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Analyzing the Routes of the Arbaeen Pilgrimage: Guiding Visitors to the Shrine of Imam Al-Hussein (PBUH)

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Abstract

The annual pilgrimage to the shrine of Imam Hussein (peace be upon him) is a significant event for Iraqi society. Millions of Iraqis from all walks of life converge on the holy city of Karbala each year on the 20th of the month of Safar. The sheer scale of such gatherings necessitates in-depth study. Various methodologies were employed in this field, including graph theory and network analysis, to determine the shortest routes pilgrims take from their governorates (places of residence) to the holy city of Karbala. All roads leading to the city are primary, secondary, international, and public transportation networks are considered. The objective is to identify the optimal route for the movement of large Crowds to ensure a safe, secure, and efficient journey that minimizes travel time and maximizes the convenience of pilgrims. The Iraqi province's road shapefile collection documents the complicated road networks within each province. The findings of this study could be used by relevant authorities to plan and provide necessary services along the identified route. A detailed analysis of the primary road network in the study area showed that most of the road network in the eastern, southern, and western governorates converges on a single main road. In contrast, the northern governorates have a more extensive road network. Consequently, the shortest route identified in this study primarily passes through the cities named.

Keywords: Network Analysis, GIS, Roads Network, Spatial Analysis, Spatial Suitability.

تحسين مسارات زيارة الأربعين: من المنازل إلى مرقد الإمام الحسين (عليه السلام)

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الخلاصة

الزيارة السنوية لمرقد الإمام الحسين (عليه السلام) حدث بارز للمجتمع العراقي. يتوافد ملايين العراقيين من مختلف شرائح المجتمع إلى مدينة كربلاء المقدسة في العشرين من صفر من كل عام. يتطلب الحجم الهائل لهذه التجمعات دراسة متعمقة. تم استخدام منهجيات متنوعة في هذا المجال، بما في ذلك نظرية الرسم البياني،

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والتحليل المكاني، وتحليل الشبكات. ستركز هذه الدراسة بشكل أساسي على نظرية الرسم البياني وتحليل الشبكات لتحديد أقصر الطرق التي يسلكها الزوار من محافظاتهم (أماكن إقامتهم) إلى مدينة كربلاء المقدسة. سيتم النظر في جميع الطرق المؤدية إلى المدينة، بما في ذلك شبكات الطرق الرئيسية والثانوية والدولية ووسائل النقل العام. الهدف هو تحديد المسار الأمثل لحركة الحشود الكبيرة، وضمان رحلة آمنة ومأمونة وفعالة تقلل من وقت السفر وتزيد من راحة الزوار. توثق مجموعة ملفات أشكال الطرق في المحافظات العراقية شبكات الطرق المعقدة داخل كل محافظة. يمكن للسلطات المعنية استخدام نتائج هذه الدراسة للتخطيط وتقديم الخدمات اللازمة على طول المسار المحدد. من خلال تحليل مفصل لشبكة الطرق الرئيسية في منطقة الدراسة، لوحظ أن معظم شبكة الطرق في المحافظات الشرقية والجنوبية والغربية تتقارب على طريق رئيسي واحد. في المقابل، تتمتع المحافظات الشمالية بشبكة طرق أكثر اتساعًا. وبالتالي، فإن أقصر طريق تم تحديده في هذه الدراسة يمر بشكل أساسي عبر المدن الوسطى في العراق.

1. Introduction

Network analysis of roadways in Geographic Information Systems (GIS) is a fundamental and valuable tool for discovering, developing, and regulating transportation networks [1]. Roads serve as vital conduits for movement within and between physical locations, and examining their interconnections provides significant insights into city planning, emergency response, transportation, and other related areas [2]. Network evaluation in GIS offers a technique for representing, mapping, and analyzing street networks, facilitating effective route planning, efficient resource sharing, and informed decision-making [3]. In the modern networked world, the efficient transportation of products and services relies substantially on well-designed road networks [4]. From convoluted city streets to extensive toll road networks, roads constitute the physical channels that shape our communities and economy [5]. However, the complexity of road networks, impacted by elements such as traffic flow, street types, speed regulations, and congestion, requires sophisticated technologies to understand their behavior accurately. This is where GIS network analysis steps in [6]. GIS technology enables the modeling of road networks as interconnected nodes (intersections) and edges (road segments), each with attributes that describe their characteristics. This structure supports various network analysis applications, such as identifying the shortest paths, estimating travel times, optimizing facility locations, evaluating network connectivity, and studying accessibility. These capabilities make network analysis indispensable in urban and regional planning, allowing planners to assess the impact of new infrastructure on traffic patterns and travel times. Emergency services can optimize response routes, logistics companies can enhance delivery efficiency, and environmental initiatives can promote sustainable mobility solutions, such as pedestrian-friendly spaces and improved public transit systems. GIS software enhances network analysis by incorporating one-way streets, turn restrictions, slope variations, and real-time traffic data [7]. These tools enable stakeholders to make data-driven decisions, ultimately improving the functionality and efficiency of transportation networks [8]. By leveraging geographical information and analytical tools, GIS-based network analysis contributes to the creation of safer, more accessible, and well-connected communities while supporting the seamless movement of goods and people. This study uses a spatial graph to determine the shortest distance between each governorate in Iraq and the Karbala Governorate [9]. Spatial graphs, derived from graph theory, represent real-world locations as vertices to facilitate the practical analysis of geographic relationships. Depending on the type of spatial graph — static or dynamic, directed or undirected — with varying weights, specific algorithms are employed to find the shortest paths [10]. The research focuses on a directed, non-negative, and static spatial graph, applying the Single-Source Shortest Path (SSSP) method to solve the problem. Among the available algorithms for SSSP, Dijkstra's algorithm is selected for its efficiency and reliability in determining the shortest paths in such scenarios [11].

2. Study area

Iraqi districts boast a diversified road network, which is crucial for linkage and prosperity. Varied landscapes, population regions, and historical landmarks determine route design. Major cities like Baghdad and Mosul are centers of road networks, facilitating commerce and travel [12]. Challenges, including maintenance, security, and mobility, remain, particularly in rural locations [13]. Road-focused GIS analysis aids in upgrading routes, bolstering infrastructure, and supporting economic development throughout Iraq governorates; Figure (1) presents all Iraqi cities.

Figure 1: Iraqi cities map

3. Methodology

Network evaluation is rooted in graph principle, a place of mathematics concerned with systems called graphs, which consist of nodes (vertices) and edges (connections) [14]. This method is crucial for resolving challenges related to systems such as transportation networks, information networks, and supply lines [15]. Equations in community analysis provide the mathematical framework for understanding, enhancing, and managing these state-of-the-art structures.

3.1. The Theoretical Foundations (Dijkstra's Algorithm)

The shortest direction problem goals to determine the quickest route between nodes in a graph. [16] Dijkstra's method allocates tentative distances to nodes and always chooses the node with the minimal tentative distance, editing distances through adjoining nodes proven inside the equation following:

$$D[v] = min\big(D[v], D[u] + w(u,v)\big) \qquad \ldots\ldots\ldots (1)$$

Where D[v] is the modern distance to node v, D[u] is the distance to the cutting-edge node u, and w(u,v) is the load of the edge between u and v.

Network evaluation models provide efficient pathways, communicate networks, and facilitate resource sharing, presenting knowledgeable choices for enhanced efficiency and connectivity. Figure (2) presents all Iraqi cities.

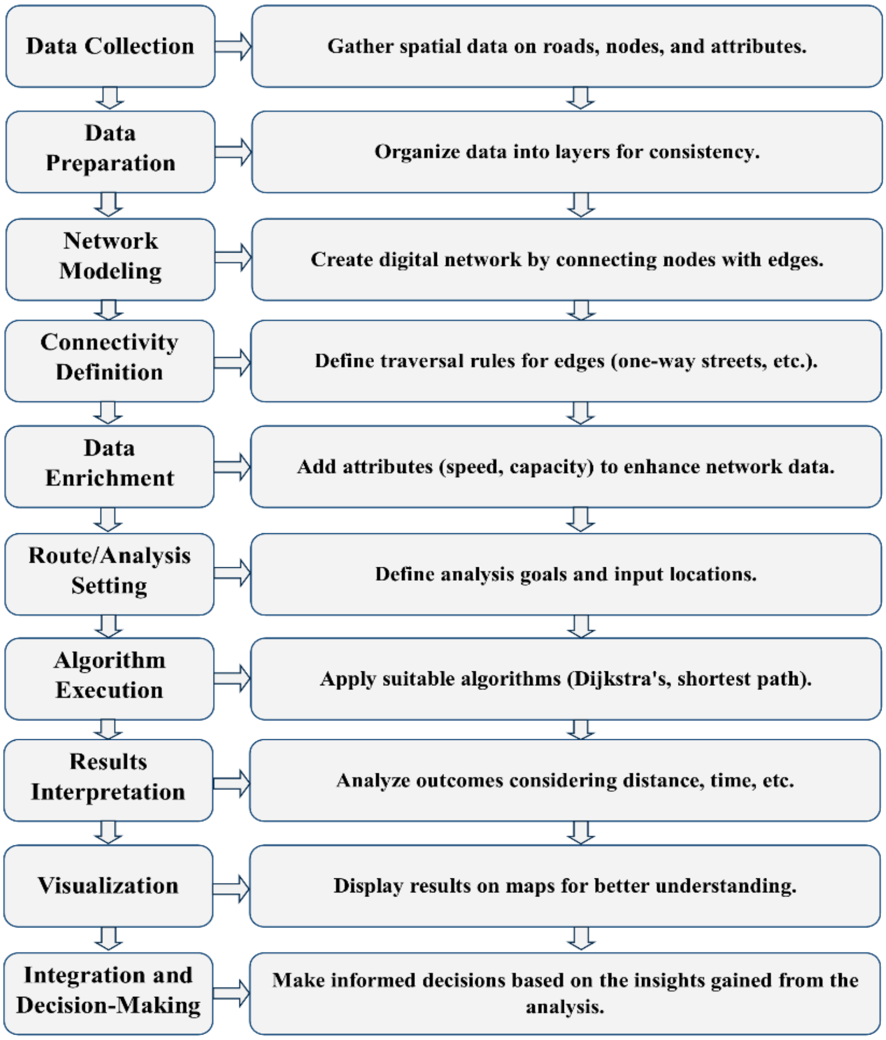

Figure 2: Flowchart for the Network analysis steps

To represent geographical data in a spatial graph to find the shortest distance to reach each Iraq and Karbala Governorate.
Given a set of vertices V representing the provinces of Iraq, a source vertex s represents Karbala governorate, a destination vertex d represents the governorate for which want to know the shortest path to S, where s, d ∈ V, and a set of weighted edges E the edges represent the distance

between s and v, find the shortest-path between s and d that has the minimum weight (distance). The input to the shortest path algorithm is a graph G that consists of a set of vertices V and edges E. The graph is defined as G = (V, E). The edges can be directed or undirected [17]. The edges have explicit weights representing the distance, where a weight is defined as w(e), where e ∈ E is shown in Figure (3).

3.2. Dataset

The Iraqi province's road shapefile collection documents the complicated road networks within each province [18]. This spatial data, crucial to Spatial Information Systems (GIS), enables extensive research on road connections, trends, and conditions [19]. The road shapefile data is a significant resource for developing transportation systems and promoting mobility throughout Iraqi territories, Figure (3) and Table (1).

Table 1: showing information about each point in the map

ID	Governorates	Latitude	Longitude
1	Dahuk	36°53'10.677"N	43°6'9.564"E
2	Mosul	36°19'31.277"N	43°7'52.241"E
3	Erbil	36°11'55.926"N	44°0'55.248"E
4	Sulaymanyah	35°33'48.143"N	45°28'11.808"E
5	Kirkuk	35°27'32.034"N	44°24'1.396"E
6	Tikrit	34°35'41.094"N	43°42'57.133"E
7	Samarra	34°12'23.218"N	43°52'21.860"E
8	Baqubah	33°44'0.152"N	44°39'25.495"E
9	Baghdad	33°19'45.119"N	44°24'52.735"E
10	Anbar	33°26'10.937"N	43°18'8.307"E
11	Hillah	32°30'54.753"N	44°26'35.413"E
12	Kut	32°29'28.159"N	45°50'26.617"E
13	Najaf	31°58'20.794"N	44°18'53.363"E
14	Samawah	31°20'28.416"N	45°17'21.516"E
15	Nasririyah	31°2'54.439"N	46°13'49.878"E
16	Amarah	31°52'3.137"N	47°9'9.789"E
17	Basrah	30°28'35.746"N	47°48'31.375"E
18	Diwaniyah	31°58'49.826"N	44°55'6.707"E

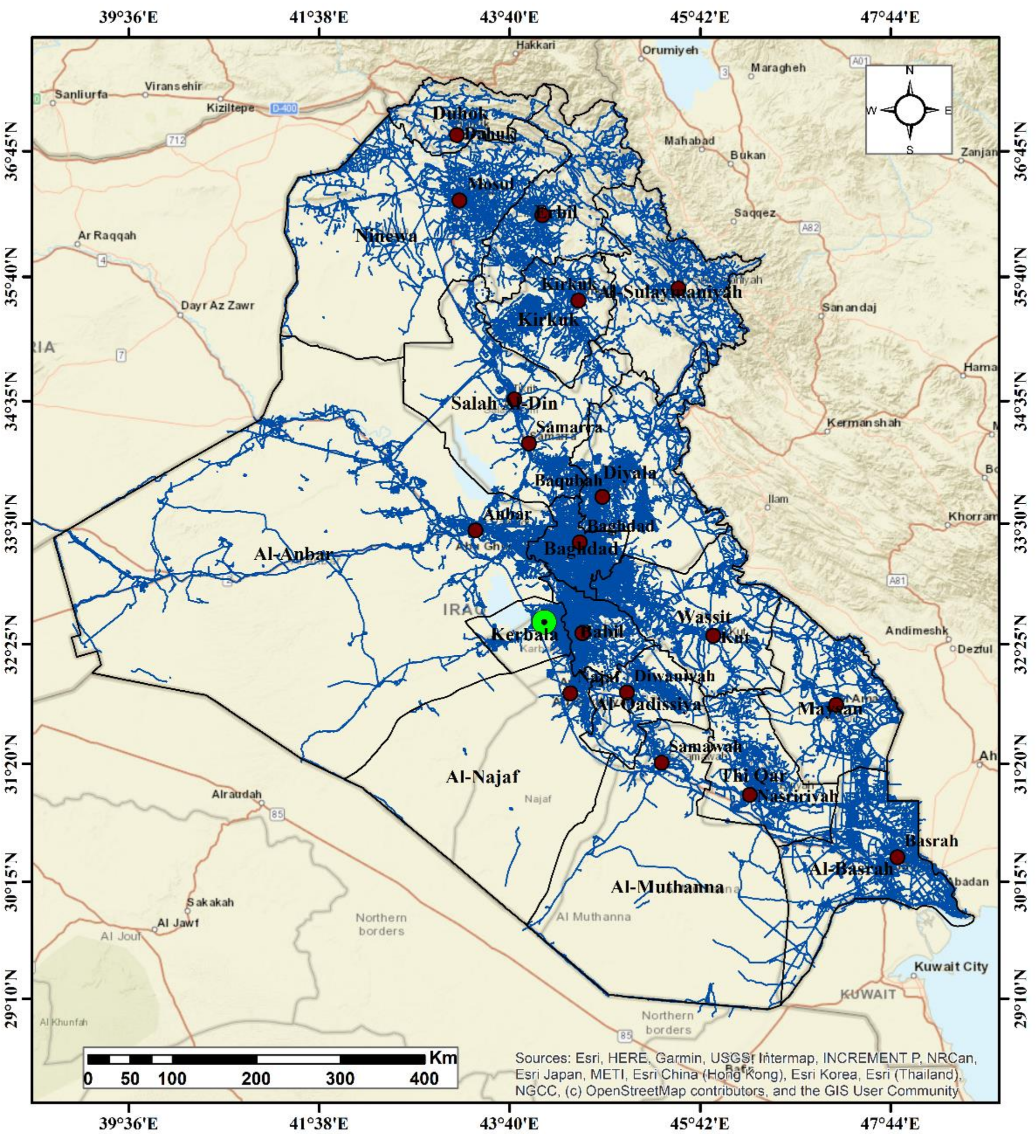

Figure 3: Observed dataset of roads and governorates centers

4. Results and discussions

The network research of Iraqi shortest street routes promises necessary transportation, operational, and decision-making records. It identifies effective pathways for traffic, firms, and concrete planners, augmenting routes and reducing transit charges. Under these conditions, it enables an expeditious response by employing rapid techniques [20]. Urban planners utilize it to enhance visitor control and public transit. Government agencies enhance resource sharing, facilitating economic progress.

Additionally, it complies with environmental objectives by minimizing the release of contaminants. For visitors, it ensures simplified journeys, collectively enhancing transportation efficiency, economic development, and quality of life in Iraq. Figure (4) shows the shortest routes for transfer visitors to Karbala.

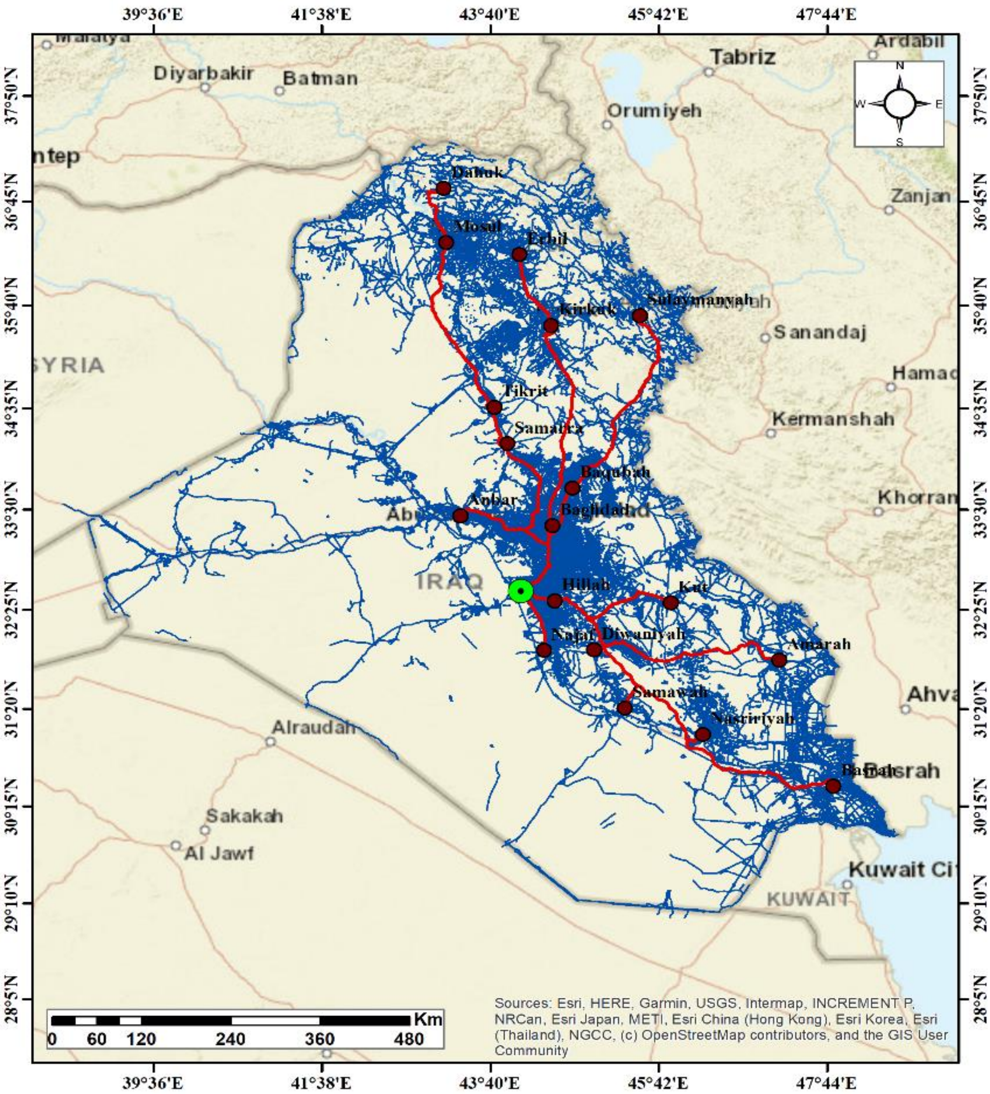

Figure 4: Presents the shortest routes for transfer visitors to Karbala.

The overview of travel choices commences in numerous towns and locales and ends in Karbala, Iraq. The precise number of kilometers needed to travel each route is listed next to each entry in the table corresponding to a particular route. For instance, the distance between Basrah and Karbala is a large 589.032 km, but the distance between Amarah and Karbala is a reasonable 437.728 km. These distances indicate the driving time required to travel by road from various points of origin in Iraq to Karbala, providing useful information for itinerary planning and logistical considerations (Table 2).

Table 2: Length of the routes from/to Karbala

ID	Route Name	Distance (Km)
1	Basrah-Karbala	589.032
2	Amarah-Karbala	437.728
3	Nasiriyah-Karbala	378.309
4	Samawah-Karbala	273.089
5	Diwaniyah-Karbala	180.045
6	Najaf-Karbala	104.162
7	Kut-Karbala	242.307
8	Hillah-Karbala	51.999
9	Baghdad-Karbala	123.031
10	Ramadi-Karbala	233.316
11	Bagubah-Karbala	187.901
12	Samarra-Karbala	293.672
13	Tikrit-Karbala	358.048
14	Kirkuk-Karbala	433.954
15	Sulaymaniyah-Karbala	516.737
16	Erbil-Karbala	559.895
17	Mosul-Karbala	630.070
18	Dahuk-Karbala	740.937

The network assessment of Iraq's simplest road networks is a sophisticated instrument with repercussions for transportation, operations, emergency response, urban planning, resource sharing, environmental sustainability, and tourism. It incorporates a comprehensive strategy to enhance transportation efficiency, promote economic development, and improve Iraq's overall quality of life. Figure (4) portrays the shortest methods for conveying visitors to Karbala, while Table (2) gives comprehensive distance information necessary for practical considerations.

5. Conclusions

The network research of the shortest road routes in Iraq surfaces as a crucial resource for intelligent decision-making in transportation and operations. This extensive study demonstrates that effective pathways benefit visitors, enterprises, and urban planners, enhancing routes and curbing transit expenses. In emergencies, it is advantageous to implement prompt response strategies. Urban planners leverage their skills to enhance traffic management and strengthen public transportation networks. Government entities may more efficiently share essential resources, bolstering economic growth and development.

Furthermore, this work aligns perfectly with environmental objectives, minimizing pollutants and promoting sustainability. For visitors, it offers enhanced travel, collectively elevating transportation efficiency and economic development and enhancing Iraq's overall quality of life. The road network is complex and has many bottlenecks, particularly in central Iraq. All optimal routes converge into a single route in the central and southern provinces, while there are multiple routes in the northern provinces.

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