

The Use of Intelligent Transportation Systems in Balad District Using Geographic Information Systems (GIS)

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ABSTRACT

Objective: This research aims to employ Intelligent Transportation Systems (ITS) in the Balad District through the use of Geographic Information Systems (GIS). **Method:** The study area lies between latitudes (37°44'48" and 37°71'61") north and longitudes (48°11'24" and 49°49'25") east, covering a total area of (2161.34 km²), equivalent to (592,145 donums). Through the analysis of the road network, the study identifies the fastest routes between specific points (e.g., from point A to point B). Service area analyses (cumulative and multiple) illustrate how accessibility changes with increased barriers; for example, determining the number of hospitals accessible within 5, 10, and 15 minutes' drive from schools. Additionally, by analyzing traffic data, the accessibility of hospitals may vary according to traffic conditions. **Results:** Key requirements for the successful implementation of ITS include political commitment, sufficient budget allocations to ensure project sustainability, the establishment of traffic control centers for monitoring and managing traffic remotely, and the creation of a central database containing information on vehicles and road networks. **Novelty:** The study integrates ITS and GIS in the Balad District to identify optimal routes and assess service accessibility dynamically based on traffic conditions, highlighting infrastructural and administrative requirements for effective ITS deployment.

INTRODUCTION

The process of network analysis is considered one of the most important functions that Geographic Information Systems (GIS) can perform with high efficiency. Since human mobility, the transportation of goods and services, and the distribution of energy all rely on road networks and infrastructure, the form and efficiency of these networks largely determine the standard of living and significantly influence the equitable distribution of services. Network analysis provides various tools to study any given network and to determine the level of resistance or impedance of each segment to movement, expressed in numerical form. This is followed by a series of operations carried out through what are known as *spatial commands*, which calculate the required routes and present them to the user in an understandable and practical format.

Research Problem:

The research problem can be summarized in the following points:

1. How have Intelligent Transportation Systems (ITS) emerged in light of environmental changes and technological developments in transportation networks?
2. What constitutes the subsystems of ITS?
3. How can ITS contribute to reducing traffic congestion within the framework of sustainable transportation development?

Research Hypothesis:

1. ITS have demonstrated significant impacts through environmental changes and technological advancement in transportation networks.
2. Analytical approaches to internal transportation networks can enhance accessibility.
3. The determination of the best and shortest routes for vehicular movement can be effectively achieved within the GIS environment.

Research Objectives:

1. To achieve optimal traffic management in Balad District, with an emphasis on improving road safety.
2. To apply the Intelligent Transportation System model to the Balad District road network.
3. To examine the concept and components of ITS.
4. To identify how ITS can contribute to mitigating transportation problems and reducing the number of potential accidents.

RESEARCH METHOD

This study adopts the descriptive-analytical approach by addressing the key determinants shaping the transportation system. Additionally, the technical approach is employed through the application of Geographic Information Systems (GIS) as an analytical environment.

Study Area Boundaries

The study area, Balad District, is one of the districts of Salah Al-Din Governorate. It consists of three administrative units: Al-Ishaqi Sub-district, Yathrib Sub-district, and the district center. The district is located in the northeastern part of the Mesopotamian Plain, approximately 90 km north of Baghdad, within the southern part of Salah Al-Din Governorate.

The study area extends between latitudes 37°44'48" and 37°71'61" N and longitudes 48°11'24" and 49°49'25" E, with a total area of 2161.34 km²** equivalent to 592,145 donums [1].

Its administrative boundaries are defined as follows:

From the northeast: Al-Dhuluyia Sub-district.

From the east: Diyala Governorate.

From the south: Al-Dujail District.

From the north: Samarra District.

From the west: Lake Tharthar and Al-Anbar Governorate.

See Map 1 Location of the Study Area.

3. Definition of ITS:

Intelligent Transportation Systems involve the application of computer technologies, electronics, and information and communication technologies (ICT) in the field of transportation. ITS applications are considered "intelligent" because they rely on cognitive functions such as sensing, memory, communication, information processing, and adaptive behavior.

These technologies play a crucial role in:

- a. Optimizing infrastructure utilization.
- b. Enhancing traffic safety and security.
- c. Promoting environmentally friendly transportation modes.
- d. Reducing energy consumption, pollution, and sources of nuisance [3].

4. Importance of ITS:

- a. Optimal use of road networks and transportation modes, and efficient distribution of traffic, thereby increasing operational capacity and accommodating the continuous rise in vehicle numbers.
- b. Providing smooth mobility, comfort, and reassurance to road users, reducing the need for continuous road network expansion.
- c. Delivering timely and accurate information to road users to improve traffic safety.
- d. Rapid provision of emergency services in case of traffic accidents.
- e. Mitigating the negative impacts of vehicle use on environmental and societal safety by reducing congestion and ensuring uniform traffic distribution [4].

5. Applications of ITS:

ITS can be classified into five main categories:

- a. Advanced Traffic Management Systems (ATMS).
- b. Advanced Traveler Information Systems (ATIS).
- c. Commercial Vehicle Operations (CVO) systems.
- d. Advanced Public Transportation Systems (APTS).
- e. Advanced Vehicle Control and Safety Systems (AVCSS).

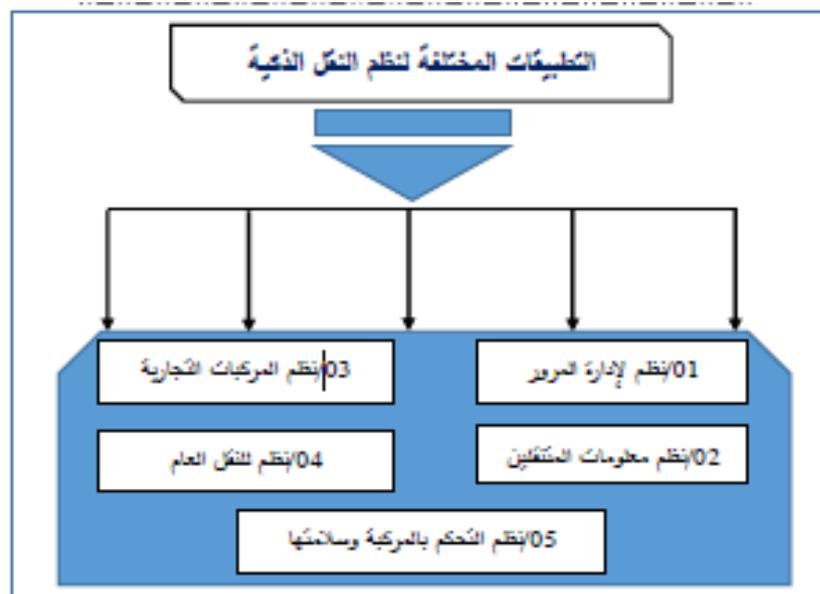


Figure 1. Different Applications of Intelligent Transportation Systems.

Delmi, Naima. 2017. The Contribution of Intelligent Transportation Systems to Traffic Management: A Case Study of Bouira City. Master's thesis, Institute of Urban Technology Management, Department of Urban Engineering, Mohamed Boudiaf University – M'sila, 11.

Network Analysis

1. Network Impedance:

When dealing with any network, such as a road network in a given district, it is observed that each road segment has a specific travel resistance, known as impedance. This impedance is a composite measure of various road characteristics, including:

Road width and capacity.

Traffic density and timing (particularly during peak hours).

Traffic signals along the road.

Maximum permitted speed.

A system analyst assigns a weight to each factor based on collected data and statistics, and then aggregates these weights to calculate the final road impedance. Geographic Information Systems (GIS) use these impedance values in various network analyses. If no explicit impedance value is provided, the street length can serve as a proxy for impedance, often referred to as cost.

2. Finding the Optimal Path:

One of the primary problems addressed by network analysis is determining the optimal path between two or more points, such that the total impedance or cost is minimized. This path is obtained by aggregating the impedances of all constituent segments of the network. In GIS, the optimal path is typically represented in two main forms depending on the type of analysis required.

3. Allocation:

Allocation in network analysis refers to identifying the portions of the network that belong to a specific point or set of points. For instance, when defining school service areas in a particular region, GIS software queries the user for the criteria upon which the division will be based, such as street length or the maximum distance a student can walk. After these parameters are defined, the software aggregates the street lengths and generates the service area for each school, enabling planners to identify underserved areas and make decisions about constructing new schools or relocating existing ones.

4. Tracing:

Tracing is the process of identifying the network segments connected to a particular point. For example, it can be used to determine areas affected by a road closure or the malfunction of a traffic signal, allowing analysts to study the impact of such events on the network.

5. Road Networks in GIS:

Network analysis is crucial due to its significant impact on geographic regions. No urban area can be developed without improving its transportation and infrastructure networks. GIS provides advanced tools for constructing and managing networks and

allows for highly efficient network [5]. analysis, including assessing the impedance of each segment and representing it numerically for further operational use.

6. Network Definition:

A network is a set of interconnected layers (lines and points) representing available routes from one location to another. Networks are classified into two types:

- a. Above-ground networks: such as roads, rivers, and railways.
- b. Underground networks: such as electricity, water supply, and gas lines.

Studying road networks and representing them cartographically is highly important, as the road network forms the backbone of a city's economy. With GIS technology, network analysis has adopted an advanced information-driven approach [6]. Software like ArcGIS serves as a key tool for creating, managing, and analyzing networks.

7. Network Analysis Dataset (Network Analysis):

Network Analysis datasets include transportation networks, such as streets and pedestrian paths, allowing complete freedom to define travel direction and destination.



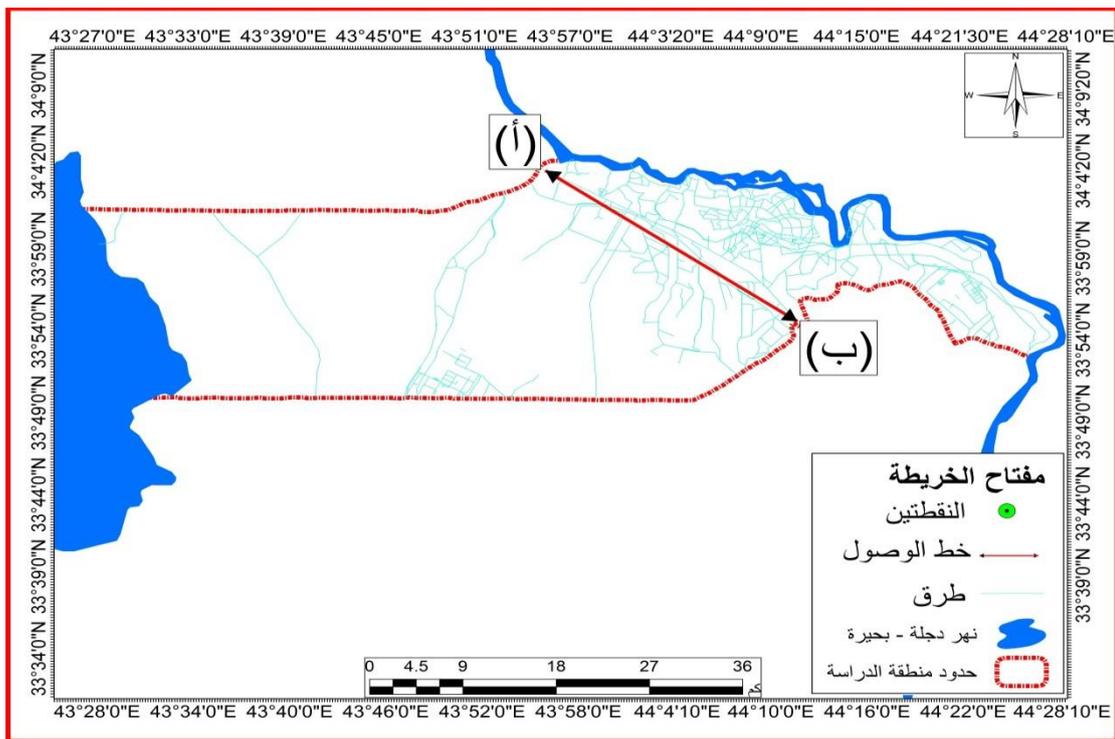
Reference: Google Earth Pro.

Figure 2. Illustrates the road network in a given district.

8. Analyses Available through Network Analyst:

The ArcGIS software, through its Network Analyst toolbar, provides solutions to common network-related problems such as identifying the best route across a city, locating the nearest emergency vehicle, and defining a service area around a specific location (e.g., the commercial catchment area of a given center).

Several questions can be addressed through network analysis, including:
What is the fastest route to travel from point A to point B?



Map 2. Example of network analysis between two points in Balad District.

Researcher's work. Based on ArcGIS 10.4.1, Network Analyst tool for road network analysis, and data from the Directorate of Technical Planning, Salah al-Din Governorate, 2022.

Which buildings can be reached within ten minutes from a specific point (e.g., a school)?
 Which ambulances are able to respond quickly to an accident?
 What are the market areas covered by a commercial activity?

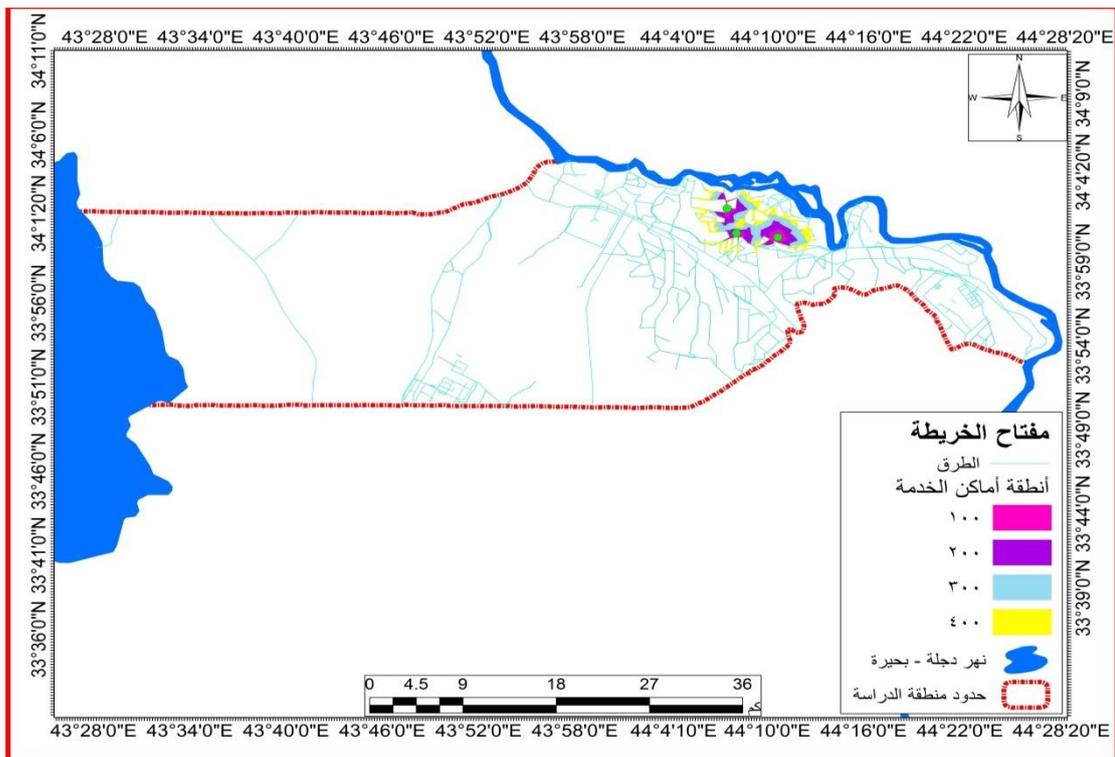
In the following figure, the black dots represent commercial centers, while the surrounding areas illustrate their respective market catchments. These catchments are divided into three rings:

The first ring represents the set of buildings that can reach the commercial center within one hour.

The purple area represents accessibility within two hours.

The light blue area indicates accessibility within four hours.

The yellow area represents accessibility within five hours.



Source: Researcher’s work, based on ArcGIS 10.4.1, Network Analyst tool for road network analysis, and data from the Directorate of Technical Planning, Salah al-Din Governorate, 2022.

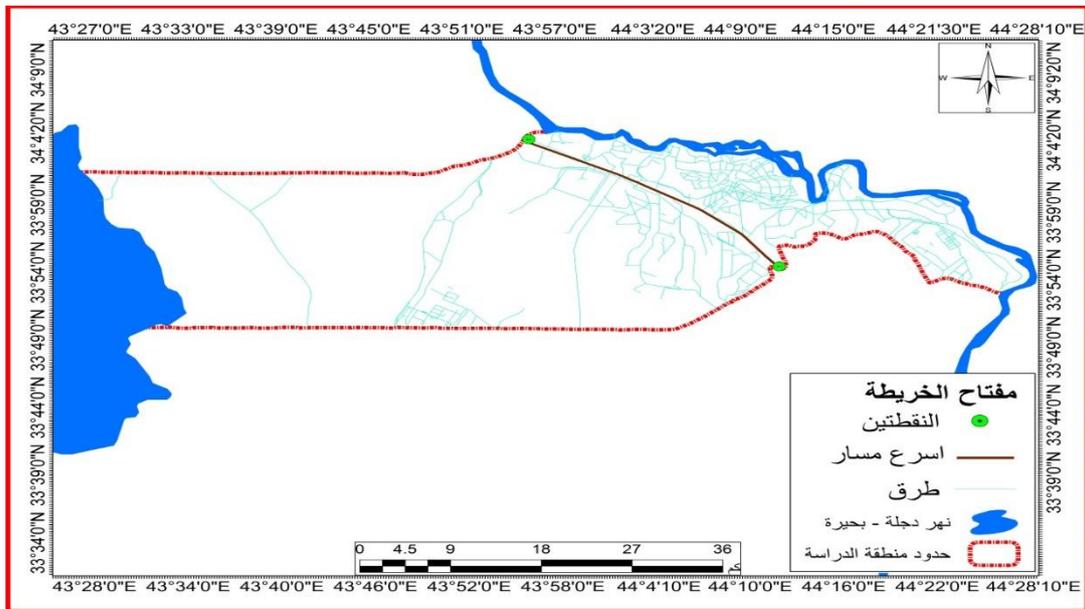
Map 3. Network analysis of market areas for commercial centers.

The following section presents the main types of analyses available through the ArcGIS Network Analyst toolbar.

1 - Route Analysis:

The Network Analyst can determine the optimal route between one location and another, or for visiting multiple locations. This can be achieved interactively and efficiently through Geographic Information Systems (GIS). The optimal route is selected based on predefined criteria and existing impediments. For instance, the best route may be the fastest, the shortest, or the most scenic, depending on the selected standard. If the problem at hand is time, then the fastest route would be the most suitable.

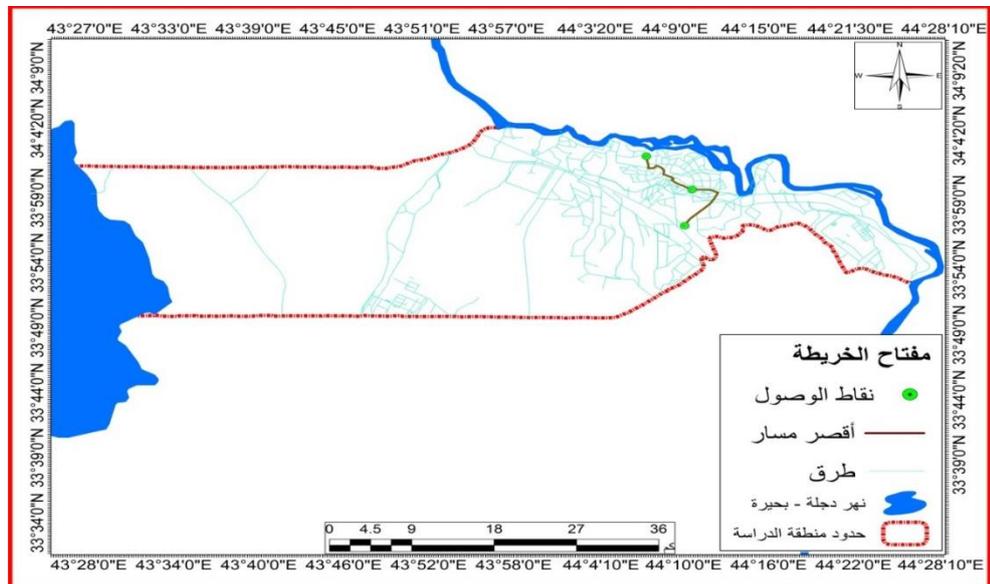
In the example below, the first case applies time as the criterion, where the fastest route is shown in brown. The total route length is 30.870747 km, with a travel time of 10 minutes.



Source: Researcher's work, based on ArcGIS 10.4.1, Network Analyst tool for road network analysis, and data from the Directorate of Technical Planning, Salah al-Din Governorate, 2022.

Map 4. The fastest road network route in Balad District.

In the second case, distance is selected as the impedance factor. Accordingly, the shortest route is 8.951456 km, with a travel time of 9 minutes.



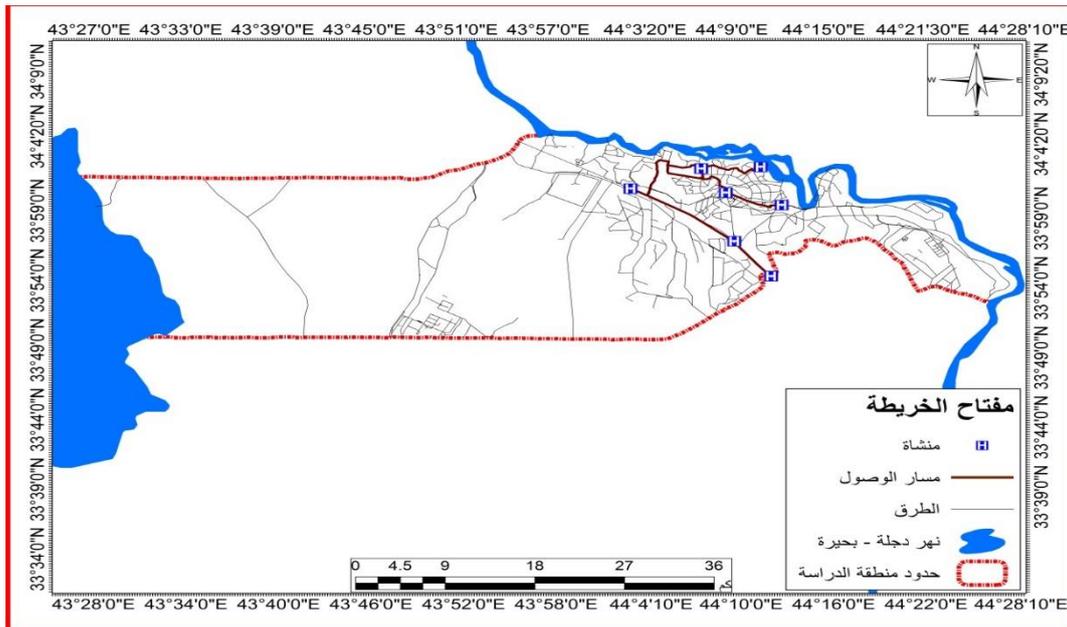
Source: Researcher's work, based on ArcGIS 10.4.1, Network Analyst* tool for road network analysis, and data from the Directorate of Technical Planning, Salah al-Din Governorate, 2022.

Map 5. The shortest road network route in Balad District.

2 - Closest Facility

This type of analysis identifies the closest facility to a specific incident location – for example, the nearest hospital to an accident site, the nearest police patrol to a crime scene, or the nearest service center to a client's address. Once the closest facilities are identified,

the analysis provides the optimal routes to or from them, the travel cost for each route, and detailed directions to each facility.

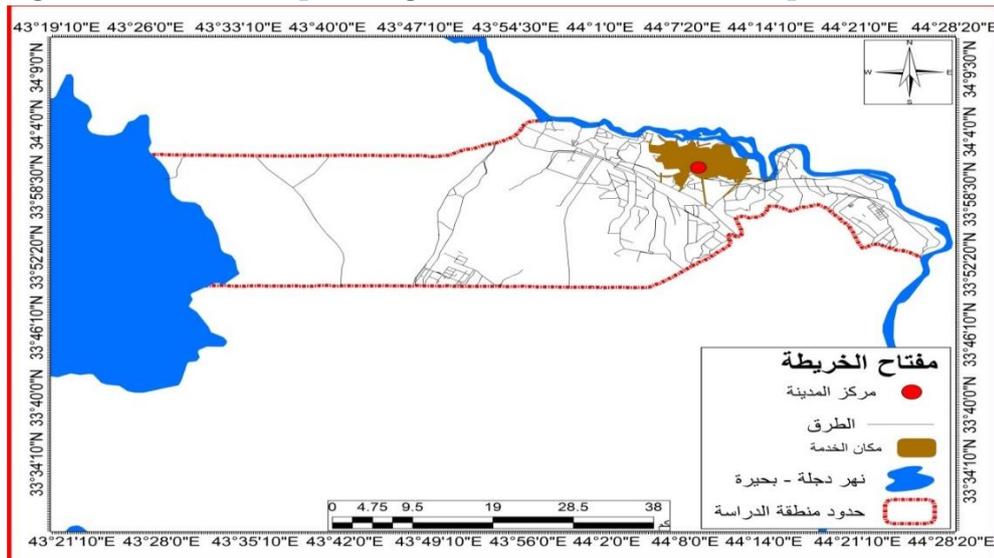


Source: Researcher's work, based on ArcGIS 10.4.1, Network Analyst tool for road network analysis, and data from the Directorate of Technical Planning, Salah al-Din Governorate, 2022.

Map 6. Directions to facilities in Balad District.

3 - Service Areas

Service areas encompass all streets accessible within a given time frame. For instance, if the requirement is to determine the service coverage within ten minutes, the software can generate the corresponding accessible area from the specified location.



Source: Researcher's work, based on ArcGIS 10.4.1, Network Analyst tool for road network analysis, and data from the Directorate of Technical Planning, Salah al-Din Governorate, 2022.

Map 7. Service area within 10 minutes in Balad District.

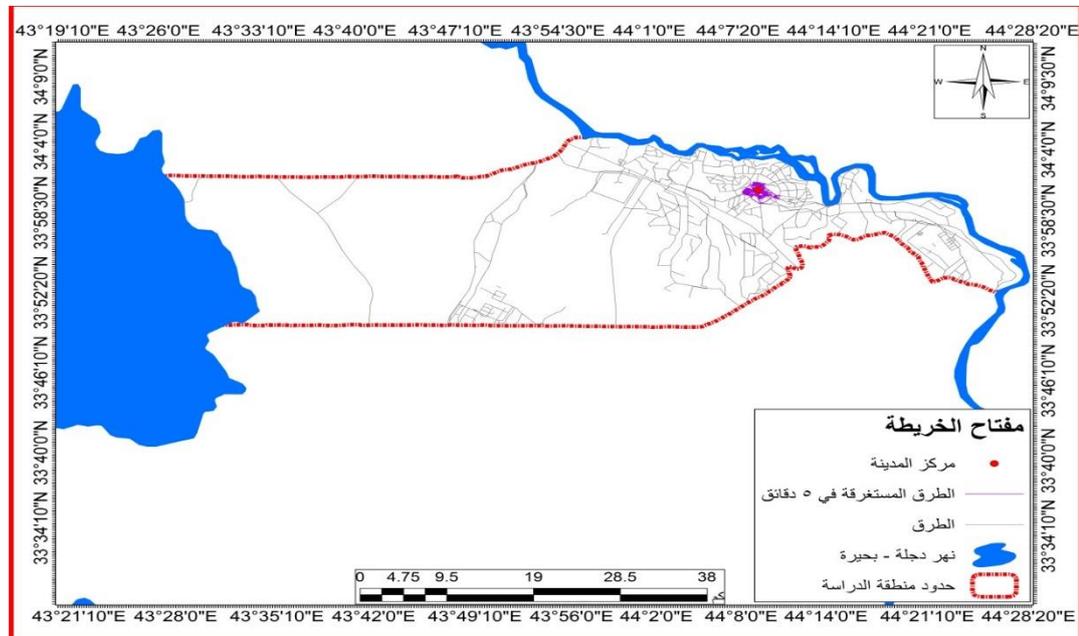
Accessibility:

Accessibility refers to the ease of reaching a particular location, which may be measured in terms of travel time, distance, or other impedance factors within the network.

Evaluating Accessibility:

One of the simplest approaches to evaluate accessibility is by creating a buffer around a point. For example, one may identify the number of customers residing within a five-kilometer radius of a site using a circular buffer. However, this method does not reflect the *actual accessibility* when considering travel along the road network. The *service area networks* generated by the Network Analyst overcome this limitation by delineating the streets that can be reached within five kilometers of a location via the road network.

Once established, service area networks can be used to determine additional spatial relationships, such as identifying competing businesses located within a five-minute drive.

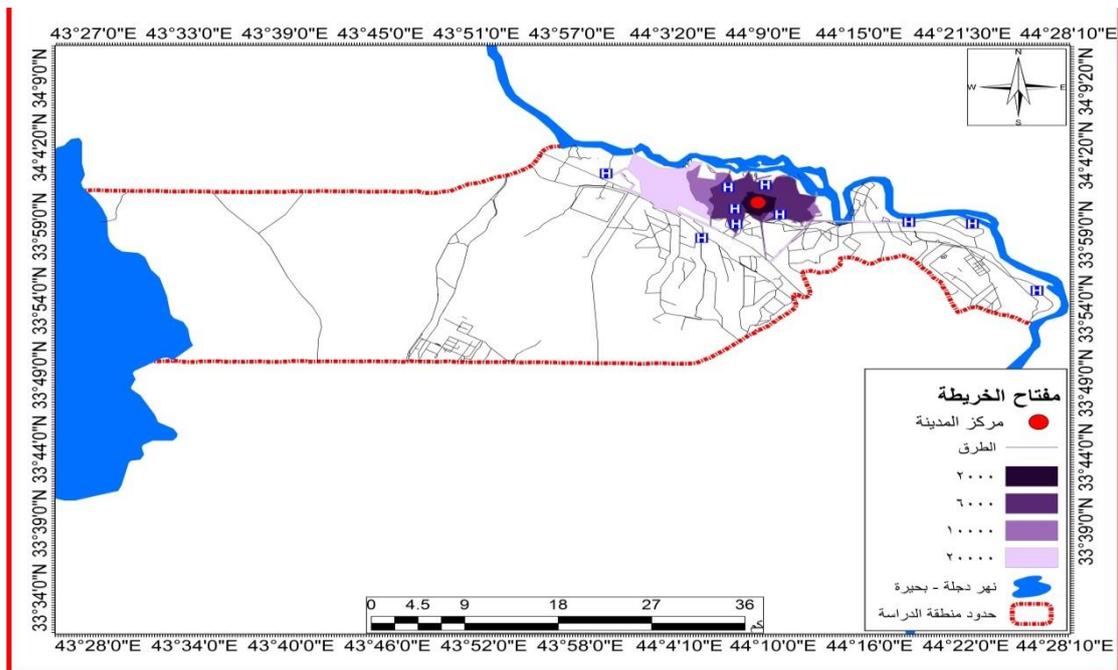


Source: Researcher's work, based on ArcGIS 10.4.1, Network Analyst tool for road network analysis, and data from the Directorate of Technical Planning, Salah al-Din Governorate, 2022.

Map 8. Five-minute travel time zones.

Service Area Steps:

Service areas, whether overlapping or multiple, illustrate how accessibility changes as impedances increase. For example, to demonstrate the number of hospitals accessible within 5, 10, and 15 minutes' drive from schools. By incorporating traffic data analysis, the set of hospitals that can be reached may change according to traffic conditions.



Source: Researcher’s work based on ArcGIS 10.4.1, Road Network Analysis, using the Network Analyst tool, and data from the Technical Planning Directorate of Salah al-Din Governorate, 2022.

Map 9. Service area lines in Balad District.

Table 1. Actual and straight-line distances, and the Detour Index of roads to the city center.

Detour Ratio %	Straight-line Length (m)	Actual Road Length (m)	Street Name	Seq
103.9	5319.7	5529.45	Al-Sayyid Mohammed St	1
104.7	883.97	926.39	Al-Areed St	2
118.9	963.86	1146.16	Shakhshid St	3
208.7	1979.75	4132.17	Aziz Balad St	4
144.1	544.47	785.01	Al-Nusour St	5
101.3	658.32	667.31	Al-Murabba St	6
100.1	182.46	182.65	Al-Muheet St	7
100.6	860.35	866.04	Municipal Council St	8
100.2	528.66	530.03	Al-Makhadher Market St	9
102.3	335.26	343.29	Behind Garage St	10
100	449.45	449.46	Al-Banzikhana St	11
100	873.75	873.86	District Administration St	12
201.2	579.42	1166.34	Second Association St	13
100.8	373.25	376.56	Second Association St	14
100	485.49	485.69	Al-Hussein Quarter St	15
102.5	1651.39	1693.19	Al-Furat St	16
108.5	6558.85	7120.93	Al-Khan St	17
106	6621.82	7022.56	14th Ramadan St	18

101.1	3778.98	3822.52	Balad-Duluiya Rd	19
103.1	3672.23	3787.43	Aziz Balad St	20
28.6	29720.78	8513.69	Samarra-Balad Rd	21
100	562.6	562.61	Municipality St	22
100	555.54	555.55	Al-Muhkam St	23
127.1	2286.2	2907.58	Al-Hawli St	24
101.8	10093.43	10278.17	Balad-Yathrib Rd	25
115.7	16969.81	19641.7	Yathrib-Sindiya Rd	26
116.8	17346.7	20267.26	Al-Qa'ida Rd	27
109.9	9122.38	10033.87	Sayyid Ghareeb Rd	28
100	8848.27	8850.22	Balad-Baghdad Rd	29
100	1691.62	1691.63	Al-Ishaqi Rd	30
121.6	62593.8	76147.3	Tharthar Rd	31
1022.3	5932.46	60649.9	Samarra-Balad Rd	32

Source: Researcher's work and spatial analysis using Geographic Information Systems (ArcGIS 10.4.1).

4 - OD Cost Matrix for Organizational Development:

Using Network Analyst, a table can be generated showing the network impedances from each origin to each destination. In addition, the tool ranks the destinations connected to each origin in ascending order based on the minimum network impedance required from that origin to each destination. Thus, the best network path is discovered, and the cost is stored in the attribute table of the output lines. Although the lines are straight for performance purposes, they always store the network cost rather than the direct distance. The chart below illustrates the results of the OD cost matrix analysis that determined the travel cost to reach the four nearest destinations from each origin.

5 - Accessibility According to Link Lengths Between Nodes (Distance):

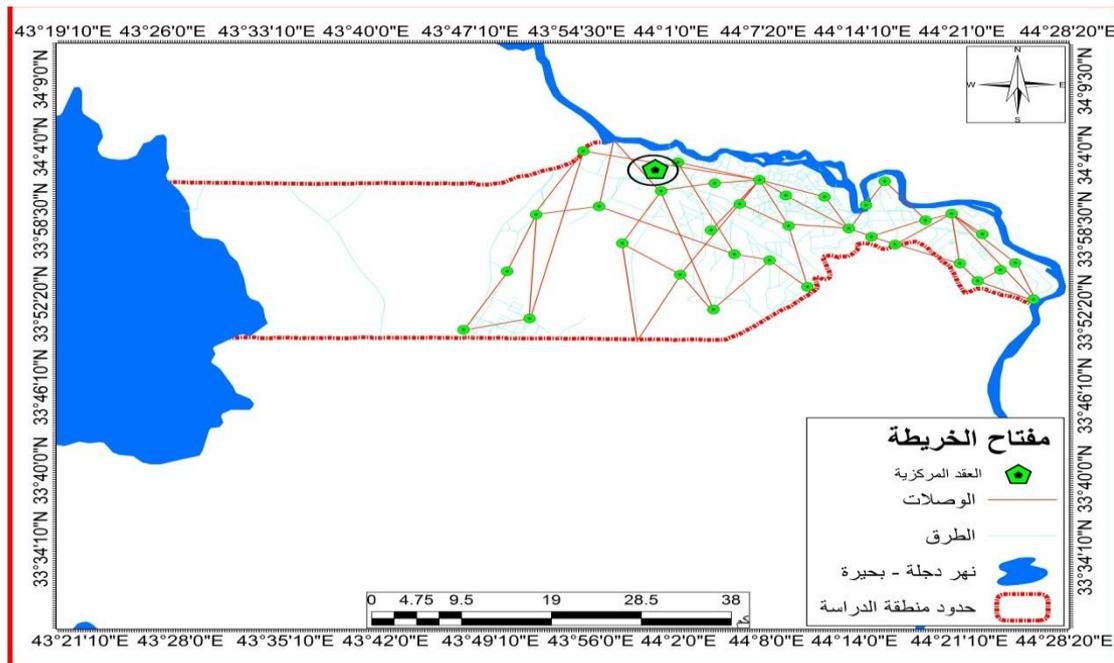
There is no doubt that distance is an important criterion in highlighting the degree of accessibility between any two nodes on the road. The shorter the distance, the easier the accessibility, and vice versa. To calculate this variable, road lengths are shown in the matrix, and then nodes are ranked according to accessibility.

The node that is connected to other nodes through the shortest cumulative distance is the most accessible within the network. The matrix shown in Table 1 demonstrates the role of distance in determining accessibility levels between nodes, with the highest accessibility recorded for Al-Ishaqi and the lowest for Yathrib. Accessibility increases with the reduction of distance regardless of other factors that may be equally important, such as geopolitical conditions, availability of road services, natural environmental conditions, or road characteristics.

Under stable circumstances, the Al-Ishaqi node ranked first because the total distances separating it from all other study nodes were the shortest. This is due to its central geographic location within the city, where urban growth has not expanded evenly in all directions due to settlements. Additionally, population density played a significant

role in making Al-Ishaqi the most accessible, as most nodes are connected to it through shorter distances.

This, however, does not diminish the importance of the city center node, which remains a vital transportation hub providing administrative, financial, commercial, and health services, as well as access to the tourist area. Despite ranking third, the city center plays a key functional role. Al-Ishaqi sub-district came second, while Aziz Balad ranked last due to its location in the far northeast of the city, requiring long travel distances from other nodes.



Source: Researcher's work using ArcGIS 10.4.1, Network Analyst tool, and data from the Directorate of Technical Planning, Salah Al-Din Governorate, 2022.

Map 10. Central node according to the number of connections in Balad District (Al-Ishaqi Sub-district).

6 - Network Connectivity:

Connectivity measures determine the type and degree of integration within the transport network. Connectivity analysis begins with converting the road network into a topological structure, through which the type and connectivity of the network can be identified.

Types of networks (Kansky classification):

Types of Networks: Road networks take linear forms composed of a number of links and nodes. By analyzing the nodes and links in the topological structure of a road network, the type of network in a district can be determined. Kansky identified four types of networks: null network, fragmented network, connected network, and fully connected network.

The results of the topological analysis indicated that the transport network in Balad District is connected; it is more than fragmented but less than fully connected. However, the previous description lacks precision in expressing the degree of network connectivity and comparing it with other variables. Therefore, Kansky proposed several quantitative indicators to measure network connectivity, including the Alpha, Beta, Gamma, and Linkage indices. a) Beta Index:

a. Connectivity Degree:

The connectivity degree in a network refers to the extent of interconnection among the network's nodes through the existing links. It reflects the level of development reached in the area. Connectivity in a network is measured using several indices, all agreeing that an increase in the number of links corresponds to a higher degree of connectivity among the network nodes.

In the urban transport network of Balad District, a set of quantitative indicators is applied to analyze connectivity, including the Beta Index, Gamma Index, Alpha Index, and the Presumption Link [7].

1. Application of the Beta Index in Connectivity Analysis:

The Beta Index is applied using the following formula:

$$\text{Beta Index} = \{\text{Number of Links}\} / \{\text{Number of Nodes}\} = 85/33 = 2.57$$

The value of this index ranges between 0 and 1. A value of 0 indicates that the network consists only of nodes with no links, which can be described as a null transport network. A value of 1 indicates a fully connected network, while values greater than 1 suggest the presence of multiple integrated and advanced networks.

Applying this formula to the transport network in the study area yielded a Beta Index of 2.57, indicating a strong degree of connectivity and the existence of more than one integrated network. However, this index is mainly suitable for simple networks without overlapping lines in a compact urban area, and therefore it is not considered the primary measure for evaluating connectivity in the district's network.

2- Application of the Gamma Index to Analyze Network Connectivity:

The connectivity of the transport network in the district is assessed using the Gamma Index with the following formula:

$$\text{Gamma Index} = \text{Number of links} / \text{Number of nodes} - 2 = 0.93$$

This index quantitatively describes the connectivity of the network. Its values range from 0, indicating a completely disconnected network, to 1, indicating a fully connected network. The analysis results for the Balad city transport network show a Gamma Index of 0.93, indicating that the network is nearly fully connected. However, the actual number of existing links in the city does not reach the maximum possible number required to connect all residential clusters efficiently, meaning the network is not perfectly connected.

Application of the Alpha Index to Analyze Network Connectivity:

The Alpha Index represents another method for analyzing the degree of connectivity in transport networks. It measures the relationship between the number of closed loops in the network (cycles) and the maximum possible number of links in the

network. The index ranges from 0 to 1, where 0 indicates no connectivity, and 1 indicates the maximum possible connectivity.

The Alpha Index for the transport network is calculated using the following formula:

Alpha Index = $\frac{\text{Number of links} - \text{Number of nodes} + \text{Number of lateral}}{3(\text{Number of nodes} - 5)}$

$$\text{Alpha Index} = \frac{85 - 33 + 2}{3(33 - 5)} = 0.64$$

This result indicates that the connectivity of the road network for the residential clusters (nodes) in Balad city is moderate according to this index. Additional links are required to reach maximum connectivity, meaning that new roads should be established to connect suburban areas and achieve comprehensive coverage across the city.

Application of the Connectivity Ratio in Transport Network Analysis:

The connectivity ratio is calculated to determine the degree of interconnection within a network. It compares the actual number of existing links in the network with the maximum possible number of links that could exist. The formula is as follows:

Connectivity Ratio = $\frac{\text{Current number of links}}{\text{Maximum possible number of links}}$

Where the maximum possible number of links is calculated as:

$$\text{Maximum links} = \frac{n(n-1)}{2} \text{ where } n = \text{number of nodes}$$

$$\text{Maximum links} = \frac{33(33-1)}{2} = 528$$

$$\text{Connectivity Ratio} = \frac{85}{528} = 0.16$$

The analysis shows that the connectivity ratio of the Balad transport network is 0.16, which is low. This indicates that the degree of interconnection between the network's nodes is weak, as most nodes are not directly connected to all other nodes, and the actual number of links is far below the maximum possible number.

7 - Centrality:

The Koenig Index is considered one of the most effective indicators for measuring the centrality of urban nodes in any road network. This index can be calculated for any urban node based on the maximum number of connections leading to the farthest urban node via the longest path within the network. The urban node with the lowest index value is regarded as the most central node in the transport network of the study area.

Table 1, previously mentioned, illustrates the centrality of different nodes in the road network of Balad according to the Koenig Index. The table shows that the city center is the most central transport node, ranking highest in the network in terms of connectivity efficiency with other nodes in the city. Its geographic centrality among the network nodes reduces the number of connections required from all directions, thereby facilitating access to and from it. Consequently, it serves as the main hub of urban movement, acting as a gathering point for residents and a key focal point for social, cultural, and other services.

8 - Network Spread:

This indicator allows for determining the degree of road network dispersion, including the spacing, proximity, or spread between urban nodes, based on the length of

individual links within the network. The road dispersion can be calculated using the following formula:

Eta Index = Total length of the network / Number of links = 1,351 / 85 = 4.13 km per link

When applying this index to the roads of Balad, the Eta Index was found to be 4.13 km per link, indicating that the link lengths within the city are relatively short. This provides a clear understanding of the closeness between residential clusters and the short distances separating them.

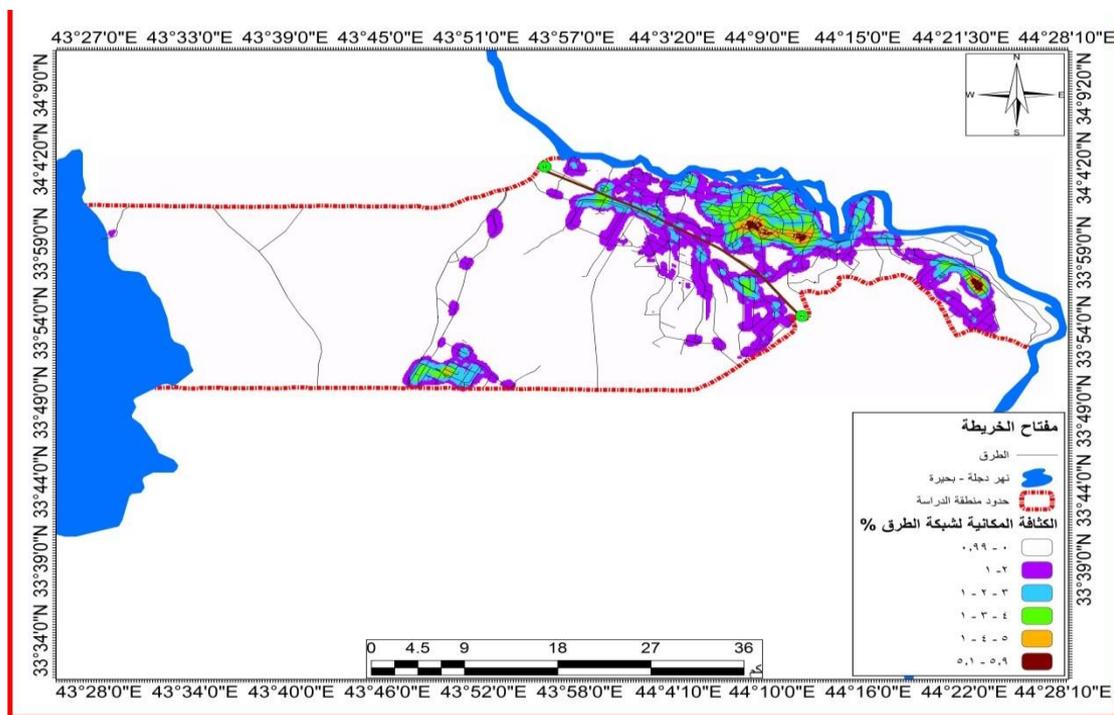
9 - Network Density:

The road network density is considered one of the key indicators reflecting the economic development of countries or cities and provides an idea of the adequacy of the network within a city or country. It is one of the simplest quantitative measures and is expressed in terms of the total network length relative to the area or population. The calculation can be expressed as follows [8]:

a. Network density by area = Total length of the city's road network (km) / City area (km²)

$$\backslash = 1,153 / 25.7 = 13.6 \text{ km/km}^2$$

By applying this formula, the road network density in the city was found to be 13.939 km/km². This is considered high, due to the relatively small area of the city, which limits horizontal expansion. This density exceeds that of developed countries, where it averages 10.7 km/km², and is significantly higher than in developing countries, where it ranges between 3.4 km/km² [9].



Source: Researcher's work using ArcGIS 10.4.1, Network Analyst tool, and data from the Directorate of Technical Planning, Salah Al-Din Governorate, 2019.

Map 11. Spatial Density of the road network in Balad District.

b. Network density by population (service) = Total length of the city's road network (km) / City population × 1,000

$$\backslash = 202,172 / 351.1 = 1.7 \text{ km} / 1,000 \text{ inhabitants}$$

Measuring density at the population level provides a more accurate and meaningful indicator than the previous area-based measure, as the population represents the actual users of the network, the primary consumers of economic resources, and the main drivers of commercial activity [10], [11], [12], [13], [14], [15].

By applying this formula, the road density was found to be 1.7 km per 1,000 inhabitants. This is considered low compared to cities in developed countries, where it reaches 4.96 km per 1,000 inhabitants, but relatively high compared to cities in developing countries, where it averages 0.4 km per 1,000 inhabitants.

CONCLUSION

Fundamental Finding : The study area is located between the latitudes 37°44'48" N and 37°71'61" N and longitudes 48°11'24" E and 49°49'25" E, covering an area of 2,161.34 km², equivalent to 592,145 dunums. The fastest route from point (A) to point (B) has been identified. Overlapping and multiple service areas illustrate how accessibility changes with increasing impediments. For example, they can show the number of hospitals reachable within 5, 10, and 15 minutes by car from schools, and accessibility may vary due to traffic conditions. Once created, service networks can be used to determine which streets are accessible – for instance, identifying competing companies within a 5-minute drive. **Implication :** Provide political will to support an intelligent transportation system. Allocate an adequate budget to ensure the continuity of the project. Establish traffic control centers responsible for monitoring and managing traffic remotely. Create a public database containing information on vehicles on the road as well as details of their owners. Develop awareness programs to educate the public on the system's importance and encourage the use of public transport buses to reduce individual car pressure and facilitate traffic management. Implement a camera system to monitor roads, detect vehicles exceeding speed limits, and enforce instant fines. **Limitation :** Accessibility may vary due to traffic conditions, and overlapping and multiple service areas illustrate how accessibility changes with increasing impediments, which indicates that real-world applications are subject to unpredictable variables beyond static mapping. **Future Research :** Future research could explore how intelligent transportation systems integrate real-time traffic data into service area analysis and the development of predictive models. It could also examine how the establishment of traffic control centers and the implementation of camera systems influence long-term transportation efficiency and public adoption of alternative transport modes.

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