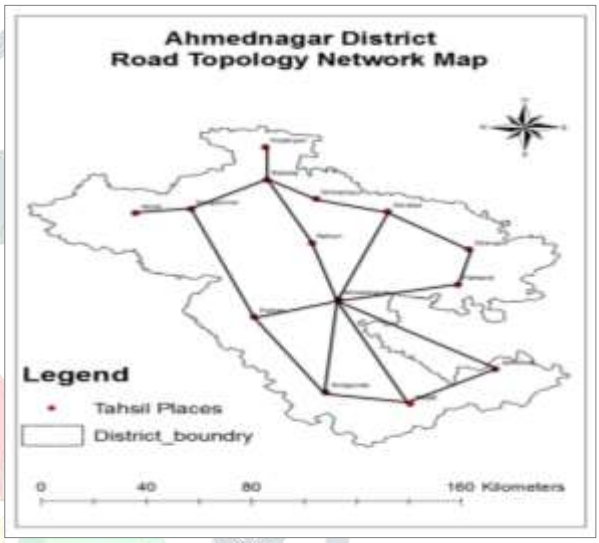
5. Objective, Data and Methodology:

The main objective of this attempt is to understand level state road network connectivity of tehsil places and accessibility of individual.

The study is based on secondary spatial data i.e.PWD road map. To accomplish the expectation of objective PWD road network map of Ahmednagar district was taken as a spatial data. The map has been georeferenced and digitized in QGIS software to extract only state roads network of tehsil headquarters. The Extracted state road network map (Map-1) transformed in state road network topological map (Map-2) for graph theory applications.

The basic quantitative information about the road network such as number of Vertex or Nodes (v or n) and Links or Edges (e) have been extracted and tabulated as an input to graph theory applications toward analysis of connectivity and accessibility of network which under study. In this sense selected network comprises 14 nodes (Tehsil Headquarters) and 19 edges (State roads). Using this data various indices of graph theory have been calculated.





Map 1: State road network map **Map 2:** State road Topology network map

Selective ratio and non-ration indices of graph theory have been chosen for present study. Followings Ratio Indices are selected to measure network connectivity-1. Beta Index (β), 2.Alpha Index (α), 3. Gamma Index (γ), Detour Index (DI) and one non-ration index i.e. Cyclomatic number (μ) (Table-3). To measure accessibility of individual node of network, Associate number and Shimbel Index (Table-3). Full forms of notations are ***e***- edges; ***n*** / ***v***- edges / vertex; *DS*-distance shortest; *DT*-distance true, ***p***-graph (complete isolated network).

Table-3: Selected Graph Theory Index with explanations

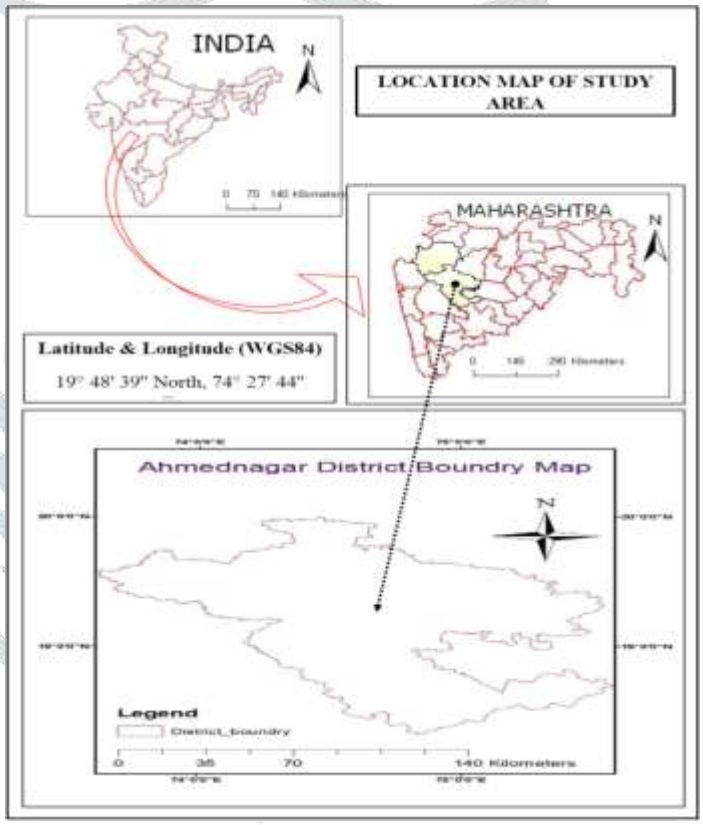
Index Name	Notation	Range	Interpretation
Network Connectivity Measurement			
Ration Index			
Beta Index (β)	β = e/ n or v	0-1,>1	Ratio of edges and vertices or nodes
Alpha Index (α)	α = e-v+1/ 2v-5	0-1	Ratio of actual circuits and maximum circuits
Gamma Index (γ)	γ = e / 3(v-2)	0-1	Ratio of observed number of edges and vertices
Non-ration Index			
Cyclomatic number	μ= e-v + p	Function of edges, vertices and graphs	

Source: Calculated and complied by author

6. Study Area:

Ahmednagar district is known by district headquarter city Ahmednagar which was established by Malik Ahmed Shah in 1494, and it later on become capital of Nizamshahi Kingdom. Ahmednagar district came in to exist 1822. The district was a part of the Pune Division till 1981, presently a part of the newly created Nasik Division. It is located in the central part of Maharashtra, having 18°02' and 19°09' N latitudes and 73°09' and 75°05' E longitudes extension. The district is bounded by Nashik & Aurnagabad (N), Beed & Osmanabad (E), Solapur (S) and Thane & Pune (W). Total area of district is about 17, 0448 sq.km which is 5.55% of Maharashtra state.

The district is largest in state, encompassing 14 tehsils i.e. Nagar (Nar), Parner (Par), Pathardi (Pat), Shevgaon (Sev), Jamkhed (Jam), Karjat (Kar), Shrigonda (Shrg), Akola (Ako), Kopargaon (Kop), Sangamner (San), Newasa (Nev), Rahta (Rah), Rahuri (Rahu), Shrirampur (Shri).



Map 3: Location map of study area

7. Connectivity Measurement of state road network.

The degree of completeness of links between nodes is known as network connectivity (Rodrigue, (2013). Whereas (Taaffe & Gauthier, 1973) stated that the degree of connection between all vertices is \a connectivity of the networks. Connectivity is a means of measuring the efficiency of network and comparing quantitatively, different networks (Waugh, 1990). The greater the degree of connectivity within a transportation network, the network is more efficient. In this attempt, connectivity of the state road transport network with reference of tehsils has measured with the Graph Theory. Indices mentioned in Table-3 have been used to measure the connectivity of district network and performance has been summarized in (Table 4).Input quantitate information is 14 vertices (v), 19 edges and 1 graph (p) of district network.

7.1 Beta Index (β)

It is a ratio of edges (e) and vertices (v) of network. Easiest method to measure connectivity involves dividing the number of edges in the network by number of vertices. Equation is $\beta = e/v$

β = 19/14; = Where… e = number of edges ; v = number of vertices \ node. :onnectivity and more efficient. The derived index value is 1.357 is greater than one hence connectivity of network is high, yet it is not concluding the actual perception of the connectivity hence further index need to calculate.

7.2 Cyclomatric number (μ)

The μ is non-ratio index of measuring network connectivity. This is express number of circuits in network. Larger the number of edges in network produce greater number the circuits. The formula of μ is liner, $\mu = e - v + p$; where p is a graph (no of non-connected sub graph). In the network is one as graph (p), hence index is μ= 19 - 14 + 1; = 6. It indicates that good connectivity of network.

7.3 Alpha Index (α)

This is significant to compare the network connectivity. It is a ratio of actual circuits and maximum possible circuits in the network. Higher the index more network is connected. Tree or simple network always has 0 value of index. The equation of index is pertains to μ and possible circuits in network and express as α = μ / 2v – 5; putting figures of μ and v derived index is α = 6 / 2*14 – 5; = 6 / 28 – 5; = 6 / 23; α = 0.26086 subsequently if multiply by 100 expression would be in percentage (%) i.e. 26.09 %.

Index shows 26 % network connectivity with reference to possible circuits in given network. It means more circuits are possible to complete the network and it improves the connectivity of network. If the index value is 1 (100%) means network is completely connected.

7.4 Gamma Index (γ).

This index is ratio of numbers of observed links (edges) and the number of possible links in network. It expressed as γ = e / 3 (v-2). The calculation of index for present network is γ = 19 / 3 (14 – 2); = 19 / 3 (12); = 19 / 36; = 0.5278; if gamma index value multiply by 100, it would be in percentage (%). Accordingly index is 52.78% which reveals that network connectivity is 52.78% with reference to possible edges in network. The range of index is 0 (0%) poor connectivity to 1 (100%) completely connected.

7.5 State Road Network Connectivity of Tehsil Headquarter in Ahmednagar District

The analyses of transportation network structural property i.e. connectivity of state road network of Ahmednagar district. Graph theory indices have been applied and derived index value to understand the level of state road network connectivity of Ahmednagar district. In aggregate three ratio (β, α, & γ) and one non-ratio (μ) indices have been applied to the state road network and produced value of index (Table-4) to infers degree of connectivity.

Table 4: Graph theory index, derived values and its explanation

SN	Index	Index Values	Explanation of Index
	Graph Theory Network Connectivity: Ratio Index		
1	Beta Index (β)	1.357	Edges & vertices base good connectivity.
2	Alpha Index (α)	0.261 (26.1%)	As per possible circuits connective is less.

3	Gamma Index (γ)	0.528 (52.8%)	As per possible edges connective is less.
	Graph Theory Network Connectivity: Non-Ratio Index		
4	Cyclomatic number (μ)	06	Total circuits are less, more are possible.

Source: Calculated and complied by author

8. Observations

The expected calculation has been done to produce graph theory index values of ratio index such as beta index (1.4), alpha index (0.26) and gamma index (0.53) and non-ratio index Cyclomatic numbers (6). These indexes are denoting about the level of connectivity. It has been observed that state road network among the tehsil headquarters of Ahmednagar district is not a complete network. The beat (β) index value is 1.4 which is more than one but road network is not complete. In the line to improve the understanding of connectivity of road network, other indices have been calculated. The values of index alpha (α) are 0.26 (26%) and gamma (γ) index 0.53 (53%) respectively. It indicate that state road network connectivity of district among tehsils destinations is 26 % with reference to possible circuits and 53% with reference to possible edges in the network is not complete. The μ (Saxena, 2005) describes circuits in the network and preset network μ index is only 6 circuits.

9. Conclusion

The ratio and non-ratio index of graph theory have been assessed state road network among tehsils headquarters of Ahmednagar district is not complete network. The level of connectivity is less as alpha (α) and gamma (γ) index shows the possibilities to be more circuits and edges in the district network. The beta index though more and Cyclomatic numbers is 6, yet more circuits are possible in network. This study reveals that there is scope to have more state road links to complete the network towards the development of region.

References:

District Survey Report for Ahmednagar District Part-A for Sand Mining or River bed Mining. (2020). Retrieved from https://cdn.s3waas.gov.in/

Edward J Taaffe. (1996). Geography of Transport. New Jersey: Prentic Hall.

Foulds, L. (1992). Graph Theory Applications. New York: Springer.

Garrison, W. (1960). Connectivity of the Interstate Highway System. Paper of Regional Science Association, Regional Science Association.

GoI MRT&H. (2021). Annual Report-2020-2021 Bharatmala Road to Prosperity. New Delhi: GoI Ministry of Road Transport and Highways.

GoI MRTHTRW. (2021). Basic Road Statistics : 2017 - 2018. New Delhi: GoI Ministry of Road Transport and Highways Transport Research Wing.

Haggett & Chorley. (1969). Network Analysis in Geography. New York: St.Martin's Press.

Jonathan L Gross, J. Y. (2003). Handbook of Graph Theory. New York: CRC Press.

Kansky, K. J. (1963). Structure of Transportation Networks:Relationships Between Network Geometry and Regional Chracteristics. Chicago III:: University of Chicago Press.

Rodrigue. ((2013). The Geography of Transport System. New York:: Routledge.

Rodrigue , J.-P., Comtois, C., & Slack, B. (2016). The Geography of Transport Systems. New York: Taylor & Francis.

Saxena, H. M. (2005). Transport Geography. aipur: Prem Rawat for Rawat.

Sybil Derrible. (2009). Network Analysis of World Subway Systems Using Updated Graph Theory. Journal of the Transportation Research Board, 17–25.

Taaffe & Gauthier. (1973). Geography of Transportation. London: Prentice-Hall.

UN. (2017). Transport and Trade Facilitation Series No-1 Road Safety- Considerations in Support of the 2030 Agenda for Sustanable Development. New York City: UN.

UN. (2020, Feb 27). Road transport: a key solution to achieving the UN's Sustainable Development Goals (SDGs). Retrieved 2021, from IRU: https://www.iru.org/resources/newsroom/road-transport-key-solution-achieving-uns-sustainable-development-goals-sdgs

UN ESCAP. (2016). Making the Road Sector a key vehicle for sustainable Development. Bankok: United Nation.

Vaidya, B. C. (2003). Geography of Transport Development in India. New Delhi: Concept Publishing Company.

Waugh, D. (1990). Geography An Integrated Approach. Surrey: Thomas Nelson and Sons Ltd.