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Analysing Iraqi Railways Network by Applying Specific Criteria Using the GIS Techniques

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Abstract:

The railways network is one of the huge infrastructure projects. Therefore, dealing with these projects such as analyzing and developing should be done using appropriate tools, i.e. GIS tools. Because, traditional methods will consume resources, time, money and the results maybe not accurate. In this research, the train stations in all of Iraq's provinces were studied and analyzed using network analysis, which is one of the most powerful techniques within GIS. A free trial copy of ArcGIS®10.2 software was used in this research in order to achieve the aim of this study. The analysis of current train stations has been done depending on the road network, because people used roads to reach those train stations. The data layers for this study were collected and prepared to meet the requirements of network analyses within GIS. In this study, the current train stations in Iraq were analyzed and studied depending on accessibility value for those stations. Also, to know the numbers of people who can reach those stations within a walking time of 20 minutes. So, this study aims to analyze the current train stations according to multiple criteria by using network analysis in order to find the serviced areas around those stations. Results will be presented as digital maps layers with their attribute tables that show the beneficiaries from those train stations and serviced areas around those stations depending on specific criteria, with a view to determine the size of this problem and to support the decision makers in case of locating new train stations within the best locations for it.

Key words: Analysis criteria, ArcGIS, GIS, Iraq railways, Network analysis.

Introduction:

A railway network is a linear network because it is represented by lines (railroads), which are called segments in GIS. The meeting point of two line segments is called a vertex. Each line has two ends, called nodes, and these points reflect train stations in reality. In the field of GIS, the term "polyline" is used to refer to a group of line segments. The railway network is considered as a one-dimensional network because it consists of a set of interconnected lines and every line consists of a set of vertex sequences (1). The problem statement for this research is the last census, which shows that Iraq has a population of approximately 32 million, so all of these people need transportation. In addition, they all need goods and other services, and transportation is required to deliver goods to the people (2).

So the research question is: What are the results if the train station distribution depends on network analysis and some criteria are applied in order to serve more people within the service area of each station? This research aims to analyze the current train stations in Iraq to determine the size of the problem by using network analysis technique within GIS to measure the access time from population density points to train stations (3).In addition, to find the accessibility time for each station depending on the existing road network. So, the network analysis technique, which is a type of GIS technique, is the most appropriate method for dealing with railway projects because railroads are designed as a network. The main factor that should be used with network analysis is the accessibility value from population density to train stations by using the existing road network. The network analysis technique relies on some algorithms to analyze the railway network, such as DIJKSTRA and VORONOI, to find the shortest path between stations (4). Figure 1 shows the railway network analysis by using the network analysis technique in GIS.

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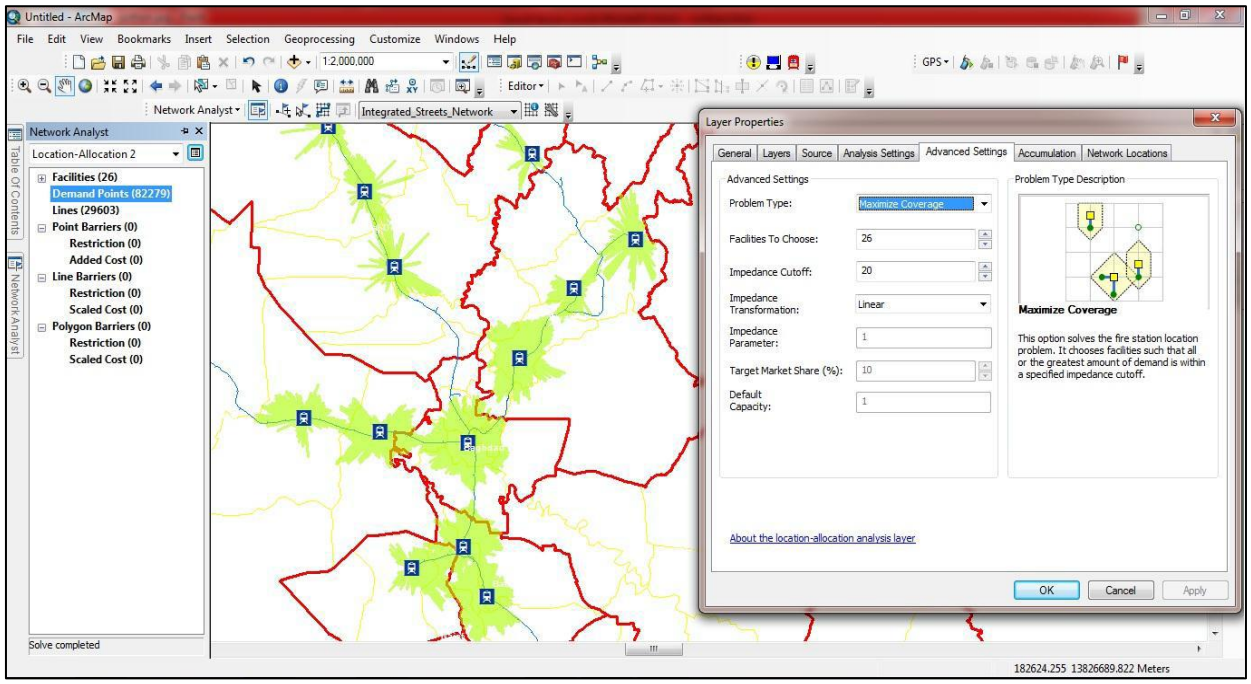

Figure 1. Railway network analysis

Rossetti, Tiboni, Vetturi, and Calderòn (2015) aimed to measure the flow of passengers to some new train stations in the Netherlands. For this aim, the authors applied two methods to measure the accessibility value of six new train stations. The first method aimed to forecast the approximate number of passengers who would use those stations. Therefore, by using this forecasting method, it is possible to get wrong or inaccurate outcomes, because this method is accompanied by two words: misrepresentation and bias toward the best, for example, if there is doubt about the number of users of any specific station. Everyone wants to present his or her project as being as perfect as possible. The second method was the use of the service area technique, which is one of the GIS techniques, in order to determine the areas serviced around each station. It seems that the authors have applied these two methods in order to compare them. In addition, this is considered a good way to see which method is the best (5).

Thus, in this study, two methods were used to analyze the current train stations and to measure their accessibility values, because it is better to apply more than one method in parallel in order to make the best decision. The outcomes of both of the methods used were new locations and new service areas.

Another study was conducted in Guangxi region, China, by Rong, Yingjie, Hongsheng and Zhuoyuan (2010). This study dealt with the relationship between population density and accessibility value of the train stations. The authors applied the cost weighted distance algorithm to measure the accessibility value. This algorithm is based on time in order to measure the accessibility value of train stations. The author used a raster map for this purpose. The results of this research show that the relationship between population density and accessibility is positive. The same idea was used in the current research but was applied in a different way by analyzing the accessibility value of the current train stations in Iraq through the use of the network analysis technique in GIS (6).

In (7), Dirkx (2012) aimed to measure the walking accessibility value of the metro stations in order to determine the best locations for new metro stations in China. For this purpose, the author used two methods: buffer analysis and cost–distance analysis. These two methods are ones of GIS techniques. The authors applied the cost–distance analysis in order to measure the walking accessibility value, and the speed parameter used in this analysis to calculate the time field was 60 m/min. For the time cutoff parameter, the authors used five levels, as follows: 0–5, 5–10, 10–15, 15–20, and 0–20 minutes. We used the same idea to calculate the time field in the network dataset and to determine the average walking time of people.

Data Acquisition

Data for this research were collected from two different resources:

- Iraqi Railways Company
- Resources bought from the Internet

All data are layers that contain both spatial data and normal data. These layers are represented as maps. These layers are:

- The railroad layer, which contains 88 records of Iraq's railway lines, as shown in Fig. 2

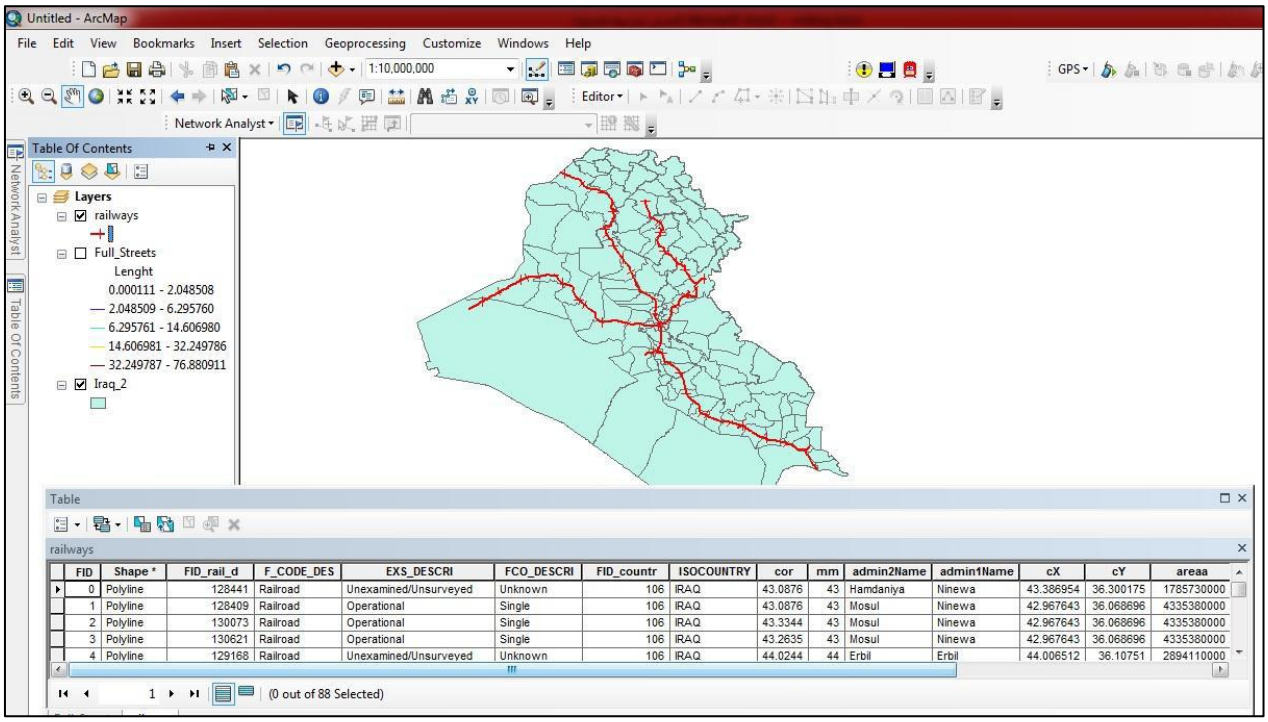

Figure 2. Iraqi railway layer

- Figure 3 shows the layer of current train stations in Iraq, which contains 26 records of train stations in the Iraqi provinces.

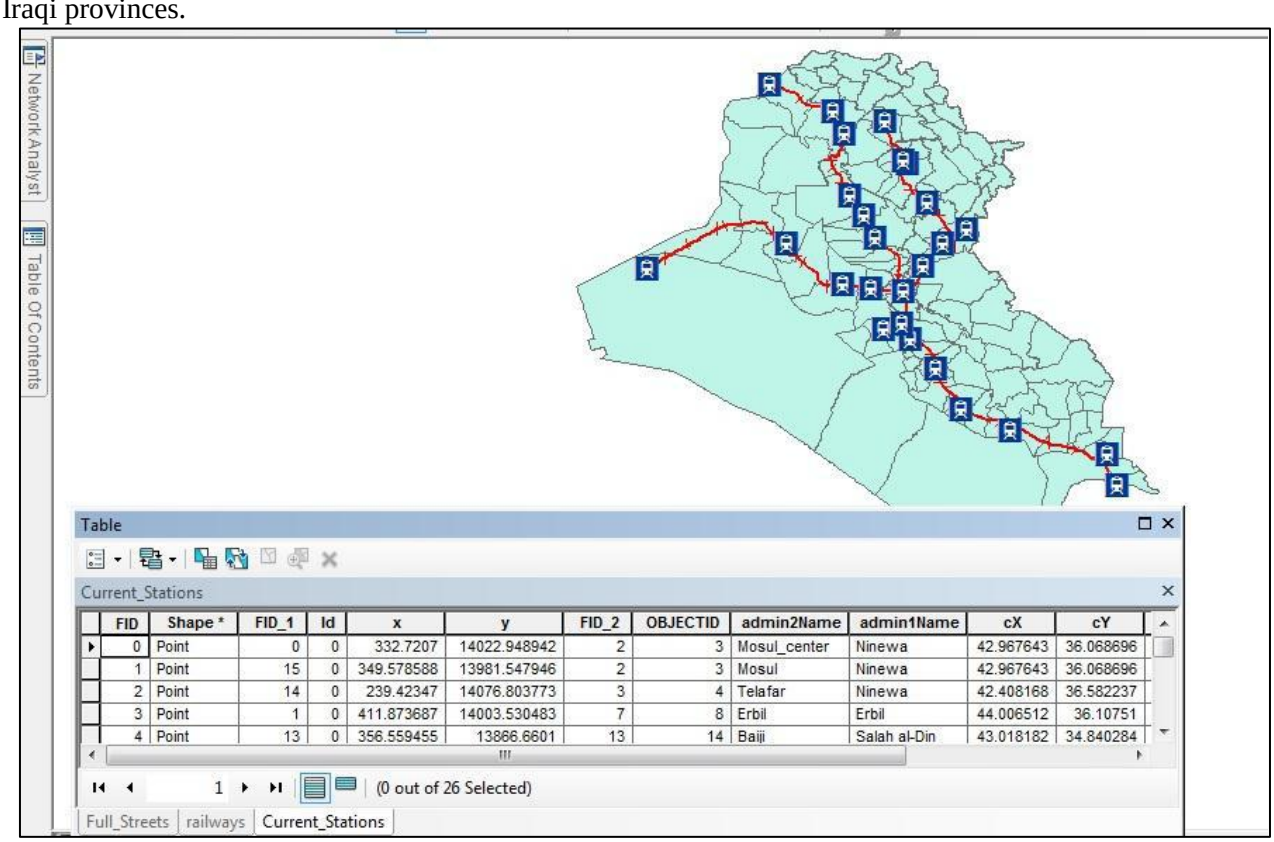

Figure 3. Iraqi train stations layer

- Figure 4 shows the road network layer, which contains 82279 records of

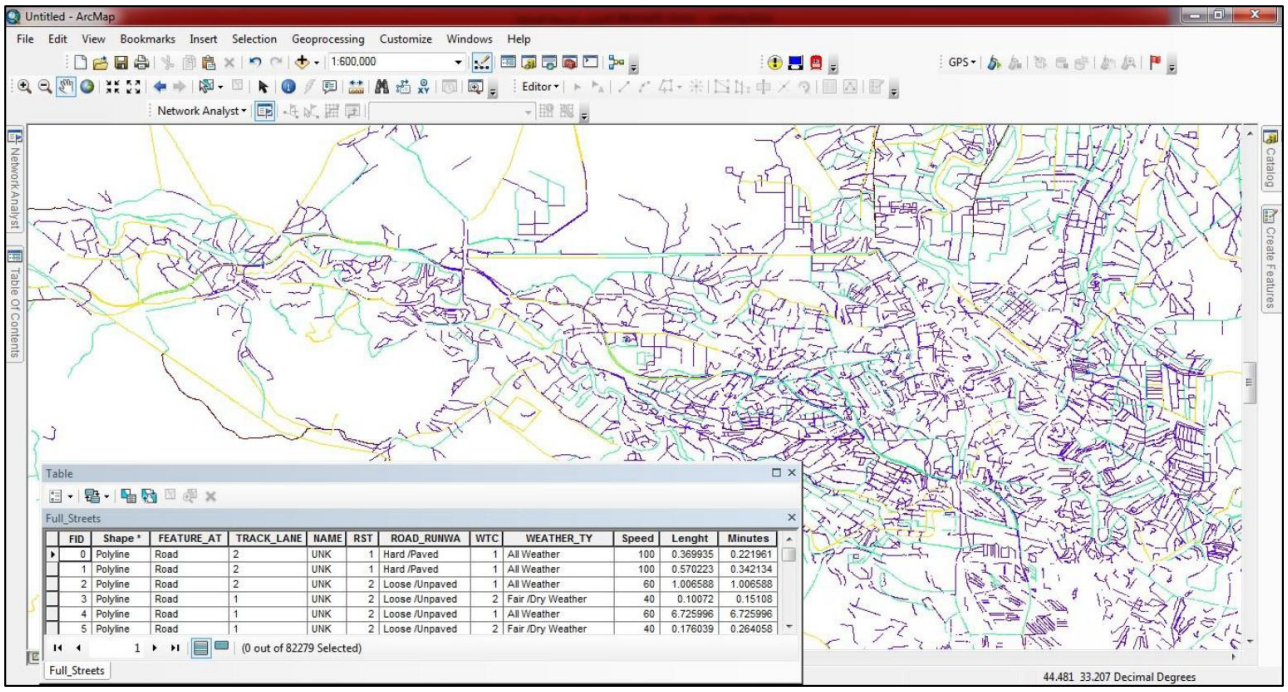

Figure 4. Road network layer

- The population density layer which is a point layer containing information about the population density of each city in all Iraqi provinces, as shown in Fig. 5.

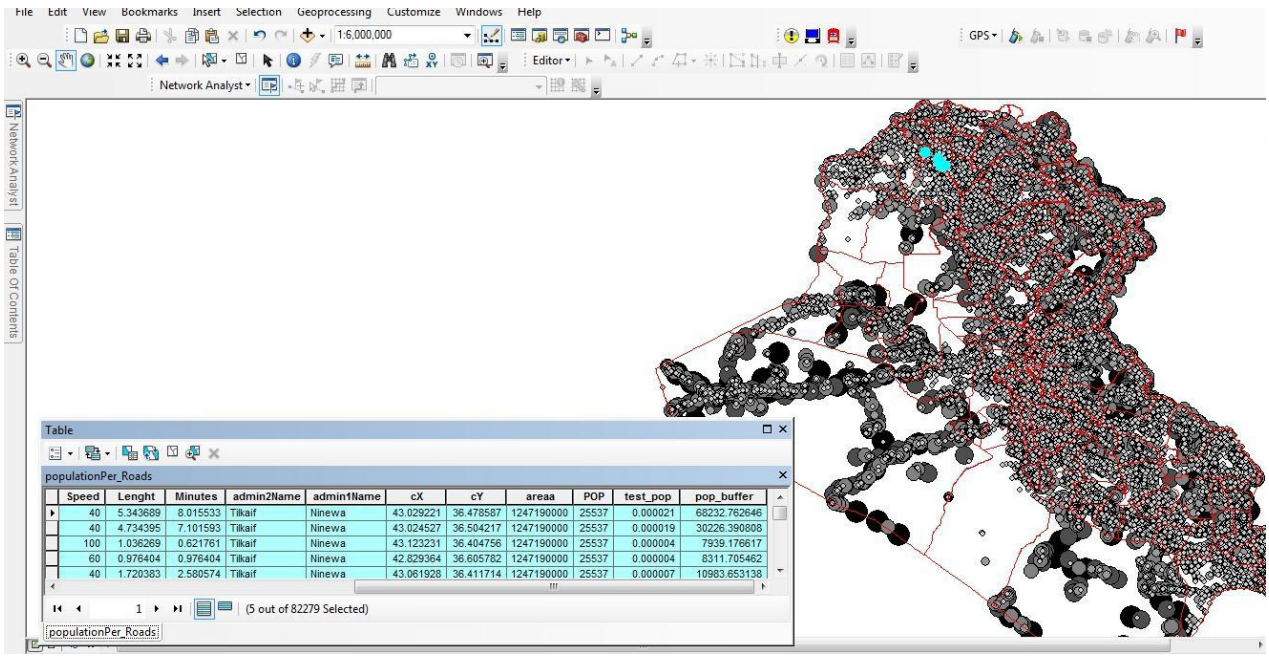

Figure 5. Iraqi population density layer

Methodology

Firstly, a lot of time was spent collecting all the data, which are related to the Iraq railways network, because without data it is not possible to work with GIS. Therefore, all data were collected to start working. These data included both spatial data and tabular data related to the spatial data and were collected from different sources. Then, all of these data were studied in order to understand them and how to use them in the research.

Next, the criteria that were applied in this research in order to analyze the current train stations in Iraq were used depending on literature studies as in points 1, 2, and 3. In addition, there are some other criteria that were assumed by us in order to achieve the predefined aim of this research such as in points 4, 5, 6 and 7. Also, there is another criteria used in order to present the results of the analysis more clearly such as point 8. The criteria used in this research are as follows:

1. The analysis of train stations is dependent on the **time** as an analysis cost.
2. **Twenty minutes** is taken as the walking time **(8)**.
3. A distance of **2 km** is taken as the area serviced around each train station. So, people can reach and take advantage of train services within those serviced areas **(9)**.
4. Travel from **demand points to facilities** was used as a type of analysis in order to measure the accessibility value of train stations (facilities) in terms of the time it takes people (demand) to reach those **(10)**.
5. **Maximize coverage** is the problem type to be solved by the network analysis. This problem type was used in order to find out the maximum border of the serviced areas around each station within which people can reach the stations inside those areas.
6. **Linear transformations** are used as an impedance transformation type for the network analysis because the network analysis is based on existing roads to analyze and measure the accessibility value **(11)**.
7. The **population density** field is set as a weight for the network analysis so the network analysis will analyze the train stations depending on their accessibility values. In addition, this analysis will assign a weight to each population point that falls within the area served by those stations and this weight will be allocated depending on the population density **(12)**.
8. **Straight lines** are used as an output shape type. This type was used in order to see the results more clearly on the map. The network analysis does not depend on those lines but depends on the existing roads and this option is used merely to display the results more clearly.

After that, the minutes column will be calculated in the layer of road network by applying a specified formula for that purpose. By taking into consideration the well-known physics formula to calculate the travel time in hours by means of the distance and the velocity in Equation 1. The values for the new field are calculated by dividing the length column by the speed column and multiplying the result by 60 (because the car's speed unit is km/h and the hour = 60 minutes and we need the time in minutes in order to measure the accessibility value in minutes), as shown in equation 2 **(13)**. Figure 6 shows the calculation window used to write the needed formula in order to calculate the minute field.

$$\text{Driving time } \mathbf{Minutes} = \left(\frac{\boldsymbol{Length}}{\boldsymbol{Speed}}\right) \times \mathbf{60} \quad \ldots (1)$$

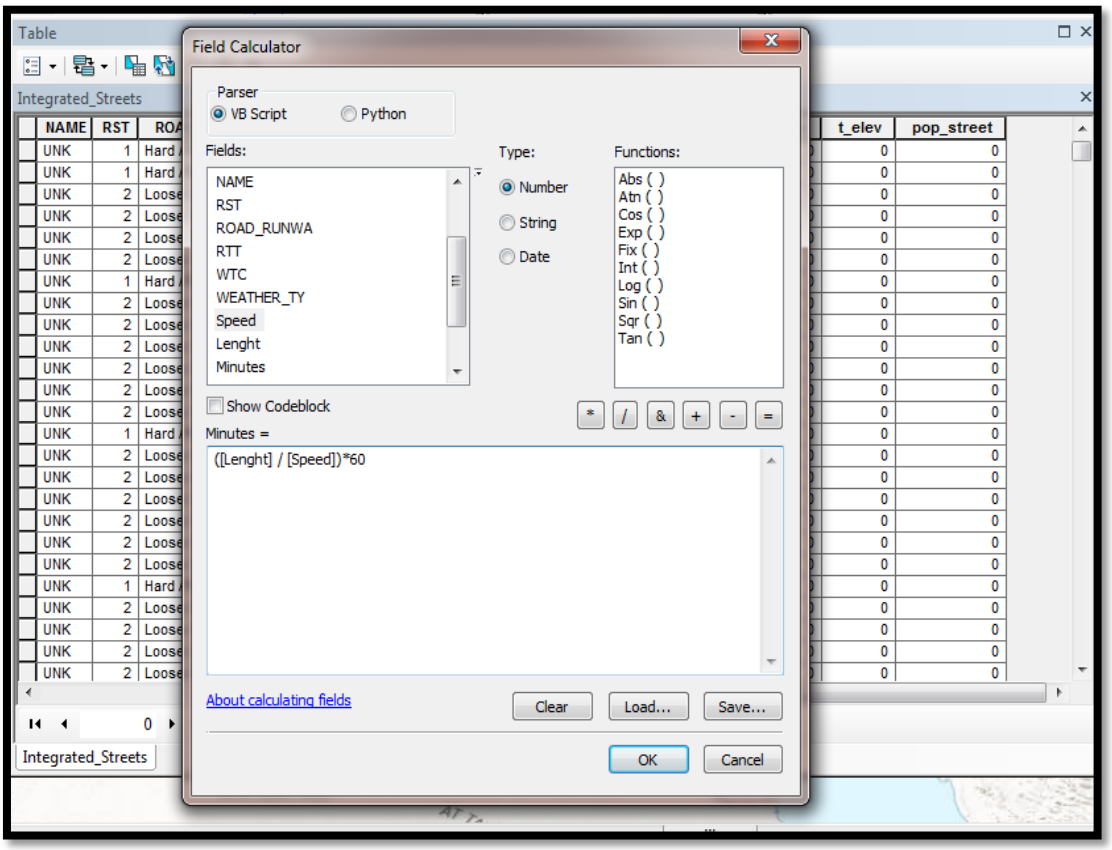

Figure 6. Calculating the minute's field

Then, we will add a new field to calculate the pedestrian's time in the layer of road. So, we can calculate the values for this field by dividing the length column by (0.1). The walking speed is determined as 0.1 KM/m. Thus the result will be in minutes), as it is seen in equation 2 .

$$\text{Pedestrian time Minutes} = \left(\frac{Length}{0.1}\right) \quad \dots (2)$$

After that, it will be possible to use the Network Analyzes in order to analysis the Iraqi train stations and to measure the accessibility value for each train station as it shown in Fig. 7.

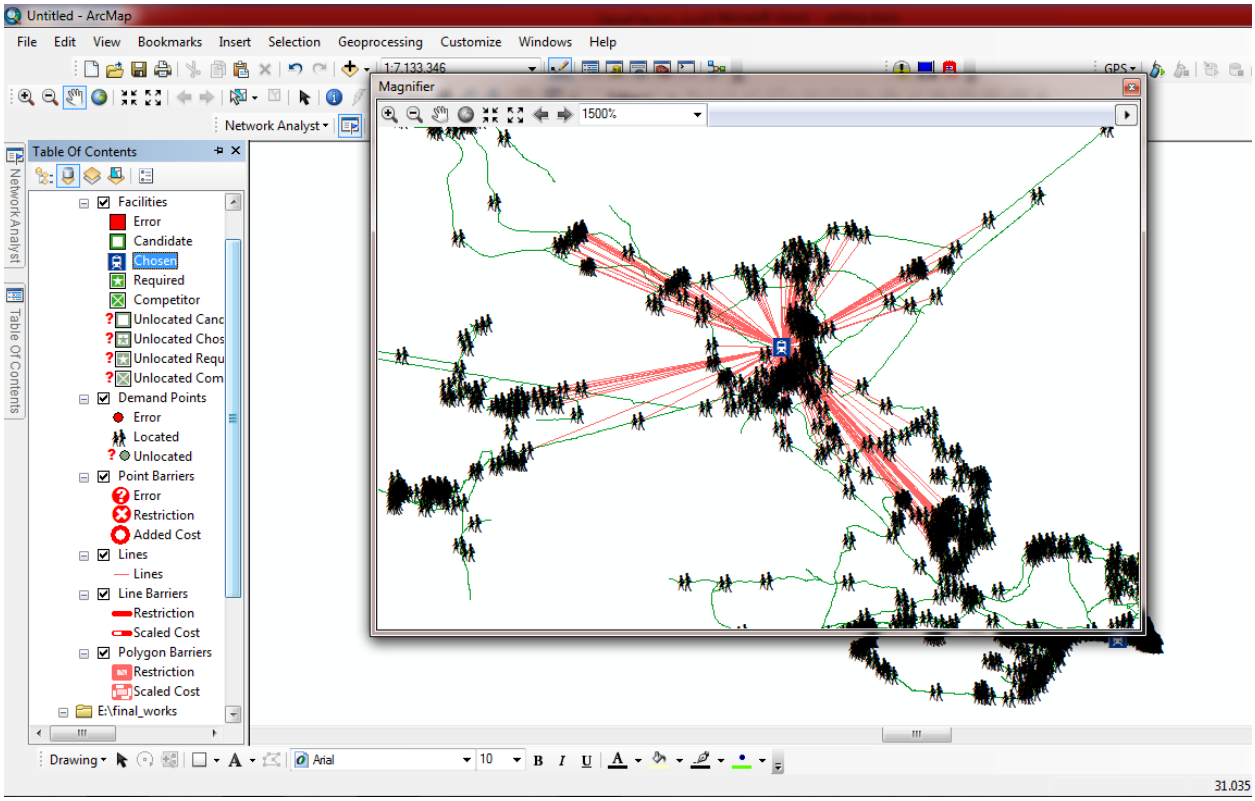

Figure 7. Network analysis

Later, the ArcGIS® 10.2 software package (ArcCatalog 10.2, ArcMap 10.2) was used in order to organize and prepare data layers. Next, the current train stations were analyzed depending on some criteria by using the network analysis technique in ArcMap software .

Network Analyzes with ArcGIS® 10.2

The network analysis technique in GIS makes it possible to analyze spatial networks such as roads, railways, and so on according to some predefined criteria that meet the required aim. Network analysis depends on the road network to calculate the accessibility value for any object based on the existing roads. There are nine types of network analysis, as follows:

- new closest facility
- new service area
- new routes
- new origin–destination matrix
- new vehicle routing
- new-location allocation

As it is mentioned above the network analysis depends on two algorithms, DIJKSTRA and VORONOI, to solve the problem, calculate the service areas, find the shortest paths, and so on .

Results and Discussion:

In this part, all the results are presented as layers and records in the form of maps with attribute tables. These results are as follows:

- The network dataset (ND). This dataset contains three layers, which are resulted from preparing the data (digital maps). Those three layers were used later in the network analysis (road network, road-network edges, road-network junctions). Because, without these three layers the network analyzes cannot be done.
- The results of the analysis of the current train stations, which were obtained through the use of the network analysis technique. These results were 29,603 demand points from which those stations could be reached within a walking time of 20 minutes, as shown in Fig. 8.

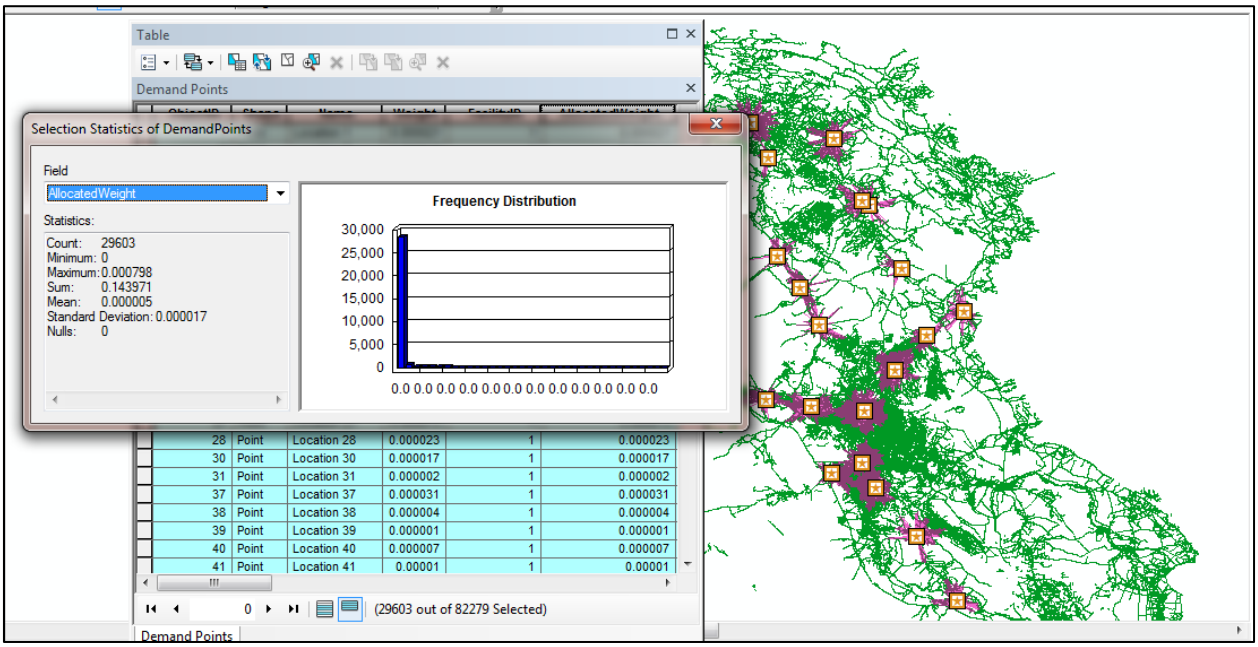

Figure 8. layer resulting from the analysis of current stations

Therefore, here we can compere those 29.603 demand points (population density) that can be reached the current train station with the all demand points in Iraq, which are approximately 82.279. So, the percentage will be (35.97%) just those population density points can reach the current train stations within 20 minutes.

- In addition, the total area serviced that benefited from the current train station service and was within 2 km of those stations was **1,694** km2, as shown in Fig. 9.

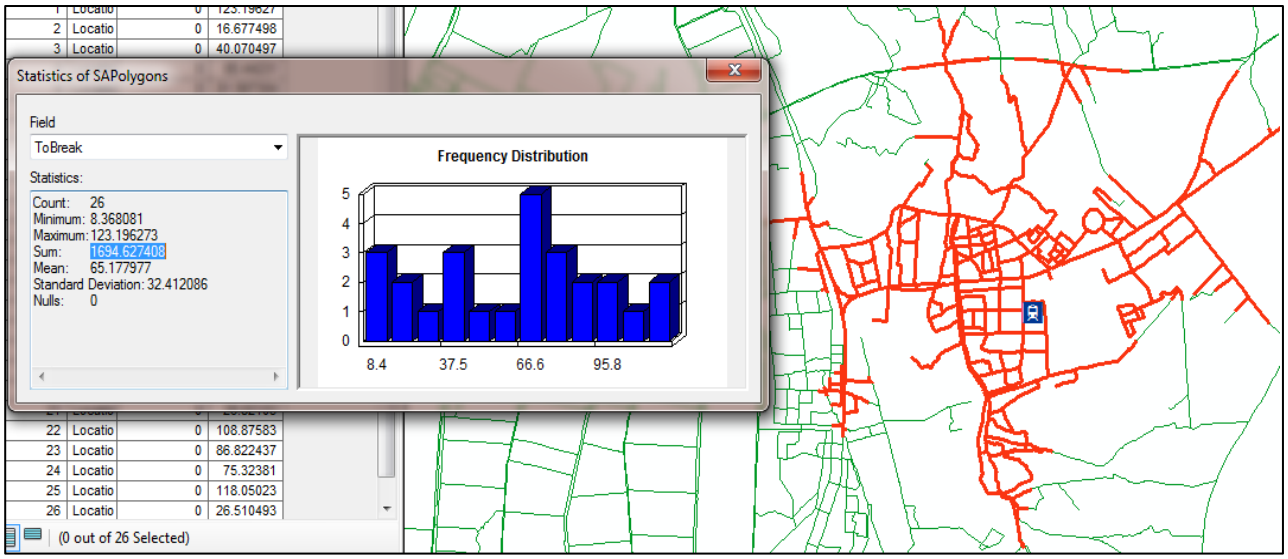

Figure 9. total area covered by surrounding stations

So, if the percentage of difference is calculated between the size of the serviced area and the size of the total urban areas in Iraq. Wherefore, the size of the serviced area is 1694 km2 and the size of the total urban areas is approximately 24904.001 km2. The percentage will be only (6.80%) of the total urban area of cities.

Conclusion:

To conclude, in this research the train stations in Iraq were analyzed by using the network analysis, which is one of the GIs techniques. The network analysis was done depending on some specific criteria. The main criterion that was used is 20 minutes as a pedestrian's time. In addition, the size of the serviced areas was resulted of network analyzes which is the size of Areas within 2_{KM} surrounds each train station. Finally, the results

show that 35.97% of population density points can reach the current train stations within 20 minutes as a pedestrian's time. In addition, the percentage of the serviced area is 6.80% of the total urban area of cities. Also, the results show that there are a lot of high density population's points out of serviced areas that mean all of these points need to train stations.

Future Works

1. It is possible to take into consideration the same criteria when it is the best locations of new train stations should be determined in order to achieve an acceptable accessibility value.
2. It will be possible to use the same method for other purposes such as analyzing locations of new hospitals, police stations, gas stations, and so on by changing the layer type for the demand as well as the facilities by applying other criteria.
3. The layer data for the train stations should be developed to include the number of daily passengers and the schedule for the trains in order to calculate the number of beneficiaries more accurately for each station .
4. Regions produced by the VORONOI algorithm could be used to determine the best areas in which it is possible to create railway lines between those new stations at the lowest cost (14).

Conflicts of Interest: None.

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استخدام تقنيات نظم المعلومات الجغرافية لتحليل شبكة السكك الحديدية في العراق بالاعتماد على تطبيق معايير خاصة

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الخلاصة:

شبكة السكك الحديدية هي واحدة من مشاريع البنية التحتية الضخمة في أي بلد من بلدان العالم بسبب كمية البيانات المرتبطة بيها. ولذلك، عندما يتم التعامل مع هذه المشاريع مثلا اذا اردنا التحليل او التطوير فيجب ان يتم استخدام التقنيات الحديثة والأدوات المناسبة لهذا الغرض، وهي الادوات والتقنيات الموجودة ضمن بيئة نظم المعلومات الجغرافية . بالإضافة الى ذلك فعندما يتم استخدام شاشة الكومبيوتر للتعامل مع الخرائط او أي مشروع اخر له تمثيل حقيقي على سطح الارض مثل السكك الحديدية سيكون اسهل بكثير من الطرق التقليدية. لأن استخدام الطرق التقليدية سوف يستهلك الموارد البشرية والوقت والمال والنتائج ربما لن تكون دقيقة. في هذا البحث، تمت دراسة وتحليل محطات القطارات في جميع محافظات العراق باستخدام تقنية تحليل الشبكة ، وهي من احد أقوى التقنيات في نظام المعلومات الجغرافية. تم استخدام نسخة تجريبية مجانية من برنامج ArcGIS® في هذا البحث من أجل تحقيق هدف هذه الدراسة. لذا، تهدف هذه الدراسة إلى تحليل محطات القطارات الحالية وفقًا لمعايير متعددة باستخدام تقنية تحليل الشبكة في نظم المعلومات الجغرافية من أجل إيجاد المناطق التي تستفاد من خدمات القطار حول كل محطة من تلك المحطات وكذلك معرفة أعداد الأشخاص الذين يمكنهم الوصول إلى هذه المحطات خلال مدة 20 دقيقة. يعتمد تحليل محطات القطار الحالية بصورة اساسية على شبكة الطرق، لأن الناس يستخدمون الطرق للوصول إلى محطات القطار هذه. وستعرض النتائج كطبقات خرائط رقمية تُظهر المستفيدين من محطات القطار هذه اعتمادًا على معايير محددة.

الكلمات المفتاحية: معايير لتحليل الشبكات، نظام ArcGIS ، نظم المعلومات الجغرافية، شبكة السكك الحديدية في العراق، تحليل الشبكات .