Pakistan's Motorway Network Analysis

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https://github.com/Aveen1/Traffic-Road-Network-of-Pakistan

Abstract:

To travel over long distances and to reach destination faster, motorways are special build roads with several lanes and special places where traffic gets on and leaves. Motorways of Pakistan are a network of multiple-lane, high-speed, controlled-access highways that links the three Arabian Sea Ports; Karachi Port, Gawadar Port and Port Bin Qasim. In this paper, the motorways network of Pakistan is analyzed by obtaining the data through web-scrapping methods from the National Highway Authority (NHA) Pakistan website. The graph for the road network is an undirected disconnected graph, in which the nodes represent the locations and the edges shows the motorway that is connecting the locations. Betweenness centrality is calculated to examine the most efficient routes for allocation of services like fuel stations, repair shops, tuck shops, hospitals. The paper further identify that which road will affect the traffic for other roads within the city.

Keywords: *Road network, betweenness centrality, motorways*

1. Introduction:

In developing countries, road networks are increasing very rapidly for several reasons that includes owners for private cars and businesses that need the transportation of goods to and from different part of the country and even for traveling for entertainment purpose. In road networks, it is not wrong to say that motorways are the backbone of a country as the inter country transport is affected by it.

Road networks are ordinarily addressed by graphs as a similarity for their structure and flows. They are preferable perceived by their connections over by their sole geography dependent on presence or nonappearance of connections because the evolution and design of road networks are physically constrained. The road networks are the basis of the graph theory as a Swiss mathematician, Euler, back in 1735 solved the Königsberg bridge problem [8] to identify the path of a seven bridge, the starting point and the ending point in a way that no bridge can be passed twice. Figure 1a represents the Konigsberg bridge problem and Figure 1b shows the graphical representation of the solution.

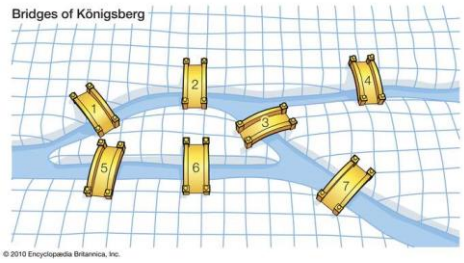

Figure 1a: Konigsberg Bridge Problem

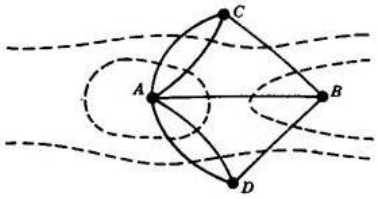

Figure 1b: Konigsberg Bridge graph network representation

This paper discusses Pakistan's motorway road network so graph network of the road is taken into consideration for better results. Pakistan's motorways are an important part of Pakistan's "National Trade Corridor Project", which aims to link Pakistan's three Arabian Sea ports; Karachi Port, Port Bin Qasim and Gwadar Port, to the rest of the country through its national highways and motorways network and further north with Afghanistan, Central Asia and China. The project was planned in 1990. The China Pakistan Economic Corridor project aims to link Gwadar Port and Kashgar (China) using Pakistani motorways, national highways, and expressways. These motorways are controlled by National Highway Authority (NHA).

In this study, motorway's road network is analyzed. The network graph is undirected disconnected graph and degree of nodes, betweenness centrality is calculated to obtain the results that which motorway could be the busiest and need to install services like tuck shops, repair shops, emergency centers etc.

2. Literature Review:

Lajos and Gergely, in their paper analysis and observation of road network topology [1] used

betweenness centrality to analyze the topology of different hypothetical and real road networks of a Hungarian city. The approach in this paper is to extend the centrality usual shortest path search by applying alternative path choices. This extension describes the betweenness of network elements much more realistically, because it takes all the reasonable paths into account, weighting them by their choice probabilities. To determine the alternative paths and choice possibilities multinomial logit model is used. Finally, the results are used to analyze the relation between the topology and the centrality indices.

Road network resilience [2] focuses on answering the major questions that how is it possible to identify the links that are most critical to the operation of the whole road network, especially with respect to day-to-day disruptions and are topological metrics adequate to measure resilience for road networks. As a result, in this paper it is identified that the link (road connection) ranking varies depending on the metric selection. Generally, the projected emphasis testing method can produce very close consequence by taking into account supply and congestion, but definite quantity procedure intense simulations, being therefore preventive even on moderate-sized networks. Antonymous, strictly inactive topologic metrics can be imprecise if they do not take into account collection demand and web dynamics.

Another method to calculate the connectivity network of large road network is explained by applying the capacity-weighted eigenvector centrality method to identify the strongly and weakly connected parts of large road networks [3]. The eigenvector centrality is one of the assessment techniques primarily based totally on community topology with a small computational load. This technique may be implemented to directed networks and does now no longer require their adjacency matrices to be symmetric. Several numerical examples confirmed that the capacity-weighted eigenvector centrality evaluation can perceive the strongly and weakly linked components of the community, and it is able to be used to assess connectivity of community for robustness. This paper proposes a singular technique to assess the connectivity of networks that belongs to vulnerability evaluation without the possibilities of incidence of disruptions.

The motive of the studies is to set up a singular connectivity assessment that may be a hallmark for vulnerability analysis. Philippe [4] et.al specializes in quantifying the influences of recuperation techniques and, greater specifically, link-restore techniques on resilience. Several numerical examples confirmed that the capacity-weighted eigenvector centrality evaluation can perceive the strongly and weakly linked components of the community, and it is able to be used to assess connectivity of community for robustness. This paper proposes a singular technique to assess the connectivity of networks that belongs to vulnerability evaluation without the possibilities of incidence of disruptions order), (iii) flow-based (where the links with the highest traffic flow in the undisputed network are repaired first), and (iv) criticality-based (where the links whose individual failure result in the maximum affects at the device overall performance are repaired first) recovery. The effects of this contrast are in the end used to assess the correlation among robustness and resilience, and signify the finest restore strategy. Lin Gao [5] et.al introduces the idea of engineering resilience into the after outcomes overall performance assessment of city avenue networks.

It reveals the internal influence principle of nodes and independent pathways on the seismic (after-slip) resilience of the network.

This technique can recognize the calculation of the seismic resilience for the prevailing community, reconstruction community, and new community and advocate the optimization, transformation, and format for the community.

The MATLAB program is developed and the overall network's seismic resilience is obtained by the sum of the product of the node importance and the average number of the reliable independent pathways.

Taking Lanzhou, city in China as the model, the complex network model of a city road network is recognized to learn its connectivity consistency. Yong-Sheng Qian [6] et.al takes several parameters of the complex road network and through computing the global efficiency and the relative size of the largest connecting sub graph under intentional assaults and random assaults, respectively, the curves of the above parameters various with the attacking instances are drawn. It was found that the average length of the roads is very long and the holistic connectivity reliability is at a lower level; these are suitable to the group-type distribution of valley town's avenue community, and the connectivity

reliability of the street community is more potent beneath neath random assaults than that beneath neath intentional assaults In this paper, Julio [7] et.al examine the topological factors of the road community of the coastal town of Cartagena de Indias using graph idea and spatial syntax tools.

They have worked on the history of the 400 years of the city and study the mobility through the network using a simple agent-based model that allows us to examine the extent of avenue congestion relying at the agents' understanding of the visitors even as they journey thru the network. The investigation found that a virtuously shortest-path portable system is not a best strategy and that conveying small weights to traffic escaping systems increases the overall act of the agents in terms of arrival success, occupancy of the streets, and traffic accumulation.

Methodology:

2.1 Data Collection and Preprocessing

The data is obtained from National Highway Authority (NHA) Pakistan website and extract through web scrapping. The map of the motorways can be seen in Fig 2 where the total 9 motorways can be seen, from M-1 to M9 linking the three Arabian Seaports with rest of the country.

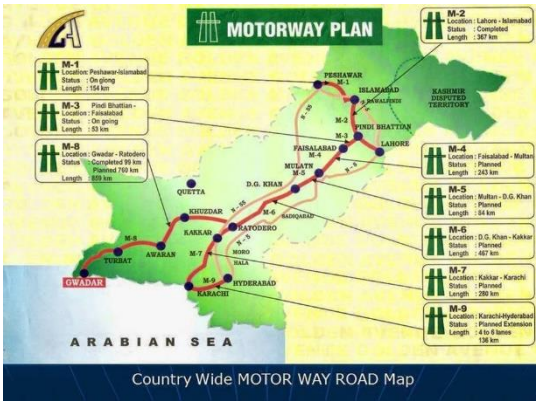

Figure 2: Motorway Road Map of Pakistan

This network of the motorways is transformed into graph network by using igraph library for R. The nodes represent the city and the edges represents the motorway that connects one city with the another. The edges are the weighted edges that represents the length (km) of the motorway. Fig 2. Shows the graphical representation of the motorway network of Pakistan. It can be seen in the figure that it is an un-directed disconnected weighted graph. The reason for disconnected graph is that one motorway only connects one city but one city can have more than one motorway connected through it.

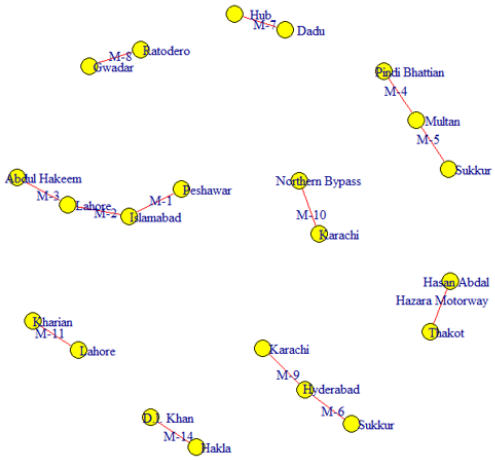

Figure 3: Graph network map of Pakistan's Motorway

2.2 Centrality measures

It can be seen in the graph network that Lahore, Islamabad, Hyderabad and Multan are connected with more than one motorway.

For the road network analysis degree centrality and betweenness centrality is calculated to observe the importance of motorway and path analysis respectively.

a. Degree Centrality

Degree centrality is calculated to show how many motorways are connected to a city. They may be connected to more than one motorway at the heart of the network, but they might also be far off or only connected to one on the edge of the network.

The results in Fig 4. Shows the degree centrality of the network which shows Multan, Hyderabad, Islamabad and Lahore has the highest degree.

Peshawar	Islamabad	Lahore	Pindi Bhattian
1	2	2	1
Multan	Sukkur	Dadu	Ratodero
2	1	1	1
Hyderabad	Karachi	Kharian	Hakla
2	1	1	1
Hasan Abdal	Abdul Hakeem	Sukkur	Hub
1	1	1	1
Gwadar	Karachi	Northern Bypass	Lahore
1	1	1	1
D.I. Khan	Thakot		
1	1		

Figure 4: Degree centrality results

b. Betweenness Centrality

Betweenness centrality is calculated to show the motorways with higher nodes representing more control over the network. In this study, the betweenness results identifies that Islamabad and Lahore has the same and highest betweenness values and there should be more services placed on these motorways. It also identifies that these two motorways, M-1 and M-2 will have the more traffic compares to others.

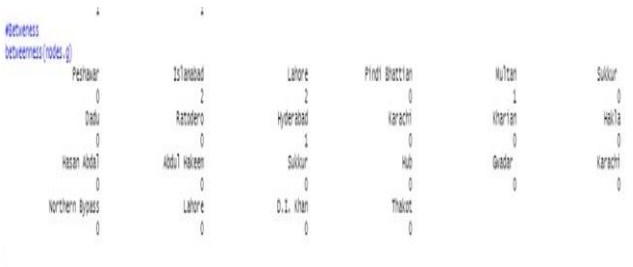

Figure 5: Betweenness centrality results

3. Results and Discussion:

The betweenness centrality reveals the busiest and most accessible areas within the country with respect to the official motorway road network considering the importance of junctions and importance of road segments. It is identified that Islamabad and Lahore motorways, M-1 and M-2 should have more services installed in the area as they will have more traffic when compared to other motorways.

In future, this study can be further expand to analyze the National Highways along with the motorways and even the ongoing projects for the motorways can be discussed and solve other trivial aspects of road network.

4. References:

1. Lajos KISGYORGY, Gergely VASVARI "ANALYSIS AND OBSERVATION OF ROAD NETWORK TOPOLOGY" International Conference of Hong Kong Society for Transportation Studies, Hong Kong. pp. 253-259. ISBN: 978-988-15814-3-3

2. Pauline Gauthier, Angelo Furno, and Nour-Eddin El Faouzi "Road Network Resilience: How to Identify Critical Links Subject to Day-to-Day Disruptions" Transportation Research Record 1–12 National Academy of Sciences: Transportation Research Board 2018

3. Hiroe Ando, Michael Bell, Fumitaka Kurauchi, K.I. Wong and Kam-Fung Cheung "Connectivity evaluation of large road network by capacity-weighted eigenvector centrality analysis"2020 Transportmetrica A: Transport Science

4. Philippe Y.R. Sohouenou and Luis A.C. Neves, "Assessing the effects of link-repair sequences on road network resilience" International Journal of Critical Infrastructure Protection (2021)

5. Lin Gao, Mingzhen Wang, Anshuang Liu, and Huafeng Gong, "Comprehensive Evaluation of Urban Road Network Resilience Facing Earthquakes" Research Article, Volume 2021 |Article ID 6659114

6. Yong-Sheng Qian, Min Wang, Hong-Xia Kang,Jun-Wei Zeng, and Yu-Fei Liu, "Study on the Road Network Connectivity Reliability of Valley City Based on Complex Network" Hindawi Publishing Corporation Mathematical Problems in Engineering Volume 2012, Article ID 430785

7. Julio Amézquita-López, Jorge Valdés-Atencio and David Angulo-García, "Understanding Traffic Congestion via Network Analysis, Agent Modeling, and the Trajectory of Urban Expansion: A Coastal City Case" A Coastal City Case. Infrastructures 2021, 6, 85.

8. Königsberg bridge problem, https://www.britannica.com/science/Konigsberg-bridge-problem