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Improvement of Transportation Network of Al-Muwaffaqiyah Town Using Gis

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Abstract

Al-Muwaffaqiyah Town lies on Wasit Governorate south east of Baghdad City. This town is divided into two sides by Al Gharraf River. The needing to travel between these two sides creates traffic concentration on the one existing bridge. Therefore, the construction of another bridge can help to improve the transportation network of this town.

Transportation planning process (find the best route) can be considered as a strategic, important and complex issue in the same time, due to collecting information and analyzing data to reach to the optimum network (journeys of shortest routes) in order to saves time, to reduce cost, fuel, noise, and air pollution.

By using GIS, the network can be analyzed and found the optimum route based on the shortest travel's time between origin and destination of journey by using the software's algorithm. Moreover, the ability of GIS to generate detailed directions along the route, providing as-you-need-it solutions for common problems.

An application of GIS tool can help to solve this problem. So Al-Muwaffaqiyah town is divided into 13 Traffic Analysis Zones (TAZ). The centered of each zone is obtained in order to compute the shortest time between each two zones.

The GIS algorithm divides the network into nodes (where lines join, start or end) and the paths between such nodes are represented by lines. In addition, each line has an associated cost representing the cost (length or time) of each line in order to reach a node. There are many possible paths between the origin and destination, but the path calculated depends on which nodes are visited and in which order.

Keywords: Geographic information systems, Network analysis, Al-Muwaffaqiyah Town.

تحسين شبكة النقل لمدينة الموفقية باستخدام نظم المعلومات الجغرافية

م. مها اسامة المميز
قسم الهندسة المدنية / الجامعة المستنصرية

الخلاصة :

تقع مدينة الموفقية في محافظة واسط جنوب شرق مدينة بغداد. نهر الغراف يقسم المدينة الى جانبين. ان الحاجة الى الانتقال بين جانبي المدينة ادى الى تركز المرور في الجسر الموجود حاليا. لذلك عملية انشاء جسر جديد يمكن ان تساعد على تطوير شبكة النقل في المدينة.

تعتبر عملية تخطيط النقل (اختيار افضل مسار) من المهام الستراتيجية و المهمة و المعقدة في نفس الوقت لما تتطلبه من جمع للمعلومات و تحليل البيانات للوصول الى الشبكة المثلى من حيث المسارات ذات الرحلات القصيرة لتوفير الوقت و بالتالي توفير الكلفة و الوقود و تقليل التلوث و الضوضاء.

باستخدام نظم المعلومات الجغرافية يمكن تحليل الشبكات و ايجاد احسن المسارات باعتبار اقل زمن للرحلة بين نقطة بداية و نهاية الرحلة من خلال خوارزمية البرنامج. بالاضافة الى امكانية البرنامج على توليد اتجاهات مفصلة على طول المسار.

ان تطبيق نظم المعلومات الجغرافية بامكانه المساعدة لحل هذه المشكلة، من اجل ذلك تم تقسيم مدينة الموفقية الى 13 منطقة. مركز كل منطقة تم تحديده من اجل حساب زمن الرحلة الاقل من مركز منطقة بداية الرحلة (المنشأ) الى مركز منطقة نهاية الرحلة (المقصد).

الخوارزمية تقسم الشبكة الى عقد (موقع ارتباط الخطوط، البداية و النهاية) و المسارات بين هذه العقد تمثل بواسطة خطوط. بالاضافة الى ذلك، كل خط له كلفة محددة تمثل اما بمسافة الخط او بالزمن المستغرق للوصول الى العقدة. يوجد عدد من المسارات بين بداية الرحلة و نهايتها، و لكن اقصر مسار يعتمد على اقل زمن للخطوط (اقل كلفة).

Introduction

The application of GIS to a diverse range of problems in Transportation engineering is now well established. It is a powerful tool for the analysis of both spatial and non-spatial data and for solving important problems of networking. Shortest path analysis is an essential precursor to many GIS operations (Advani et al., 2005) [1].

A GIS is a digital computer application designed for the capture, storage, manipulation, analysis and display of geographic information. Geographic location is the element that distinguishes geographic information from all other types of information. Without location, data are termed to be non-spatial and would have little value within a GIS. Location is, thus, the basis for many benefits of GIS: the ability to map, measure distances, and tie different kinds of information together because they refer to the same place (Longley et al., 2001)[2,12,13,14].

Transportation data encompasses a wide range of spatial data entities that are fundamental to many GIS and cartographic applications. Transportation data is normally considered a key element of base maps and serves as essential reference data in this context. Besides its role as reference data, transportation data is at the core of applications, such as emergency response, routing, urban and regional planning, public transport, municipal service provision and general purpose mapping (Rodrigue, 2005)[3].

In general, topics related to GIS studies in the field of transportation can be grouped into three categories (Rodrigue, 2005) [3]:

- Data representations.
- Analysis and modeling.
- Applications.

Data representation is a core research topic of GIS. Before a GIS can be used to tackle real world problems, data must be properly represented in a digital computing environment.

GIS integrate graphical user interfaces for data visualization with spatial databases. These systems allow the association of network elements to attributes like street names, lengths and traffic directions, among others, commonly used as input for location and transportation problems (Filho, et. al. (2006))[4].

Route location has been always used by common people in navigating from one place (origin) to another (destination). The using of GIS-Network Analysis software determines the best route by using an algorithm which finds the shortest path (least cost route). The algorithm divides the network into nodes (where lines join, start or end) and the paths between such nodes are represented by lines. In addition, each line has an associated cost representing the cost (length or time) of each line in order to reach a node. There are many possible paths between the origin and destination, but the path calculated depends on which nodes are visited and in which order (Karadimas et al., (2007)) [5].

Aim of the Study

The application of GIS to a diverse range of problems in transportation engineering is now well established. It is used for the analysis of both spatial and non-spatial data and for solving important problems of networking, so the main goals of this study are to:

1- Use ArcGIS 9.3 software to locate the optimum bridge location in Al-Muwaffaqiyah Town, which has congestion in the existing bridge.
2- For each zone in the left side, the generations of trips are determined, and then the shortest routes (minimum cost routes) between each zone in the left side to every zone in the right side are investigated using GIS-network analysis.
3- Locate the optimum bridge location to reduce congestion in the passing between the two sides of the town.

Network Representation

In GIS-Network Analysis software the network is made up of a series of points and lines connecting these points. The points, or network nodes, represent the intersections within the street system. The lines, or network links, represent the streets.

Network Analysis in GIS software uses the Dijkstra's Algorithm (Dijkstra 1959) [6] in order to find shortest path and it can be generated based on two criteria (Lakshumi et al 2006) [7]:

Distance criteria: The route is generated taking only into consideration the length of the links in the origin-destination trips. The volume of traffic in the roads is not considered in this case.

Time criteria: The total travel time in each road segment should be considered as the: runtime of the vehicle in each road segment. The runtime of the vehicle is calculated by considering the length of the road and the speed of the vehicle in each road. The volumes of traffic are taken into account in each road segment.

The other factors affecting on the selection of best route are accident factor, construction cost, residence displaced, city traffic, air quality, noise, trees removed, and runoff. For study area these factors have almost the same weights for all routes due to the same culture, terrain, and environment so for this study we focus only the travel time between all zones of study for choosing the best location for the bridge.

Using the time criteria, several routes could be generated during a random day in order to compare the total travel time between these predefined time intervals. Hence, routes could be generated during the day time or during the night time in order to compare the total travel time in these different time intervals during the day.

Dijkstra's algorithm is the simplest path finding algorithm, even though these days a lot of other algorithms have been developed. Dijkstra's algorithm reduces the amount of computational time and power needed to find the optimal path. The algorithm strikes a balance by calculating a path which is close to the optimal path that is computationally manageable (Olivera 2002) [8].

The algorithm breaks the network into nodes (where lines join, start or end) and the paths between such nodes are represented by lines. In addition, each line has an associated cost representing the cost (length or time) of each line in order to reach a node. There are many possible paths between the origin and destination, but the path calculated depends on which nodes are visited and in which order. The idea is that, each time the node, to be visited next, is selected after a sequence of comparative iterations, during which, each candidate-node is compared with others in terms of cost (Stewart 2004)[9].

The following comprehensible example, which is an application of the algorithm on a case of 6 nodes connected by directed lines with assigned costs, explains the steps between each iteration of the algorithm **(Figure 1).** The shortest path from node 1 to the other nodes can be found by tracing back predecessors (bold arrows), while the path's cost is noted above the node.

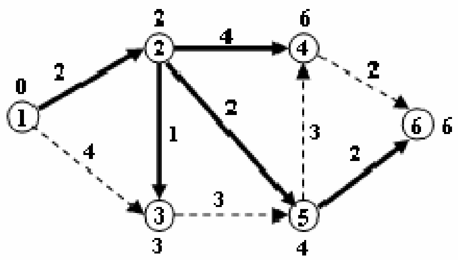

Fig .(1) An example of Dijkstra's algorithm (Orlin 2003) [10].

Study Area

A case study of Al-Muwaffaqiyah Town is choose for this study, it lies in Wasit Governorate, in the south east part of Al-Iraq; and the situation at Al Gharraf River's Channel, make it occupies a strategic planning concern, see **Figure (2).** 4 Km^2 is the total area of the town, divided by Al Gharraf River's Channel of about 1.35 Km long. There is one bridge in the town which suffers from heavy congestion so we need to a solution, three alternative bridge locations can help us to determine the optimum bridge's location.

the town of Al-Muwaffaqiyah is divided to 13 Traffic Analysis Zones (TAZ), 8 TAZs are in the left side and 5 TAZs are in the right side, as shown in **Figure (3),** the centered of each zone is obtained in order to compute the shortest time from the center of first zone (origin) to the center of second zone (destination), see **Figure (4).**

Al-Muwaffaqiyah City was subjected to many patterns of growth during the past decades; the land use of the town is shown in **Figure (5).** Significant commercial and residential developments have occurred for the past several years, which have increased traffic volumes on the study area's transportation system, and very significant additional development is expected to happen.

Abdjabbar, (2005) [11] reported that the TAZ define geographic areas which are mainly used to relate travel demand to socioeconomic characteristics. There are several basic principles which are used in selecting the boundaries of TAZs. The road network to be modeled is a prime consideration. The second consideration is that zones must be small enough to identify travel on important corridors. Geographic features frequently serve as natural boundaries of TAZs, reflecting a natural barrier to travel. The above principles establish guidelines for selecting TAZ boundaries. As may be expected, it is not always possible to satisfy each principle for every TAZ when modeling an actual transportation network.

Fig .(2) Study area, Microsoft Corporation Bing map (2013)

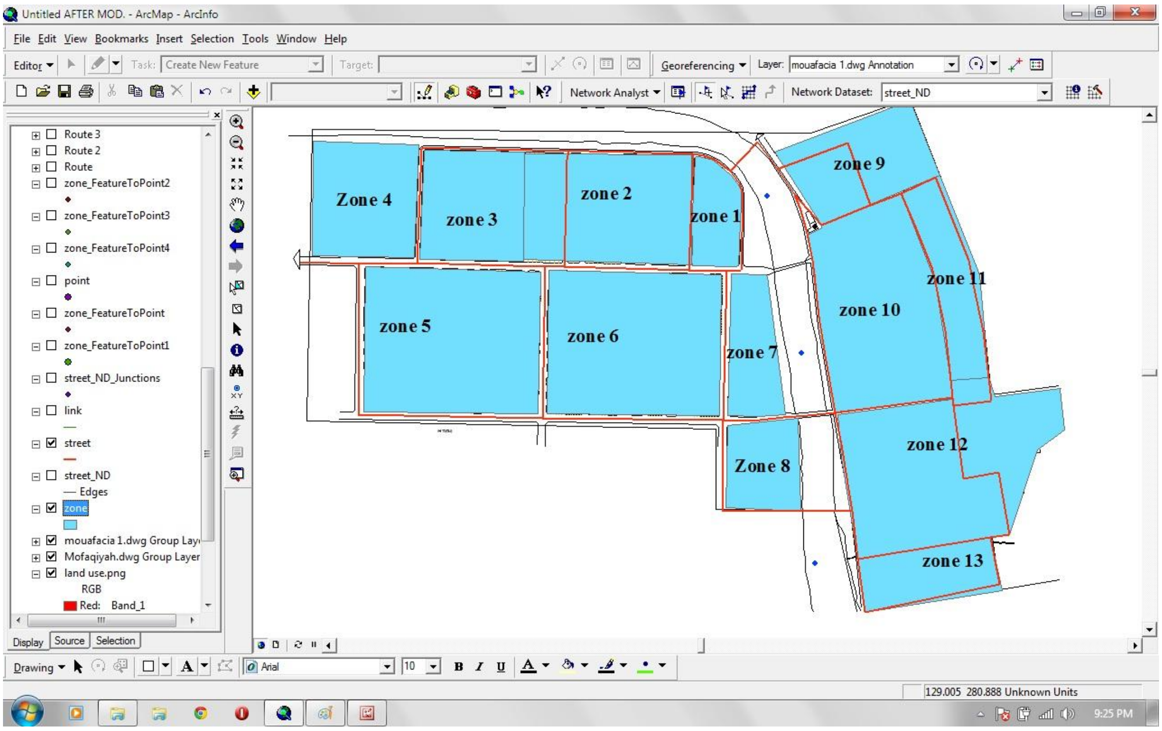

Fig .(3) Zones of Al- Muwaffaqiyah town

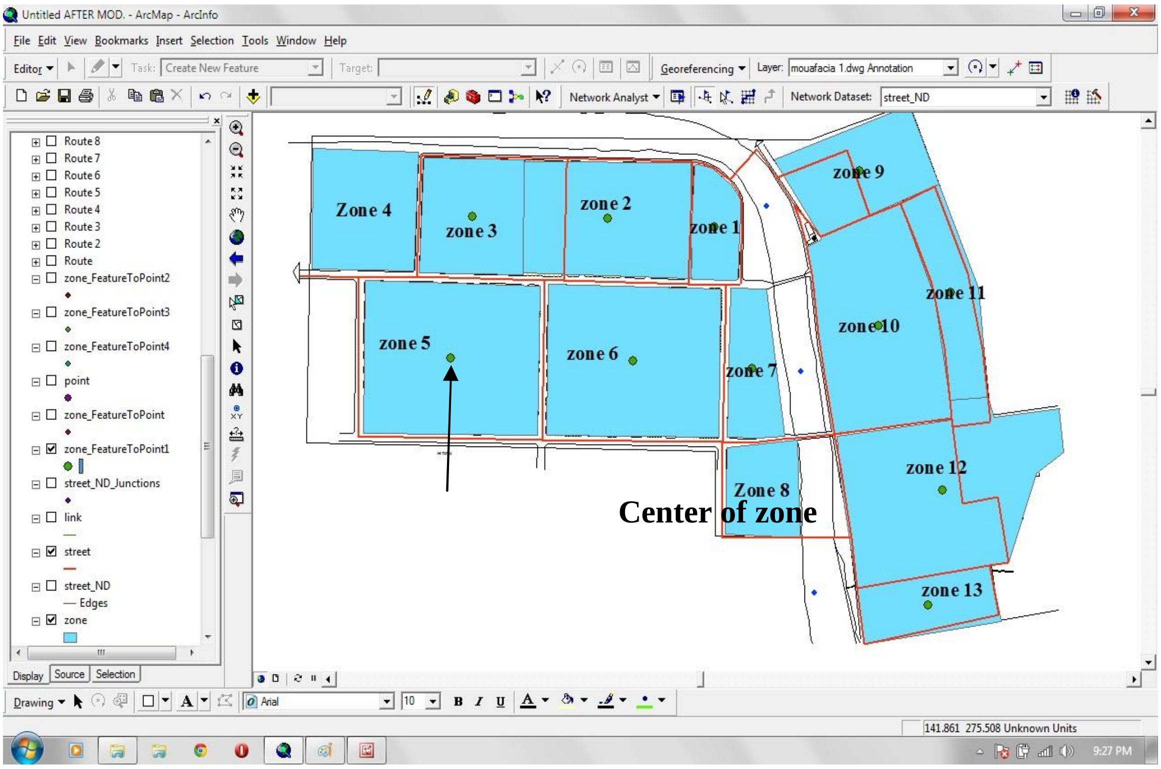

Fig .(4) Centered of zones in Al- Muwaffaqiyah town.

Fig .(5) Land use of Al- Muwaffaqiyah town.

Major Arterials in Al- Muwaffaqiyah town

The major arterials in the city are shown in **Figure (6)**

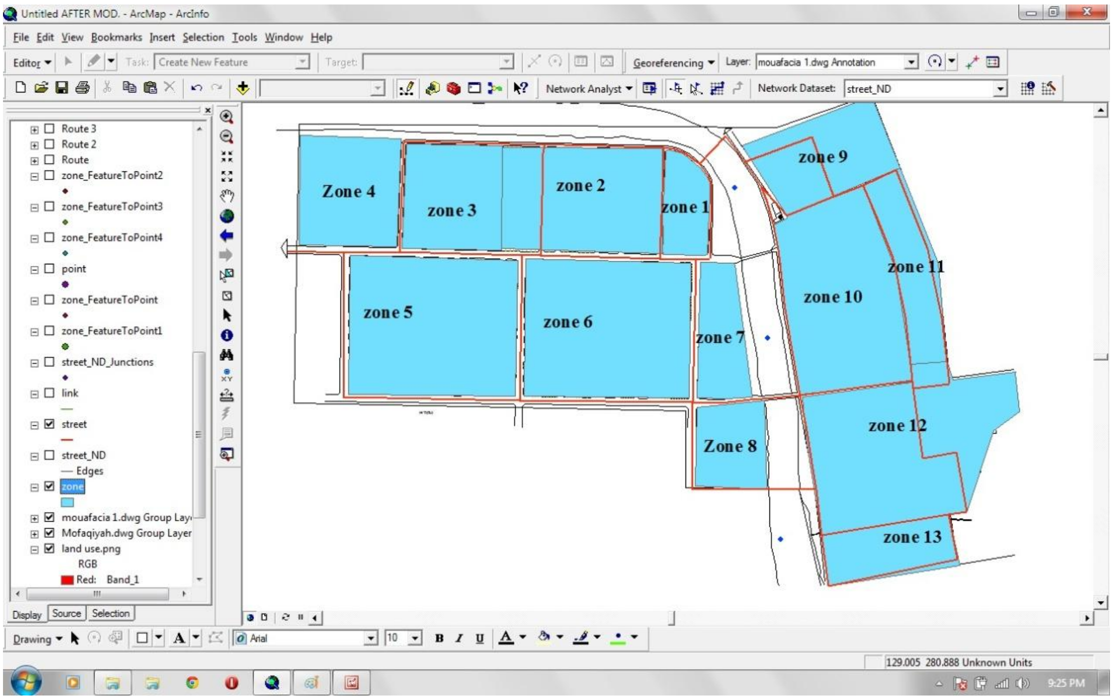

Fig .(6) Major arterials in Al- Muwaffaqiyah town

Research Methodology

GIS-Network analysis software determines the best route by using an algorithm which finds the shortest path, developed by Dijkstra, (1959) [6]**.** The algorithm breaks the network into nodes (where lines join, start or end) and the paths between such nodes are represented by lines. In addition, each line has an associated cost representing the cost (length) or (time) of each line in order to reach a node. There are many possible paths between the origin and destination, but the path calculated depends on which nodes are visited and in which order. The idea is that, each time the node, to be visited next, is selected after a sequence of comparative iterations, during which, each candidate-node is compared with others in terms of cost. Finding the best route can be generated based on two criteria Lakshumi, et. Al. (2006) [7]:

1- Distance criteria: The route is generated taking only into consideration the location of the O-D. The volume of traffic in the roads is not considered in this case.
2- Time criteria: The total travel time in each road segment should be considered as the: Total travel time in the route = runtime of the vehicle. The runtime of the vehicle is calculated by considering the length of the road and the speed of the vehicle in each road.

Here, in this study, the using of time criteria was choosed in order to determine the best route.

The volume of traffic is counted; morning peak is taken into account because it is higher from evening peak. The center of each zone is coordinated using GIS tool in order to compute the travel's time from the center of first zone (origin) to the center of another zone (destination).

As mentioned in the previous paragraph, the shortest travel's time are calculated between centers of zones. Wherever the arterials are not passing in the center of zone, the distance from the nearest point on arterial to the center of zones is pointed. Link is made to join nearest point on arterial to center of zone as shown in **Figure (7)** and the time of link is computed and added to time of route on arterial.

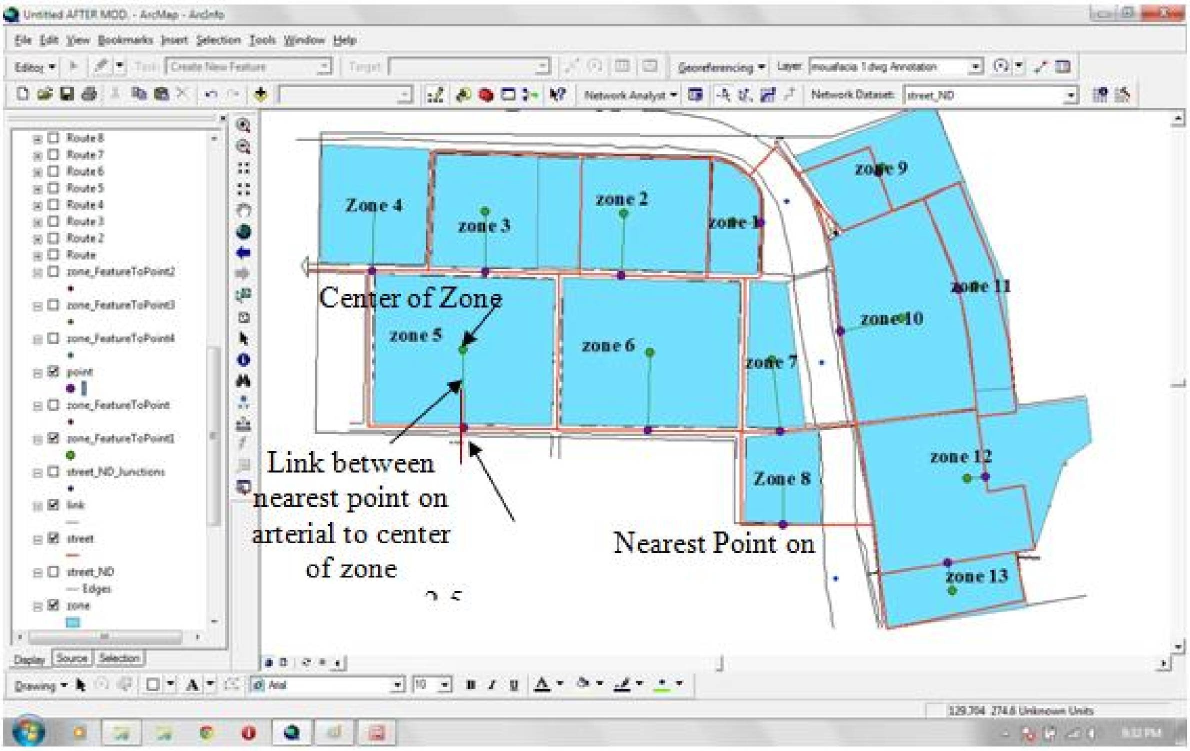

Fig .(7) Linking Between Nearest Point On Arterial To Center Of Zone 5

Results :

order to obtain the optimum bridge's location. The total travel time is obtained using the network analysis (an application of GIS), the total travel time for the journey from zone 1 (origin) to all 5 zones (destination) in the right side of the town is obtained, and the total travel time from zone 2 (origin) to all 5 zones (destination) in the right side of the town is also obtained, and so on for all the zones in the left side of the town (the directional distribution is 50%).

(Figure 8) shows the routes from zone 1 (origin) to all 5 zones (destinations) in the right side of the town.

(Figure 9) shows the routes from zone 2 (origin) to all 5 zones (destinations) in the right side of the town.

(Figure 10) shows the routes from zone 3 (origin) to all 5 zones (destinations) in the right side of the town.

(Figure 11) shows the routes from zone 4 (origin) to all 5 zones (destinations) in the right side of the town.

(Figure 12) shows the routes from zone 5 (origin) to all 5 zones (destinations) in the right side of the town.

(Figure 13) shows the routes from zone 6 (origin) to all 5 zones (destinations) in the right side of the town.

(Figure 14) shows the routes from zone 7 (origin) to all 5 zones (destinations) in the right side of the town.

(Figure 15) shows the routes from zone 8 (origin) to all 5 zones (destinations) in the right side of the town.

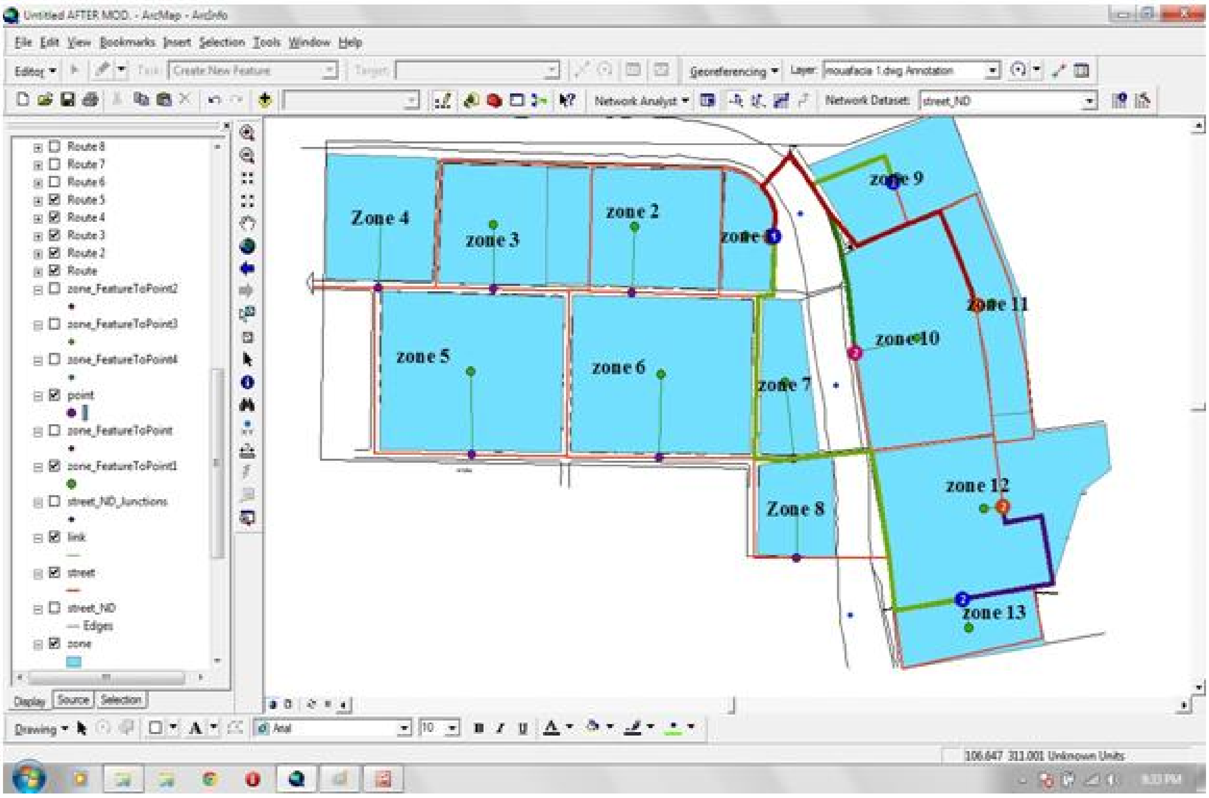

Fig .(8) Routes from zone 1 (Origin) to all 5 zones (destinations) in the right side of the town.

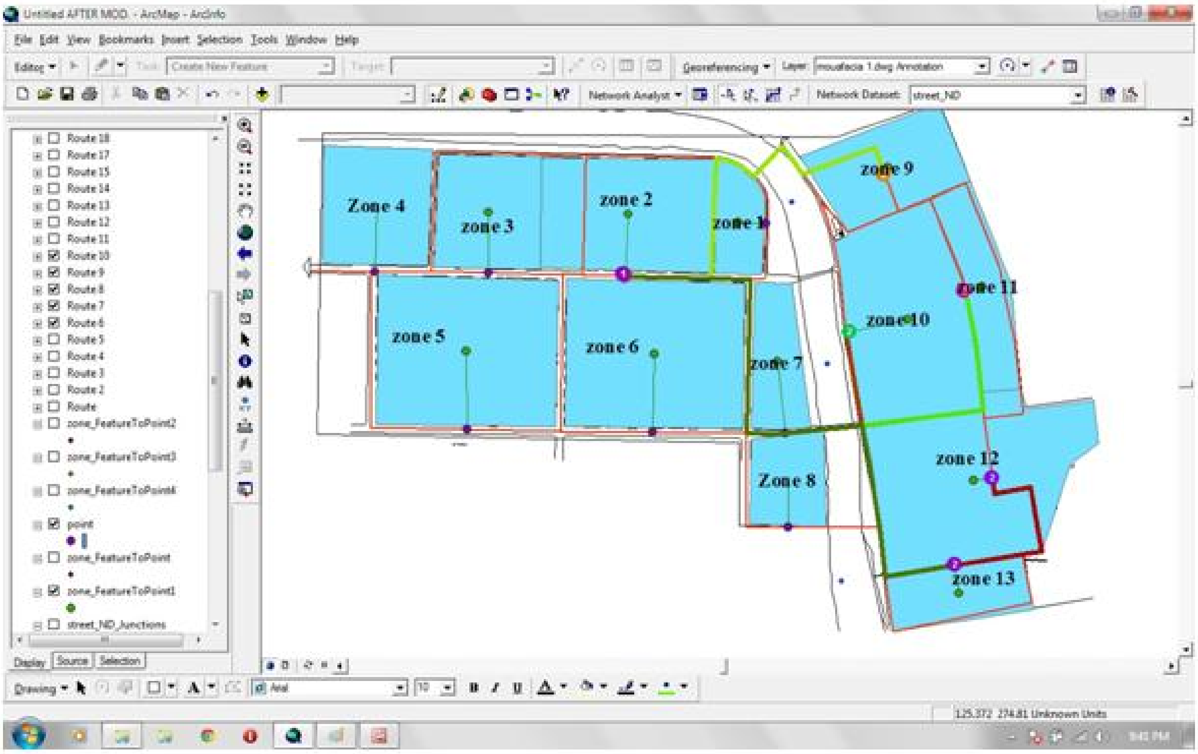

Fig .(9) Routes from zone 2 (Origin) to all 5 zones (destinations) in the right side of the town.

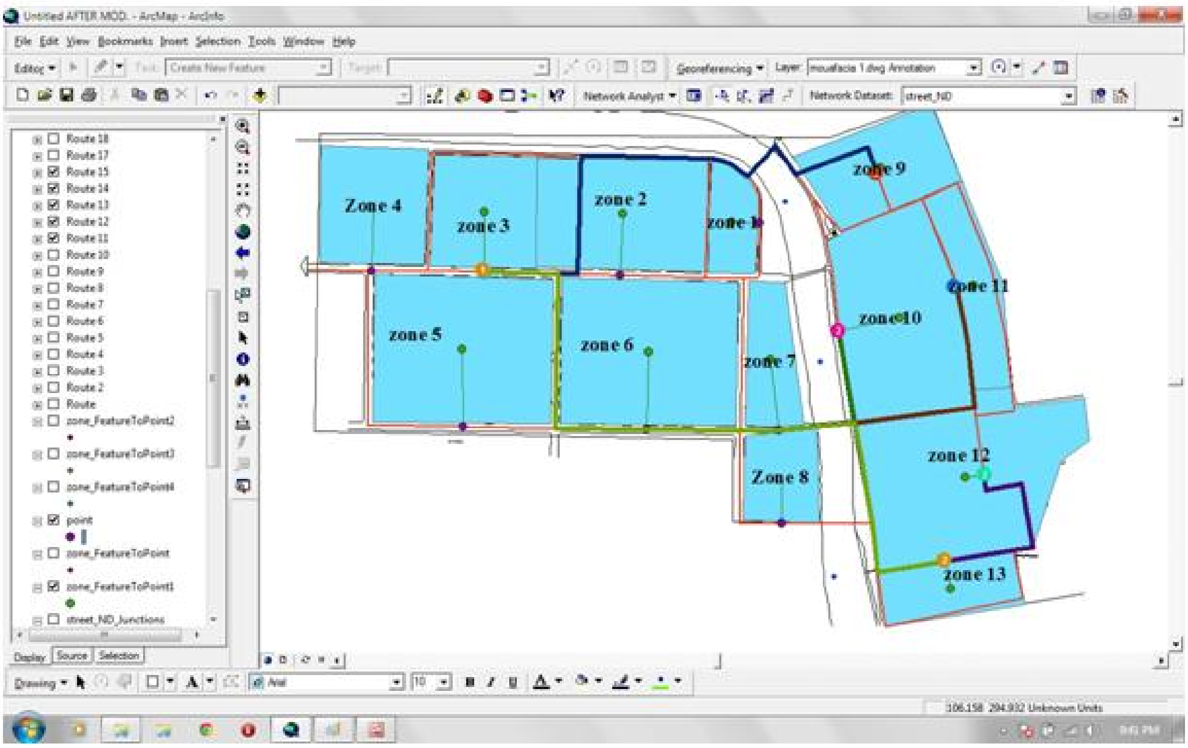

Fig .(10) Routes from zone 3 (Origin) to all 5 zones (destinations) in the right side of the town.

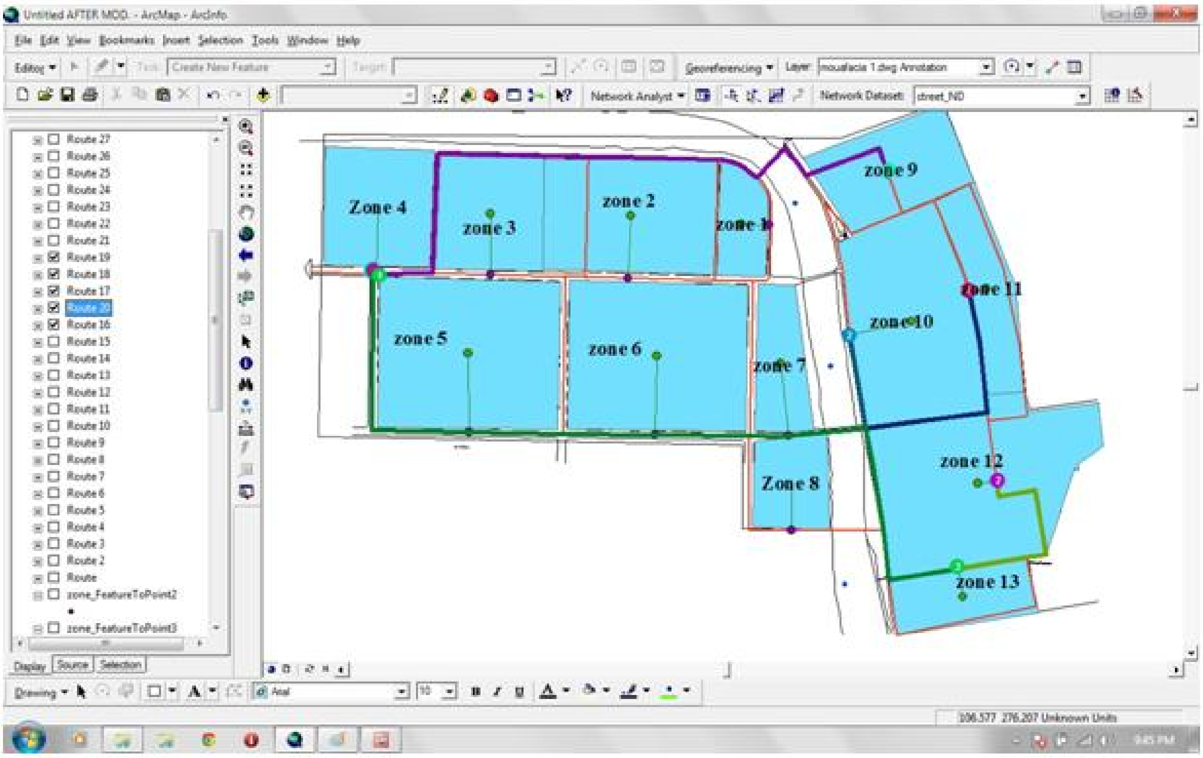

Fig .(11) Routes from zone 4 (Origin) to all 5 zones (destinations) in the right side of the town.

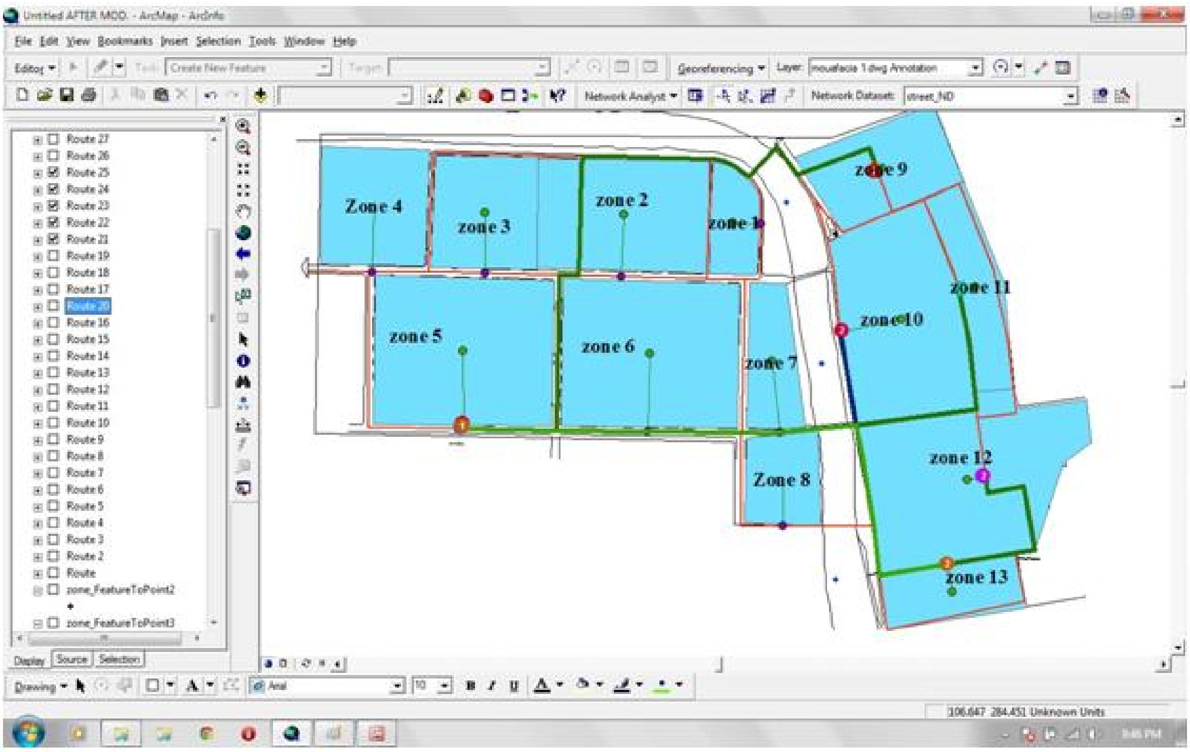

Fig .(12) Routes from zone 5 (Origin) to all 5 zones (destinations) in the right side of the town.

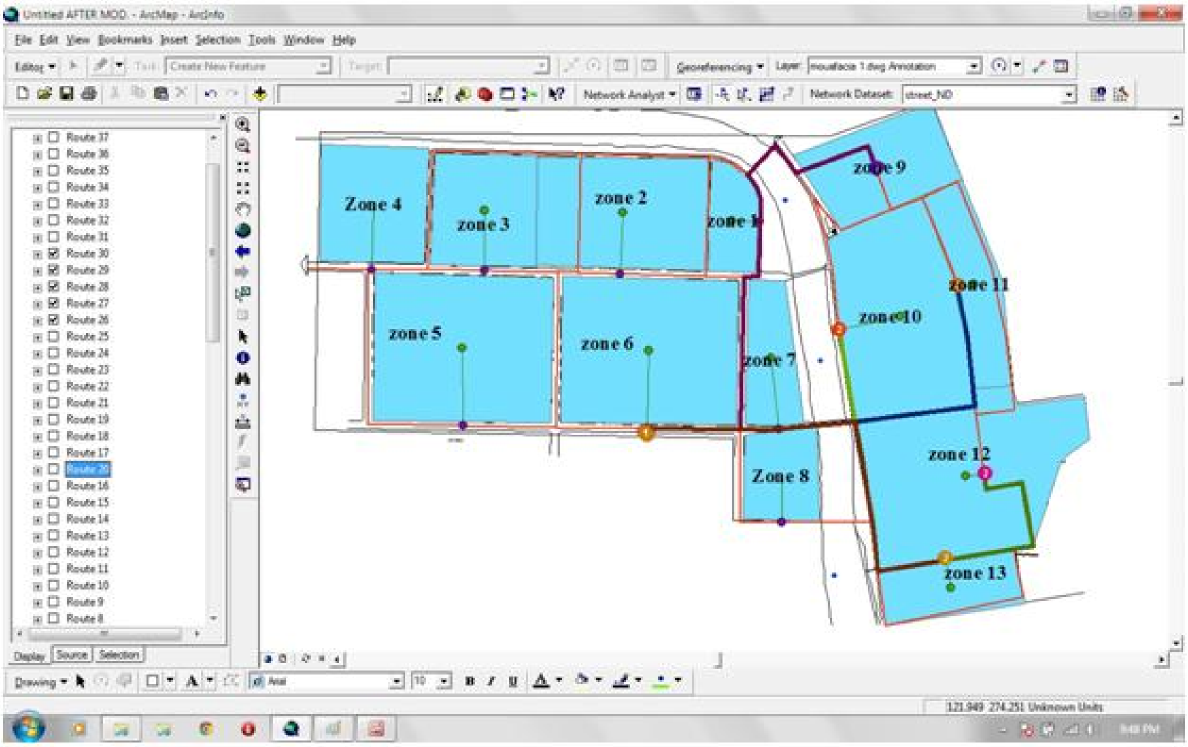

Fig .(13) Routes from zone 6 (Origin) to all 5 zones (destinations) in the right side of the town.

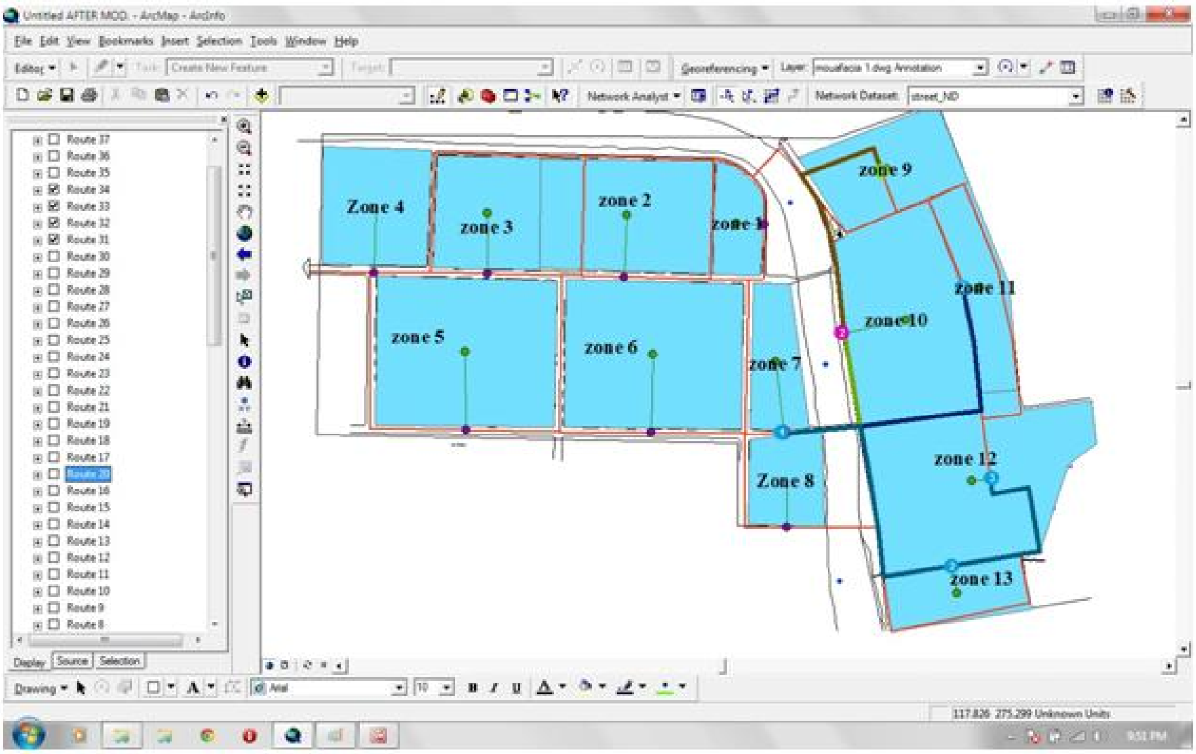

Fig .(14) Routes from zone 7 (Origin) to all 5 zones (destinations) in the right side of the town.

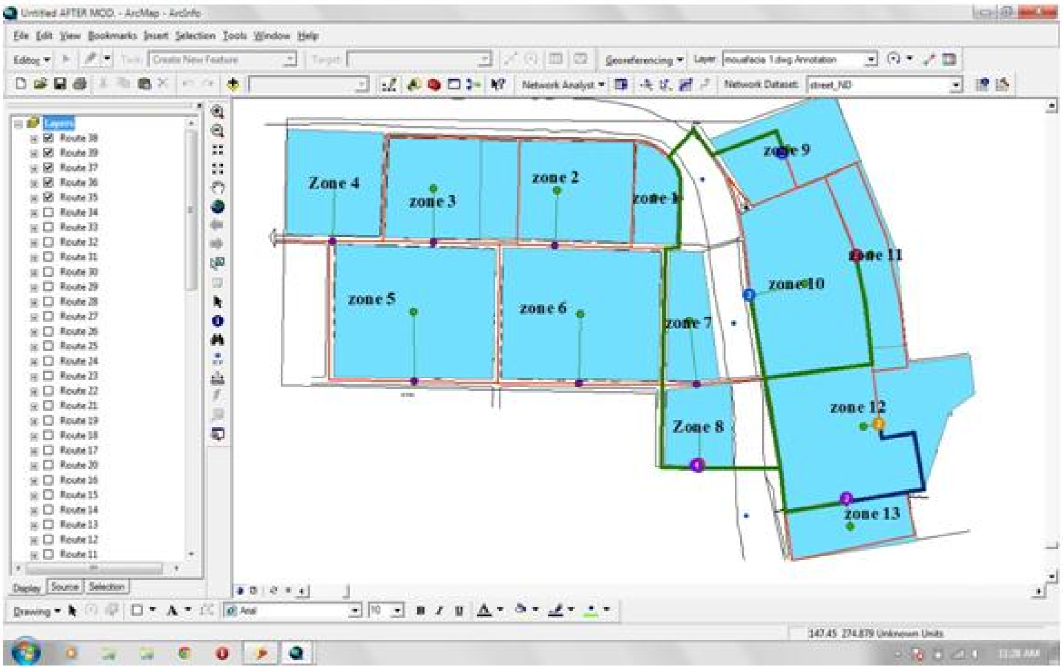

Fig .(15) Routes from zone 8 (Origin) to all 5 zones (destinations) in the right side of the town.

Optimum Bridge's Location

The Alternatives Bridge locations (proposal) that are used in this study are shown in **(Figure 16).**

(Table 1) shows the result of GIS application.

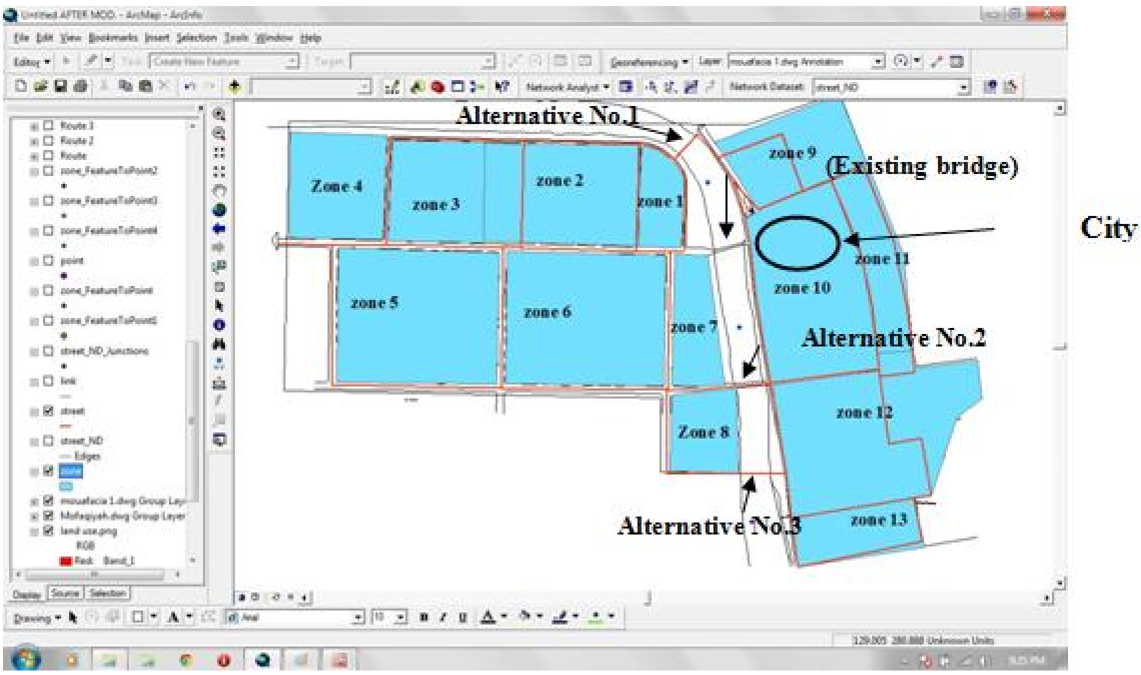

Fig .(16) Alternatives Bridge locations (proposal) in Al- Muwaffaqiyah town

Table .(1) The result of GIS application.

From zone	*To zone*	*proposal*	*Program Time (seconds)*
1	9	1	200
	10	1	206
	11	1	270
	12	2	302
	13	2	250
2	9	1	247
	10	2	222
	11	2	290
	12	2	307
	13	2	255
3	9	1	276
	10	2	248
	11	2	316
	12	2	334
	13	2	282
4	9	1	304
	10	2	274
	11	2	340
	12	2	360
	13	2	307
5	9	1	316
	10	2	216
	11	2	284
	12	2	301
	13	2	249
6	9	1	283
	10	2	175
	11	2	242
	12	2	260
	13	2	208
7	9	2	267
	10	2	145
	11	2	213
	12	2	231
	13	2	179
8	9	1	295
	10	3	182
	11	3	250
	12	3	206
	13	3	153

The above table shows the shortest route between zones, and the alternative bridge (proposal) that are used for passing between left and right zone in the town, no. of using the appropriate proposal are shown in (**Table 2**)

Table .(2) No. of using the appropriate proposal

No. of passing	***Alternative Bridge's location***
9	**1**
27	**2**
4	**3**

From **(Table 2),** we notice that alternative 2 is the best alternative (optimum bridge location).

Conclusion

As a result of this study, the bridge across the Al-Garraf River connected between two parts of Al-Muwaffaqiyah town location was found by differentiate between three alternatives using the GIS network analysis. The chosen location has the following beneficial:

1- Minimize the travel time up to 50%, i.e. minimize pollution and fuel consumption..
2- Reduce congestion in the current bridge approaches.
3- Improve new lands, which the new bridge is adjacent to them.

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