Article

Determining the Access routes to Kirkuk University and Kirkuk Technical College using GIS-Based Network Analysis

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Abstract: The large number of staff and students at Kirkuk University and Kirkuk Technical Engineering College turn the University to the most crowded place in the City, causing traffic jams on nearby roadways. Remedies to reduce travel time to and from these focal points to the rest of the city must be found. The purpose of this study is to conduct network analysis of the roads in the study region (Kirkuk city), to determine the optimum routes to reach Kirkuk University and Kirkuk Technical College. The findings of the study of 6 designated routes from 6 sectors of the city of Kirkuk to reach Kirkuk University and Kirkuk Technical Engineering College indicate that travel time vary depending on the distance between each sector and the destination point. Scenario 6 has the shortest travel time of 4.97 minutes, cutting a distance of 5.168 km, Scenario 2, instead, has the longest travel time with 13.97 minutes for a distance of 12.892 km. Scenarios 1 and 3 have the same travel time of 13.61 minutes despite having different distances of 13.053 km and 10.559 km, respectively. The analysis of the remaining two scenarios show that scenario 4, has a travel time of 8.73 minutes with a distance of 8.179 km, while scenario 5 has a travel time of 9.02 minutes with a distance of 8.134 km.

Keywords: Network Analysis, Travel Time Cost, Accessibility Area, GIS

1. Introduction

Traffic jams take place every day and start early on all the routes connecting the University and the technical college to the rest of the City of Kirkuk.[1][2] People use private and public transportation means to travel, including cars and buses. Traffic congestion causes long delays for the staff and students in their efforts to reach their destinations. Arriving on time and at a reasonable cost is one of the most basic needs of individuals. Individuals, government agencies, and companies are affected by transportation issues. Therefore, Finding appropriate solutions to solve this problem becomes very important.[3] GIS can help to solve such problems by using network analysis. Appropriate analysis by Geographic Information System is critical to help us to reach our destination with ease, Shrinking Costs, Time, and other problems created by traffic jams .[4][5] The particular situation of network analysis known as spatial network analysis involves nodes representing locations in the real world and, optionally, connections with geometry .[6] The most efficient route is the one that uses the least amount of impedance while operating. Any measurable value, including time, distance, money, and so on, can be an impedance.[7]

This study aims to develop a network analysis of the roads of the study area (Kirkuk city), which leads to the finding of the best routes resulting in the optimum time usage for the arrival to Kirkuk Technical College and Kirkuk University.[8][9] In addition, it intends to create a geographical database, aiming to properly produce the existing sectors in the city of Kirkuk as well as the transportation network by integrating the different road entities.[10] Moreover, the produced network analysis map for several locations in Kirkuk sectors solves the problem.[11]

Study area

Kirkuk is the capital city of the province of Kirkuk.[12] A major urban centre of the northern Iraq. Located at longitudes 44°18′ E to 44°26′ E and latitudes 35°23′ N to 35°32′ N and with an area of 96.79 km2 that makes Kirkuk the 5th largest city in Iraq in terms of area 35°32′ N with area about 96.79 km² . Kirkuk has a multi-ethnic population of about 900,000 people, according to the 2014 census. [13] Kirkuk is a city that was subjected to drastic urban development during the 20th century due to its strategic location within the country and its richness in energy resources such as oil and gas.[14][15] Figure (1) shows the study area and its location within the country of Iraq [16].

Kirkuk University and the Kirkuk Northern Technical College are located in the Sayada area, in the southwest part of Kirkuk city, at the left-hand side of the main entrance to the city from the South-eastern side.[17]

Figure 1. The study area (Kirkuk City

2. **Materials and Methods**

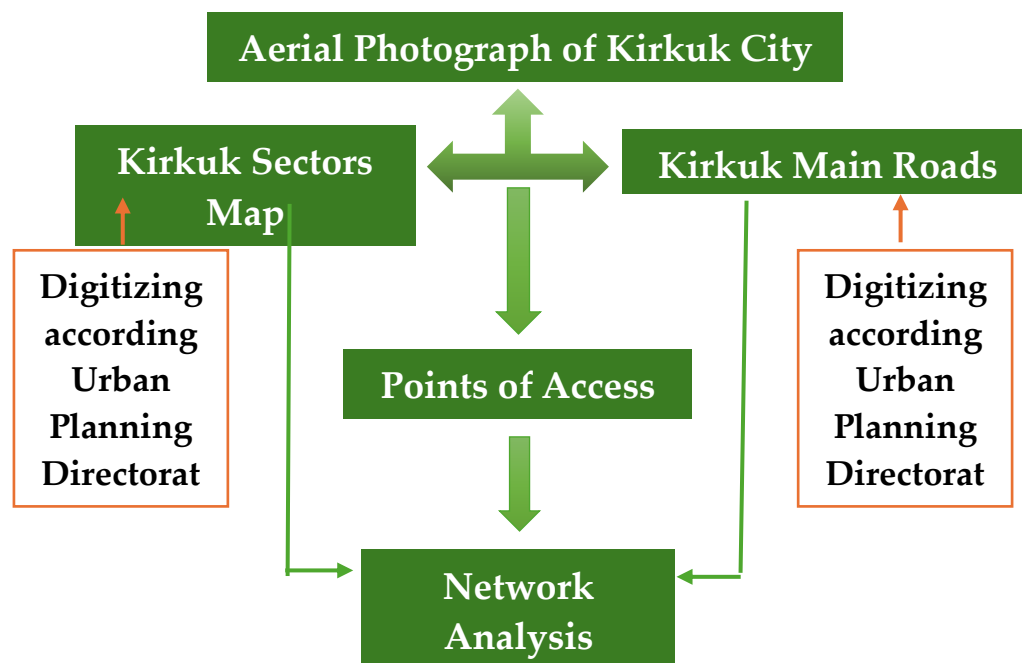The overall methodologies are illustrated in figure (2):

Figure 2. Flowchart of the overall methodology

Data used

In this study, three types of data were used:

Kirkuk sectors map: According to the Urban Planning Directorate of Kirkuk City, it contains seven sectors, and this information is used to produce the sectors map of Kirkuk.

Aerial photograph: Aerial photograph from the year 2016 obtained from Kirkuk governorate.

Information about University population in Kirkuk city: Addresses in the city were collected after obtaining the approval of the University of Kirkuk and Technical College of Kirkuk from the students themselves, and their databases in the colleges.

Network dataset in ArcMap GIS

Basic network knowledge can be useful for understanding transmission network analysis. A network is a set of lines connected to a set of vertices (Oliveira & Gama, 2012). GIS stores these edges and intersection features with their own . Spatio-temporal networks show the difference of topology and information over time . They are very important for many applications including emergency traffic management and route optimization . GIS tools and Remote Sensing data have been extensively, used for planning and analyzing in fields such as environment, economy, and management to make important planning decisions . GIS network analysis has its origins in the mathematical sub-disciplines of topology and graph theory . The important link between network and graph theory is topology. Topological attributes such as chance, connectedness, and neighborhood are keys to network analysis . A significant benefit of a GIS-based network as opposed to graph theory is the geographic factors of length or shape. The length is necessary to calculate trip time . GIS use for network analysis is critical to improve emergency response guidance based on the information of trip time .

Curtin Network analysis is one of the most important areas of study and use in GIS Science. Hasnat, It's said that network analysis is an influential way in GIS to find the best path in the network. Networks are everywhere. Roads, railways, streams, pipelines, cables, and other phenomena that must be depicted and analyzed as a network. Networks are important to transport people and goods, communicating information, and managing energy and matter movement. As a result, the development of techniques is done to analyze most of these geographical phenomena.

Network analysis allows us to solve problems, for example locating the busiest routes, creating travel instructions, locating the nearest facility, and selecting service places depending on the time frame. There must be a network to make analysis on it. So, the second step is adding the layer of the network dataset to ArcMap. If the network is not created, it will need to be created. If the source features have been changed or the network properties referring to the source features have edited, there will be need to rebuild the network dataset. In this project, a network data set was implemented for the main roads in the city of Kirkuk according to the city sectors as shown in Figure (3).
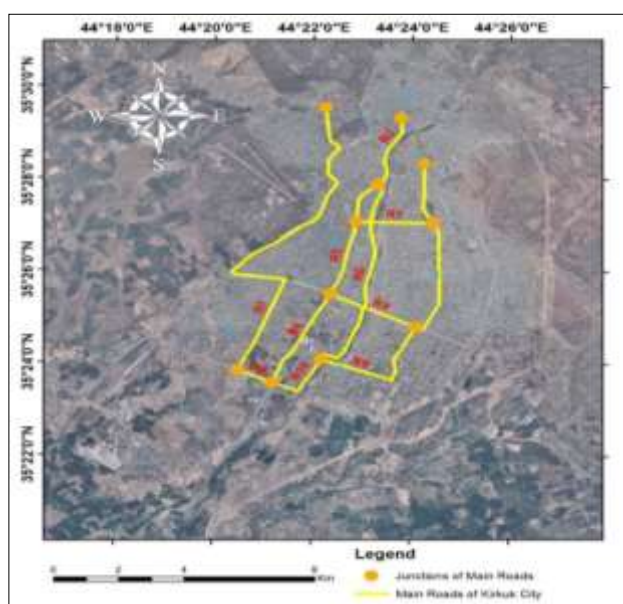

Figure 3. Main roads and their junctions of Kirkuk City

Shortest path analysis

The issue of the shortest path is to find the shortest route to travel from an origin in any direction in a network . Shortest path analysis is very important due to its broad applications in transportation . Finding the optimum route to get from one position to the other is accomplished by optimal routing, which uses the shortest path in its calculation . Users decide to choose the route, if it be short or fast . The shortest path is calculated for a known start time or for selecting start time and the way leading to the least trip time. The problem of the shortest path and locating the suitable path to steer vehicles in fixed road networks has been broadly investigated over the years . Developing efficient algorithms to compute the shortest path in a time-difference spatial network is difficult .

3.   Results and Discussion

The vector data structure, objects topology, and related qualities make vector data more difficult to collect than bitmaps, even though vector data structures are the main method of graphic data processing in the majority of GIS and CAD products. The methods used for obtaining vector data and their advantages and disadvantages are in the following.[18] Manual digitization has been widely used with a digital disk. This way, the user manually draws the stripes from the printed map using a pointer and creates a digital map . The digital line is the collection of a series of points along the line .[19] In spite of this method being straightforward, it needs the efforts of an experienced worker for long time (Vanegas et al., 2018). For a complex work, it may take 10-20 days for a person to complete the digital map of a contour map. Another main flaw of the last method is its low accuracy(reliability), depending, solely, on how accurately the computer-printed map copied by hand. One experiment was conducted at a university, and the same map is digitized and the final digital maps were placed over each other to create a new map . The produced map is, as expected; distorted in comparison to the original map. Most of GIS packages supports the manual digitizing with a link to tablets of digitizing through an I/O port in a computer.[20] In this work, the points of accessibility represented by the University of Kirkuk and Technical College were digitized, as well as the seven sectors of Kirkuk City as shown in figure (4).
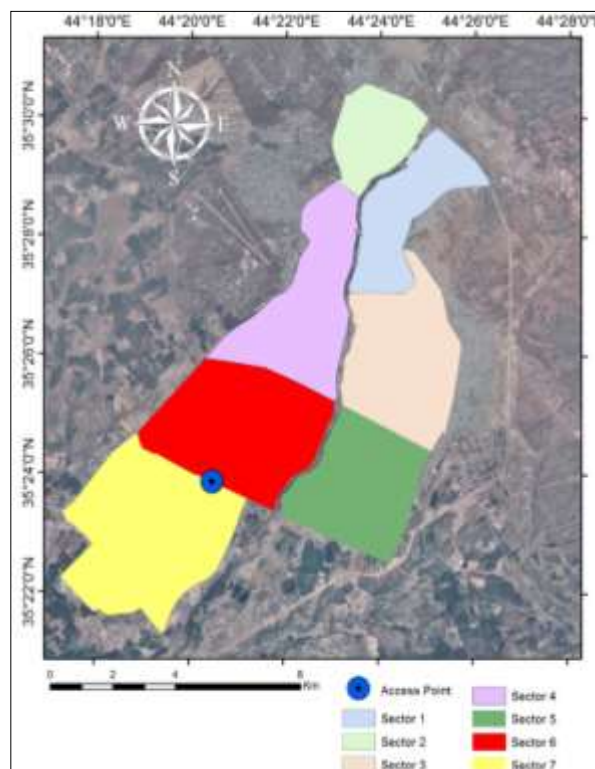

Figure 4. Main sectors of Kirkuk City

Network Analysis

Network characteristics

A network is a package of linear shapes through which resources flow. Nodes are used as origins and destinations and link lines Traverse between the nodes.[21] Nodes have importance but the most important elements are the characteristics of the links (De Winter et al., 2018), which include:

Length

Direction

Connectivity

Pattern.

A classification of networks is discussed by Laurini and Thompson (1992). They divided them, as illustrated in figure (5), to four kinds: -

a. Un- oriented

b. Oriented
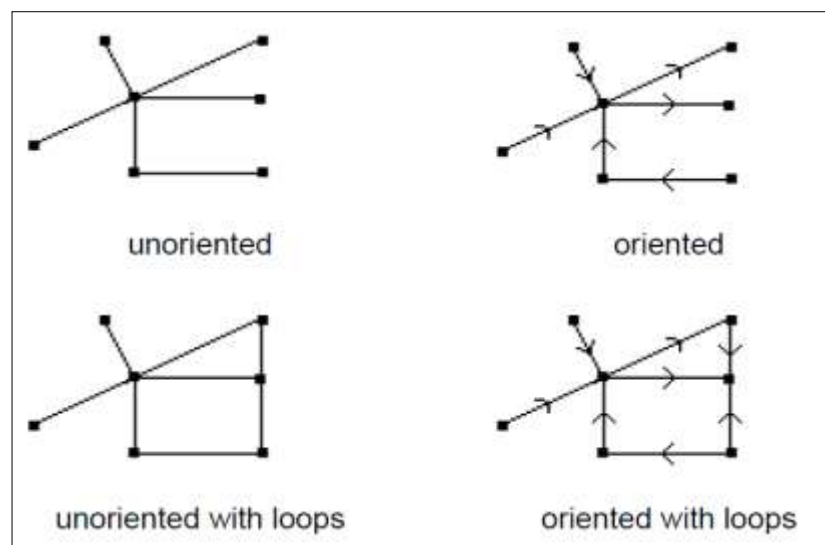
c. Un- oriented with loops

d. Oriented with loops.

Figure 5. A classification of networks

Scenario 1 of the Route Analysis

Scenario 1 is the analysis of the route run from Sector 1, located in the northeast of Kirkuk City, to the University of Kirkuk and Kirkuk Technical College situated in the southwest of Kirkuk City, as shown in figure (6). [22] This route contains R7, R3, R4, and R5 with a total length equal to 13.053 km. Travel time of this route is 13.61minutes.[23]
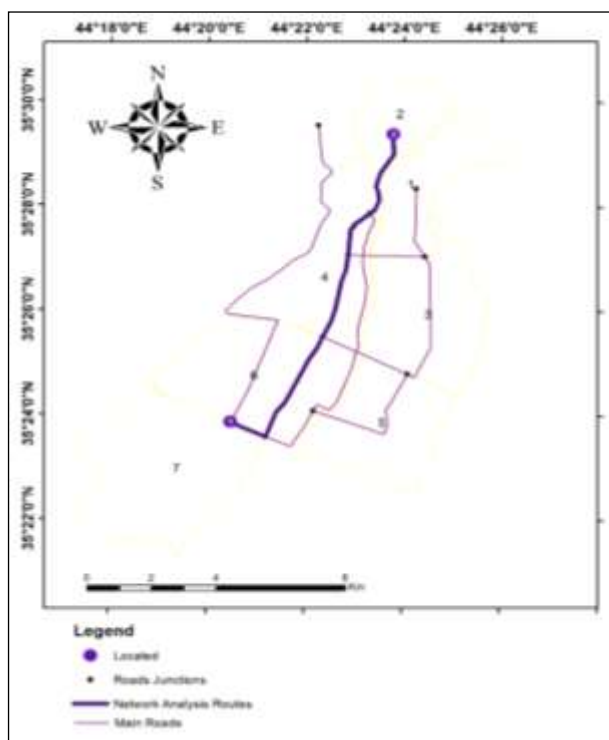
Figure 6. Route Analysis Scenario 1

Scenario 2 of the Route Analysis

Scenario 2 is the analysis of the route run from Sector 2, covering north of Kirkuk City, to the University of Kirkuk and Kirkuk Technical College located in the southwest of Kirkuk City, as shown in figure (7). [24] This route includes R2, R3, R4, and R5 with a total length of 12.892 km. Travel time registered for this route is 13.97 minutes
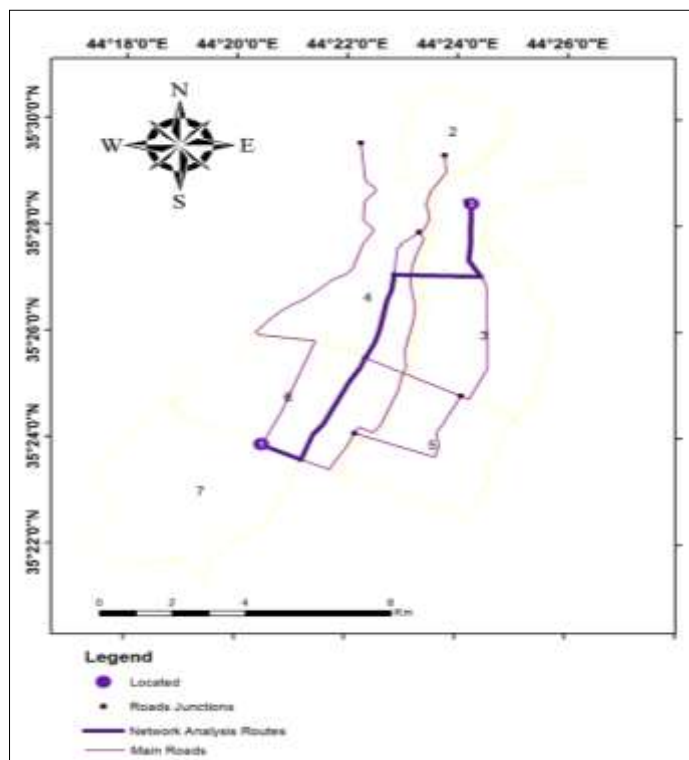

Figure 7. Route Analysis Scenario 2

Scenario 3 of the Path Analysis

Scenario 3 is the analysis of the path run from Sector 3, located west of Kirkuk city, to the University of Kirkuk and Kirkuk Technical College situated in the southwest of Kirkuk City, as shown in Figure (8). This track contains a portion of R7, R3, R4, and R5 with a total length of 10.559 km. Travel time for this route is 13.61minutes.[25]

Figure 8. Route Analysis Scenario 2

Scenario 4 of the Route Analysis

Scenario 4 is the analysis of the route run from Sector 4, covering the eastern middle of Kirkuk City, to the University of Kirkuk and Kirkuk Technical College located in the southwest of Kirkuk City as shown in figure (9). This route contains R3, R4, and R5 with a total length equal to 8.179 km. Travel time of this route is 8.73minutes.[26]
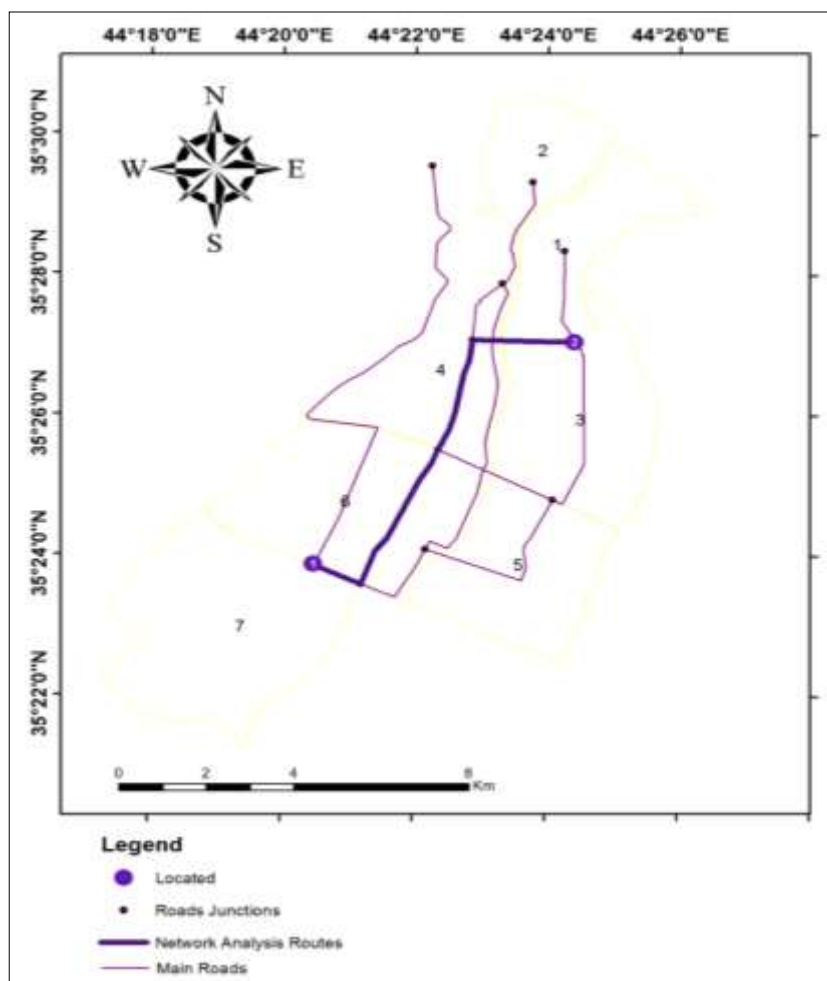
Figure 9. Route Analysis Scenario 4

Scenario 5 of the Route Analysis

Scenario 5 is the analysis of the route run from Sector 5, located at the southeast of Kirkuk City, to the University of Kirkuk and Kirkuk Technical College located in the southwest of Kirkuk City, as shown in figure (10).[27] This route contains R9, R10, and R5 with a total length equal to 8.134 km. Travel time of this route is 9.02 minutes.[28]
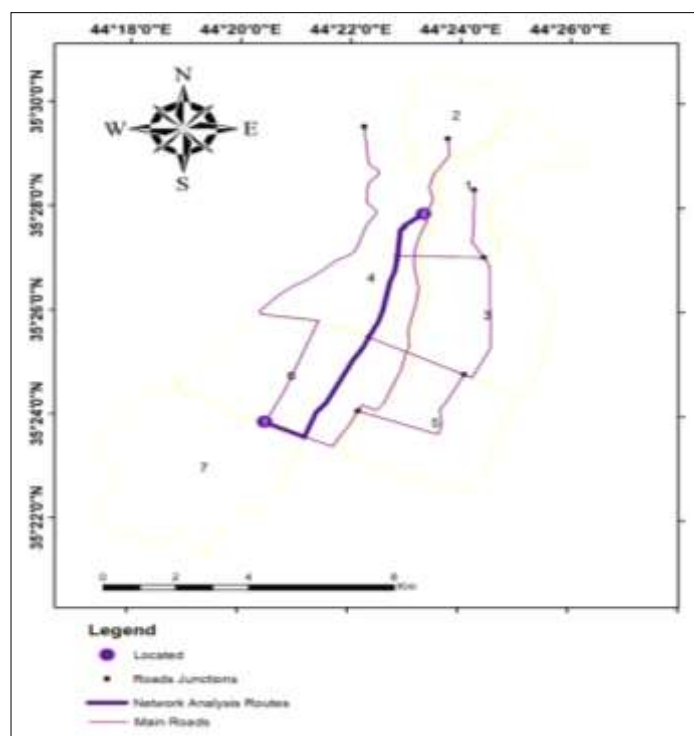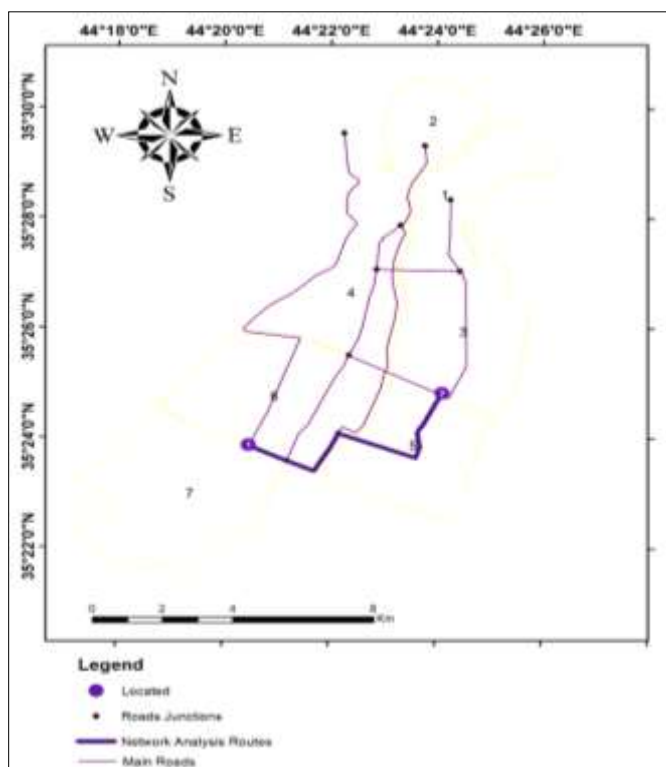

Figure 10. Route Analysis Scenario 5

Scenario 6 of the Route Analysis

Scenario 6 is the analysis of the route run from Sector 6, located in the southwest of Kirkuk City to the University of Kirkuk and Kirkuk Technical College situated in the southwest of Kirkuk City, as shown in figure (11).[29] This route contains R4and R5 with a total length equal to 5.168km. the travel time cost of this route is 4.97 minutes.Table 1
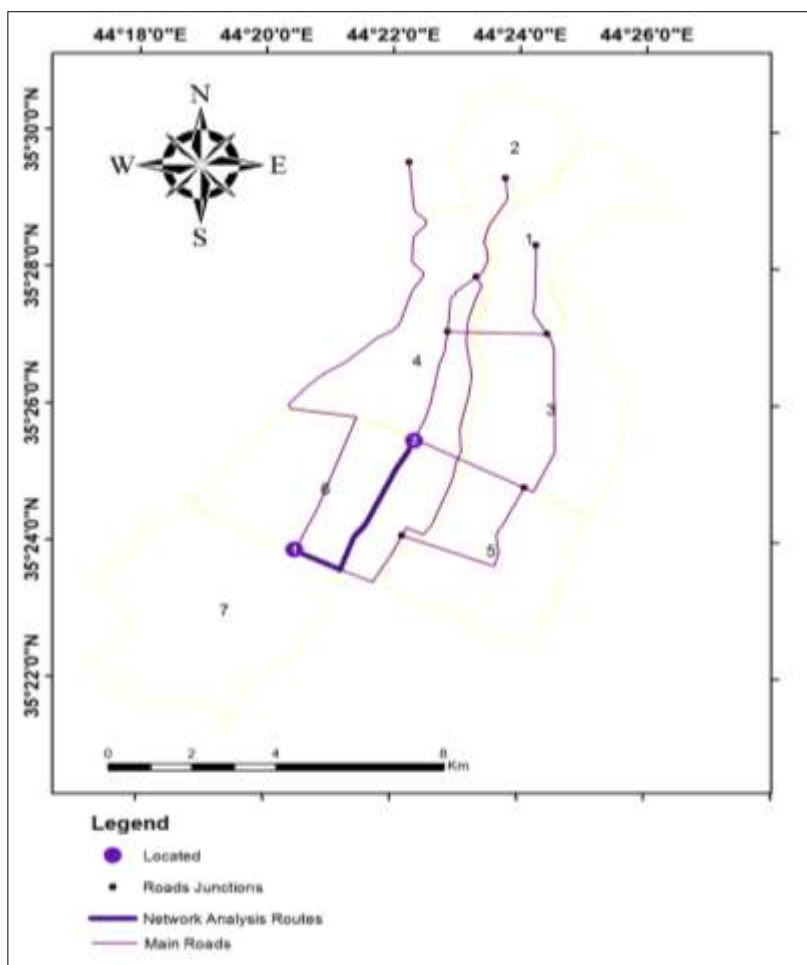

Figure 11. Route Analysis Scenario 6

Table 1. The lengths of all roads of the Network of Kirkuk City

Road Name	Distance in Kilometer
R1	13.93861
R2	4.71319
R3	3.01129
R4	3.98206
R5	1.18606
R6	7.98094
R7	4.87406
R8	7.59569
R9	4.65473
R10	2.29375

Table 2. The Travel Time Cost (T.T.C) for all roads of the Network of Kirkuk City

Name	The Travel Time Cost (T.T.C) in minutes											
	T.L (m)	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Total of T.T.C
Route 1	1305.47	0	0	3.764	3.982	0.988	0	4.874	0	0	0	13.608
Route 2	12892.6	0	5.237	3.764	3.982	0.988	0	0	0	0	0	13.971
Route 3	10559.81	0	0	3.764	3.982	0.988	0	4.874	0	0	0	13.608
Route 4	8179.41	0	0	3.764	3.982	0.988	0	0	0	0	0	8.734
Route 5	8134.54	0	0	0	0	0.988	0	0	0	5.172	2.867	9.027
Route 6	5168.12	0	0	0	3.982	0.988	0	0	0	0	0	4.97

4. Conclusion

This project explores the use of public and private transit, including buses and taxis, as the travel mode for commuting to the University of Kirkuk and Kirkuk Technical College. The most important objective of this study is to conduct a spatial accessibility analysis of the University of Kirkuk and Kirkuk Technical College by bus and taxi transit.

The work displayed the spatial distribution of arrival to the University of Kirkuk and Kirkuk Technical College from different sectors of Kirkuk City. A method for quantifying the travel time usage (TTC) has been presented by the use of a GIS network analysis, with information containing spatial distances and times used to arrive at the University of Kirkuk and Technical College in Kirkuk from various sectors of the city. Hypotheses presented by the study can be quantitatively verified. The study helps decision-makers to choose how to get to the mentioned destination. The best performing results for this type of analysis can be obtained through combined and enhanced qualitative local data from different sources with different needs and perceptions of educational places. The results show that the path analysis of the study has 6 scenarios related to 6 sectors to the Kirkuk University and Technica l Engineering College. Travel times are different according to the distances between each sector and the destination point. The shortest travel time was recorded in scenario 6 concerned with sector 6 with a time of 4.97 min and a distance of 5.168 km, while the longest travel time of 13.97 minutes and a distance of 12.892 km was related to scenario 2 covering sector 2. Scenarios 1 and 3 have the same travel time with 13.61 minutes but with different distances of 13.053 km and 10.559 km, respectively. The route covered by scenario 4 has a travel time of 8.73 minutes with a distance of 8.179 km, while scenario 5 has a time of 9.02 minute along 8.134 km.

This project by merging network analyses by GIS with regression methods to socioeconomic information offers a general method to measure the quantity of the changes occurring in providing variety of goods and services such as education, health, and environment. It can be a start for another geographical analyses on a larger scale such as (regional and national) and a method to assess the spatial distribution of the access of various groups of communities concerned with issues such as deprivation, disability, occupation, economic activity, household tenure and types, age groups and health.

This study may benefit other discussions and research by illustrating the importance of GIS spatial analyses and its usefulness to the study of various socio-economic factors in order to expand access to a variety of community goods and services.

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