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Transportation Indicators for Roads Network in Ramadi City

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ABSTRACT

One of the most important aspects of developing any area is creating a viable road network and defining the relationship between landscape use and road networks. Proper communication and direction are essential to the proper construction of any network. In addition to providing chances for production and consumption, resource extraction, and social cohabitation, the road network also functions as a hub for these activities. As a consequence, this contributes to the development of cities and the improvement of the level of living. However, Ramadi's road network has not received much attention and evaluation. To identify Ramadi road network transportation indicators, the researchers used geospatial information systems. Connectivity was assessed using the alpha, beta, gamma, and eta indices to describe and analyse the network. The data was collected in the first quarter of 2024. The Alpha, the beta, the gamma, and the eta indexes show weak Al-Ramadi road network connections. Indexes are 0.197, 1.26, 0.43, and 0.82. The research indicates a loss in network connectivity in the study region, necessitating the prioritization of new roads and a city plan to mitigate network shortages.

1. Introduction

The city of Ramadi is considered the center of Anbar Governorate, as it is witnessing continuous change and expansion in all dimensions. As a result of rapid economic and social change, there is inevitably high traffic for goods and passengers, which has led to a high demand for transportation. This demand requires an equivalent and efficient delivery of network system infrastructure, modes, and services. Despite the fact that the roadway infrastructure is the major part in the establishment of the transportation systems, the area covered by the road network indicates the degree of mobility of persons, goods, and services inside an area, and the excellence of the network methods the ease and cost of this movement, we find that The roads in the city of Ramadi suffer from insufficient infrastructure in terms of availability (the absence of many essential links from its construction), and the lack of several network contacts, followed by the shortest paths, especially those that represent a direct link among two neighboring towns or even two routes to connect, limits the level of movement of people and goods

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within a specific path through the existing contacts. The development of mobility favors long and frequent trips by private car. These disruptions to the transportation system will result in significant economic and social pressures, such as hindering people's ability to get to work on time, affecting businesses through delayed deliveries and supplies, increasing freight costs, and causing delays or cancellations of industry, meetings, and other events (Gil, 2014; Jenelius, 2009).

The urban transport system is a traditional transport network that has piqued the interest of several research studies (Wang et al., 2012). Among the transportation network methodologies, the most beneficial is connectivity assessment. It has various indices, each with its own meaning (alpha, beta, gamma, and eta) these indices measure the most basic components of a transport system (Rodrigue, 2020). To obtain the connectivity index, the network (line) and intersection (node) are required. System and traffic assessments can use these indicators to detect changes in network structure. (Levinson, 2012). Alpha index measures the ratio of a network's exact number of interconnects to its highest allowable number of interconnects. The gamma index measures the number of links in a network as a ratio, while the beta index determines the degree of road connectivity. (Obafemi et al., 2011).

To achieve the goals of this research, we must undertake an analysis of the roadway system. Techniques for evaluating transportation networks are based on graph model. The goal of graph model will be to represent the structure of the network rather than its appearance. The focus is on writing mathematical code for networks and measuring their attributes. Networks, nodes, and linkages are all visual representations of information. A network usually consists of a group of nodes and links. Connectors refer to the lines connecting the two vertices, while nodes represent the number of contacts. In the transmission network, there are many methods of analysis, each with its own methodology (Sarkar et al., 2021).

2. Review

In order to evaluate the effectiveness, robustness, and overall performance of transportation networks, connectivity analysis is a key component. Because of the urgent requirements for urban development, post-conflict rehabilitation, and effective urban mobility, connectivity analysis has become an increasingly significant field in Iraq. This study of the relevant literature investigates the most important methodology and discoveries associated with the connectivity analysis of transportation networks in Iraq. Particular attention is paid to the utilization of graph theory, Geographic Information Systems (GIS), and contemporary analytical tools.

Graph theory provides a foundational framework for studying the connectivity of transportation networks. This framework is achieved by modeling networks as graphs, with nodes representing intersections and edges representing highways. Graph theory has extensively utilized numerous indices to evaluate connectivity in Iraqi cities. These indices include the alpha (α), beta (β), gamma (γ), and eta (η) indices specifically.

- Alpha Index (α) is a parameter that evaluates the ratio of real loops to the maximum feasible loops in order to determine the level of redundancy in a network.
- Beta index (β) is a measure that evaluates the proportion of edges to nodes, which is a reflection of the complexity and density of the network. A higher value of β indicates a greater number of direct links and a more favorable potential flow of traffic.
- Gamma Index (γ) is a metric that evaluates the overall network integration by comparing the number of real linkages to the total number of different conceivable links.
- Eta Index (η) index is a crucial indicator in the field of connectivity analysis, which is employed to evaluate the structure and effectiveness of transportation networks.

In order to get useful insights into the individual issues and opportunities that each metropolitan region faces, case studies of connectivity analysis are carried out in a number of Iraqi cities. In 2009, Khazaal completed a spatial assessment of Erbil, Iraq's constructed road network, to analyze its connectivity. Furthermore, the research concentrated on detour analysis. Because of the steep terrain, the results indicated poor connectivity (Khazaal, 2009). Connectivity and direction are essential for network development. This study examined Al-Kufa's road network connectivity. Additionally, this study used GIS to illustrate the city's primary features. This study used beta, gamma, alpha, spreading, and correlation indices to evaluate the road network. The results show that new roads are needed immediately. Finally, network density may improve another crucial road network metric prediction (Abdlabass & Al-Jameel, 2020). The proposed algorithm assessed Najaf (Iraq) traffic network connection and efficiency. traffic network using graph theory. A survey and forecast were done to improve Najaf's urban traffic network. For all Najaf traffic network indices, more links are needed (Dudkin et al., 2021). A comparison between urban and rural road networks in the Al Anbar Governorate was evaluated. It was concluded that there were differences in the levels of connectivity between the two types of road networks and proposed measures to improve the integration of rural roads with metropolitan areas (Ali, 2023). In Al-Kadhimiya and Al-Adhamiya municipalities, this study examines the impact of road network connectivity on travel time. The study analyzes topological structure by focusing on elements related to road connections. These included the cyclomatic number, Eta parameter, ATS, beta, gamma, and alpha directories. Findings indicate that the Al-Adhamiya road network is more advanced, better connected, and has greater general connectedness than the Al-Kadhimiya network. (Mahdi et al., 2023).

3. Methodology

The research relied on an analytical approach using the geographic information systems program to find the transportation indicators that affect the roadway system. The road network of the research area (Al-Ramadi city) is represented as a graph consisting of points and lines, where the points refer to the nodes and the lines represent the network links. To facilitate the description and analysis of the network, its connectivity was measured using the alpha, beta, gamma, and Eta indices (see Figure 1). The grid lengths were measured based on ArcGIS 10.8 (see Figure 2).

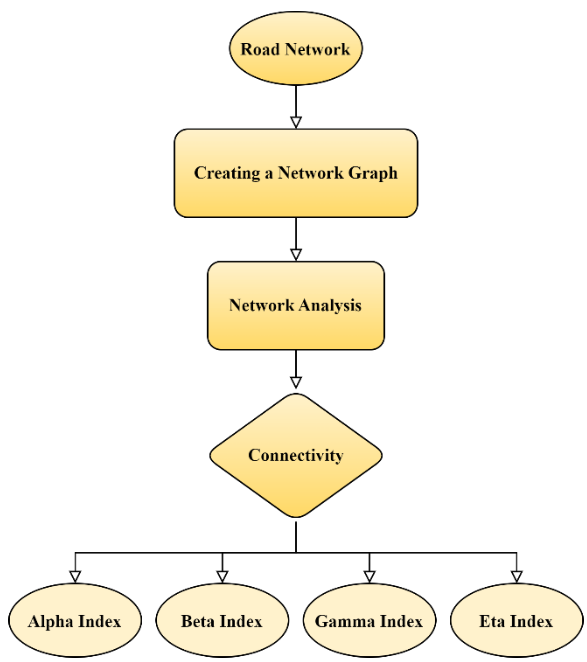

Fig. 1 Research Methodology Chart

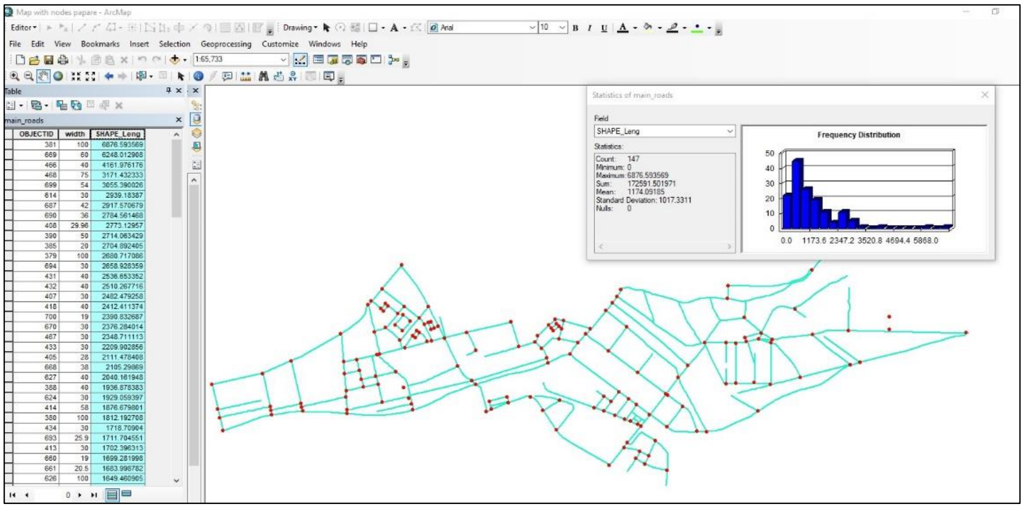

Fig. 2 Lengths of Ramadi City Road network

There are two crucial steps to follow to transform a real network into a flat graph:

- First, every endpoint and intersecting spot is a node.
- The second point is that a drawn line connects each connecting node.

By graphically depicting the network, analysis is enabled. The network and access were studied using a graphical depiction of the roadway system. For link and coverage analysis, the following indices are used: Alpha index (α), Beta index (β), Gamma index (γ), and Eta index (η). Table 1 displays the equations and interpretations used to calculate these indicators (Singleton & Arribas-Bel, 2021).

Table 1 – Indexes of connectivity analysis.

No	Index name	Equations		Description
1.	Alpha	$\alpha = \frac{e-v+p}{2v-5}$	(1)	This indicator measures network connection by comparing the numeral of cycles in the graph with the extreme number of cycles. Network connectivity increases with an increase in the alpha value. The value of this indicator ranges between (0 to 1), where the value of 1 shows high correlation and this is very rare, while the value of 0 is owned by networks and simple quarrel.
2.	Beta	$\beta = \frac{e}{v}$	(2)	The beta indicator is used to measure the extent of connectivity of a network, as it can be represented by the correlation among the numeral of contacts and nodes in the graph. When the network is connected in one turn, the value of the indicator is equal to 1, while this value increases with the increase in the number of nodes and paths, and this is what happens in more complex networks.
3.	Gamma	$\gamma = \frac{e}{3(v-2)}$	(3)	A measurement of connectivity that takes into account the connection between the number of seen and anticipated links. Gamma has a value between 0 to 1, with 1 representing a perfectly connected system, which is extremely uncommon.
4.	Eta	$\eta = \frac{L}{e}$	(4)	Average link length. Adding new nodes reduces Eta because the length of each link is decreasing. The eta values of complex networks are low.

e: The number of linked connections.
v: The number of nodes in the network.

P: The number of non-connected sub-graphs in the grid.
L: The total network length.

The city of Ramadi is situated in the western portion of Iraq, specifically at the crossing of the longitudes (43°-20') and (43°-12') east, and the latitudes (33°-27') and (33°-23') north. The majority of the city is located in the southern part. The Al-Anbar Province and the Euphrates River have a geographical divide, with the eastern portion of the governorate located on one side of the river. Ramadi, according to the Anbar Statistics Directorate, is a vast terrain that spans 318,088 square kilometers and has a built area of 7,375 hectares. The city serves as a lively hub for community activity, with a significant concentration of major government institutions. This is due to the city's central location and administrative significance. Additionally, it is a vital transportation hub that acts as a point of intersection for a number of transportation routes, including major highways and international roads such as 10 and 12. The road network of the city of Ramadi was chosen as a case study in this research, with a total length of 172 km.

4. Results and Discussion

Table 2 displays the results of applying the equations, based on the number of links and nodes obtained from the network diagram (Figure 3) and the equations in Table 1.

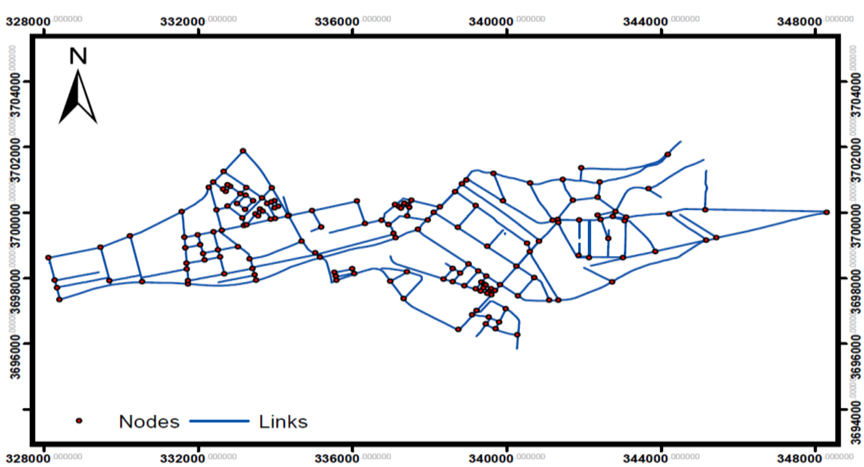

Fig. 3 Network diagram

Table 2 – Results of indexes of connectivity of Ramadi network.

No.	Index Name	Index Value	Explanation
1	Alpha	0.197	The connectivity of network is low.
2	Beta	1.26	The network was moderately complex.
3	Gamma	0.43	The Ramadi network has low level connectivity.
4	Eta	0.82	The average node separation is modest.

Alpha index = (211-167+21) / (2*167-5) = 0.197

The alpha value indicates that the network connection is weak, as it requires 264 connections to reach its maximum level. Therefore, the construction of new lines connecting the suburbs is necessary to fully cover the neighborhoods of Ramadi.

Beta index = (211/167) = 1.26

Based on the beta index, the road network was relatively complicated, with an index slightly higher than one and short connection lengths.

Gamma index = (153/3) (132-2) = 0.43

Based on to the gamma index value, this shows that the network connection on this scale is at a low level; for the network link to be optimal, there must be (237) new links among the existing nodes in the city to reach the network's full degree.

Eta index = (172/211) = 0.82 km/link

Based on to this measure, the network's degree of spread is 0.82 km/link, indicating that the street network in Al-Ramadi city is well spread; this also indicates that the lengths of connections in the city are short, providing a clear picture of the convergence between residential communities and the closeness of their distances.

5. Conclusion

The connectivity analysis of Ramadi's road network, using graph theory indices, provides significant insights into the network's strengths as well as areas that could use development. The surrounding parts of Ramadi suffer from sparse networks and low redundancy, in contrast to the center of Ramadi, which demonstrates very good connectedness and integration. Addressing these discrepancies through targeted infrastructure construction, redundancy strengthening, and technological integration has the potential to considerably improve the overall performance and resilience of Ramadi's road network, which in turn will enable urban growth and mobility. Here are explanations of the most significant findings from this study:

1. The connection of the Al-Ramadi Road network is considered to be minimal, as indicated by the indexes (alpha, beta, gamma, and eta). Specifically, the values of the indexes are 0.197, 1.26, 0.43, and 0.82, to be exact.
2. According to the findings of the research, the area under investigation is experiencing a decrease in network connectivity, according to the research findings. Therefore, the city must prioritize the construction of new roads and devise a strategy to address the network's shortfall, thereby enhancing its connectivity. To accomplish this goal, the city increases the number of links between its various neighborhoods.
3. Improve accessibility and integrate outlying neighborhoods into the city's transportation network. Building and renovating roads.
4. Roads must be regularly maintained and upgraded to enable smooth traffic flow and prevent deterioration that can affect connectivity.
5. Using technology can reveal connectivity trends and inform infrastructure construction and traffic management

Reference

Abdlabass, A. Y., & Al-Jameel, H. A. (2020, November). Evaluation of Al-Kufa City Road Networks Using GIS. In *IOP Conference Series: Materials Science and Engineering* (Vol. 978, No. 1, p. 012014). IOP Publishing.

Ali, K. A. (2023). The characteristics of the road network in Anbar Province, according to the measures of accessibility. *Journal of Kirkuk University Humanity Studies*, *18* (special issue).

Dudkin, E., Abujwaid, H., & Losin, L. (2021, May). Urban Traffic Network Connectivity and Efficiency Evaluation (Through the Example of Iraq). In *International Scientific Siberian Transport Forum* (pp. 627-636). Cham: Springer International Publishing.

Gil, J. (2014). Analyzing the configuration of multimodal urban networks. *Geographical analysis*, *46*(4), 368-391.

Jenelius, E. (2009). Network structure and travel patterns: explaining the geographical disparities of road network vulnerability. *Journal of Transport Geography*, *17*(3), 234-244.

Khazaal, Kh. A. (2009). Geographic analysis For the paved road network system in Erbil Governorate. *Diyala Journal of Human Research*, (34), 170-183.

Levinson, D. (2012). Network structure and city size. *PloS one*, *7*(1), e29721.

Mahdi, H. J., AL-Bakri M., & Ubaidy A. L. (2023). Evaluating Roads Network Connectivity for Two Municipalities in Baghdad-Iraq. *Journal of Engineering 29*(06): 60–71.

Obafemi, A. A., Eludoyin, O. S., & Opara, D. R. (2011). Road network assessment in Trans-Amadi, Port Harcourt in Nigeria using GIS. *International Journal for Traffic and Transport Engineering*, *1*(4), 257-264.

Rodrigue, J. P. (2020). The Geography of Transport Systems (5th ed.). Routledge. https://doi.org/10.4324/9780429346323.

Sarkar, T., Sarkar, D., & Mondal, P. (2021). Road network accessibility analysis using graph theory and GIS technology: a study of the villages of English Bazar Block, India. *Spatial Information Research*, *29*(3), 405-415.

Singleton, A., & Arribas-Bel, D. (2021). Geographic data science. *Geographical Analysis*, *53*(1), 61-75.

Wang, Y., Han, Q., & Pan, H. (2012). A clustering scheme for trajectories in road networks. In *Advanced Technology in Teaching-Proceedings of the 2009 3rd International Conference on Teaching and Computational Science (WTCS 2009) Volume 2: Education, Psychology and Computer Science* (pp. 11-18). Springer Berlin Heidelberg.