A GIS-BASED DECISION SUPPORT SYSTEM FOR LOCATING NEW TRAIN STATIONS IN IRAQ

HAYDER FARIS NAJI NAJI

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Title of the Thesis: **A GIS-BASED DECISION SUPPORT SYSTEM FOR LOCATING NEW TRAIN STATIONS IN IRAQ.**

Submitted by **Hayder Faris Naji NAJI**

Approval of the Graduate School of Natural and Applied Sciences, Çankaya University

Prof. Dr. Can ÇOĞUN
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Assoc. Prof .Dr. Fahd JARAD
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. H. Hakan MARAŞ
Supervisor

Examination Date: 1/8/2017

Examining Committee:

Assoc. Prof. Dr. H. Hakan MARAŞ (Cankaya University)

Assist. Prof. Dr. Shadi AL SHEHABI (THK University)

Assist. Prof. Dr. Abdül Kadir GÖRÜR (Cankaya University)

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ABSTRACT

A GIS-BASED DECISION SUPPORT SYSTEM FOR LOCATING NEW TRAIN STATIONS IN IRAQ

Hayder Faris Naji NAJI

M.S, Information Technology Department

Supervisor: Assoc. Prof. Dr. Hakan MARAŞ

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Railway networks are one of the most necessary infrastructures all around the world. Today, to manage these networks, Geographic Information System (GIS) techniques should be used in order to study and analyze the railway network and its stations. It is very difficult to deal with railway systems by using traditional methods and the results may become inaccurate because of the huge amount of data related to them. In addition, by using GIS techniques in the development of the rail networks, the decision-making process will be improved and supported. Moreover, the results will be accurate because they result from using specific criteria to achieve a defined aim.

In this study, the train stations in all of Iraq's provinces were studied and analyzed by using network analysis, which is one of the most powerful techniques within GIS. A GIS-based system was built by using the free trial copy of ArcGIS® software, PYTHON™ programming language, and ASP.Net (C#) programming language in order to develop a full decision-making environment to manage and locate train stations in the country of Iraq. The main methodology for this study is divided into two parts.

The first part identifies the problems in the current stations through the analysis of those stations by using network analysis. The second part determines the best candidate locations for new train stations depending on the number of people around those locations and the distance between those people and the new candidate locations according to the existing road network. In addition, the new locations should be accessible by people who are within a walking time of 20 minutes from the new locations as an accessibility value.

The results will be presented as spatial maps, which portray the best locations for new train stations, and tabular data of the areas and the number of people to be served by the new stations.

Keywords: GIS, Iraq, Railways System, Network Analysis, Train Stations.

ÖZ

IRAK'TA YENİ TREN İSTASYONU YERLERİNİN BELİRLENMESİ İÇİN CBS DESTEKLİ BİR KARAR DESTEK SİSTEMİ

Hayder Faris Naji NAJI

M.Sc., Department of Computer Information Technology

Yüksek Lisans, Bilgi Teknolojileri Anabilim Dalı

Tez Yöneticisi: Doç. Dr. H. Hakan MARAŞ

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Demiryolu ağları tüm dünya için çok gerekli altyapılardır. Günümüzde, bu ağları yönetebilmek için demiryolu ağının ve istasyonlarının analizi ve değerlendirilmesi amacıyla Coğrafi Bilgi Sistemleri (CBS) tekniklerinin kullanılması gereklidir. Demiryolu sistemleri ile ilgili çalışmalarda klasik yöntemlerin kullanılması oldukça zordur ve ilgili verinin büyük boyutu nedeniyle sonuçların hatalı olabilmesi mümkündür. Buna ilave olarak, demiryollarının yönetilmesinde CBS tekniklerinin kullanılması ile karar verme işlemi geliştirilecek ve desteklenecektir. Üstelik, amaca ulaşmak için özel kriterlerin kullanılabilmesi nedeniyle sonuçlar daha doğru olacaktır.

Bu çalışmada, Irak'ın tüm şehirlerindeki tren istasyonları, CBS'nin en güçlü tekniklerinden biri olan Ağ Analizi ile incelenerek analiz edilmiştir. Irak'taki tren istasyonlarının konumlandırılması ve yönetilebilmesi amacıyla ArcGIS® yazılımı, PYTHON™ programlama dili ve ASP.Net (C#) programlama dili kullanılarak CBS tabanlı, bütünleşik bir karar verme ortamı oluşturulmuştur. Bu çalışmada kullanılan metot iki bölümden oluşmaktadır.

İlk bölümde Ağ Analizi kullanılarak tren istasyonların analiz edilmesiyle mevcut istasyonlardaki problemlerin belirlenmektedir. İkinci bölümde ise mevcut yol ağı üzerinden çevrede yaşayan insanların istasyona uzaklıkları ve sayılarına bağlı olarak yeni tren istasyonları için aday konumları belirlemektedir. Ayrıca, istasyona erişebilme kriteri olarak istasyona 20 dakikada yürüme uzaklığının olması kabul edilmiştir.

Sonuçlar, yeni tren istasyonları için en uygun yeri gösteren konumsal haritalar, yerleşim yeri alanları ve yaşayan nüfusu gösteren tablosal veriler ve olarak sunulmuştur.

Anahtar kelimeler: CBS, Irak, Demiryolu Sistemleri, Ağ Analizi, Tren İstasyonları

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ASP Active Server Page

CAL Create Address Locator

CPU Central Processing Unit

ESRI Environmental Systems Research Institute

GIS Geographic Information System

GPS Global Positioning System

GUI Graphical User Interface

IRT Iraq Railways Tool

PY Python Scripting

RS Remote Sensing

NA Network Analysis

ND Network Dataset

SQL Structured Query Language

MySQL Open-Source Structured Query Language

PC Personal Computer

OS Operating System

XLS Microsoft Excel

CHAPTER 1

Introduction

This research aims to study and analyze the train stations in Iraq, to find the accessibility time for each station depending on the existing road network, and to find the best locations for constructing new train stations able to serve people depending on some criteria. So, it is necessary for the reader to know some simple background information about the railway network and its stations in Iraq.

1.1 Iraq's railway network:

Iraq is one of the Middle Eastern countries and consists of 18 provinces. The country of Iraq is one of the Asian countries and has borders with Jordan, Turkey, Syria, Iran, and Kuwait, as shown in Figure 1.

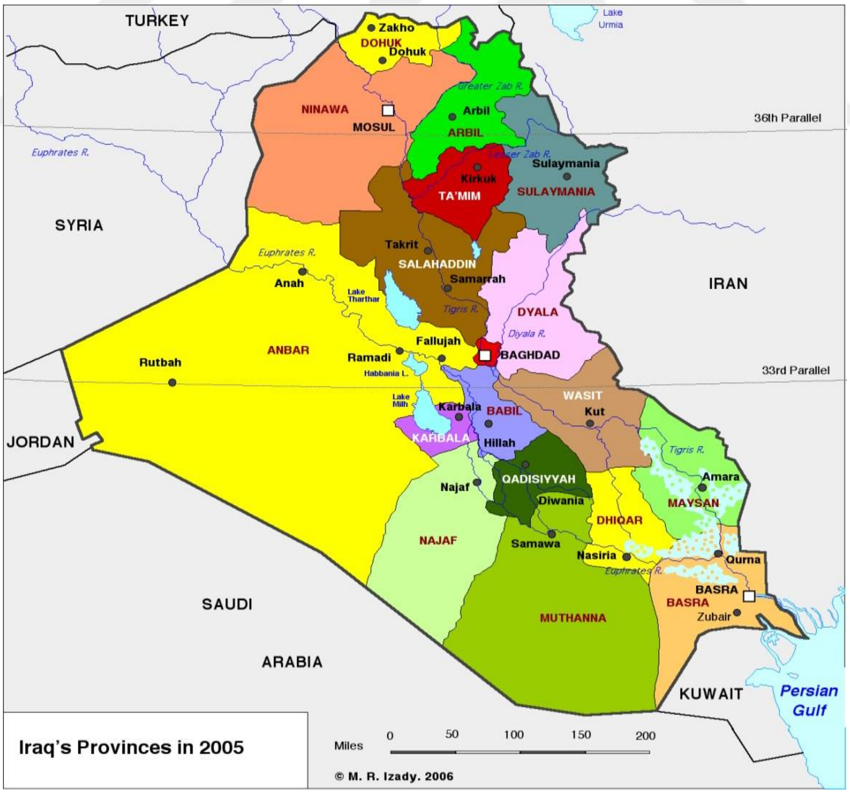


Figure 1 Map of Iraq

The last census 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. Firstly, the reader should know a brief history of the Iraqi railway system and its stations **[1]**.

The first attempt to create a public transport system in Iraq was the train system, called "*TRAM*". The "*TRAM*" system was established in 1869 in Baghdad province, the capital of Iraq, by the Ottoman governor "*Medhat Basha*". The train was called "*Alkary*" at that time, and its wagons were wooden and were pulled by horses, as shown in Figure 2.

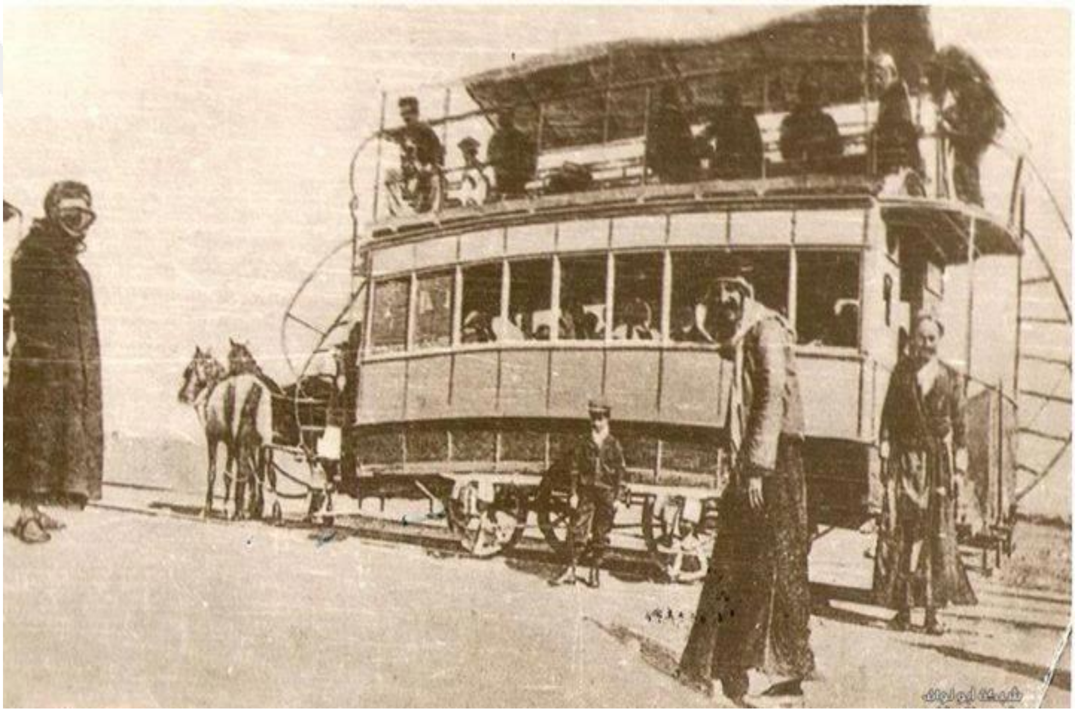


Figure 2 Alkary wagon

After that, a new railway line was established between Baghdad and Najaf. Then, a German company won the contract for building a new railway line between Baghdad and Mosul during 1902. After that, the first milestone for Iraq's railway company was during the middle of the year 1916, when the company owning Iraq's railways, called the Iraqi Railways Company, was established for the first time. It was controlled and managed by the British military at that time. Then, the management of the railway company moved to a British civilian administration in 1920 and then became an Iraqi civil administration on April 16, 1936, which became the national day of Iraqi railways **[2]**. Figure 3 shows the Iraqi Railways Company in 1976.

Figure 3 Iraqi Railways Company in 1976

After, that the Iraqi Railways Company continued to develop and construct new lines and train stations. Next, these new stations will be listed sequentially below.

- Baghdad
- Samarra
- Basra
- Mosul
- Babylon
- Kirkuk

- Erbil

That means that in the end of 1936 there were seven train stations in Iraq, as shown in Figure 4.

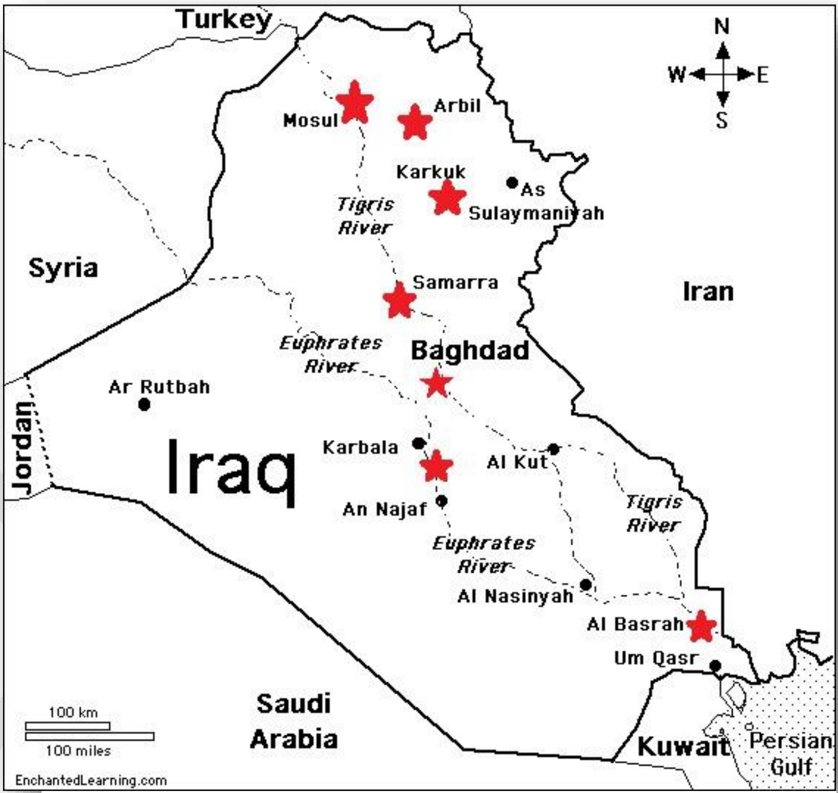


Figure 4 Old railroads in Iraq

The Iraqi Railways Company continued with the development and construction of new train stations until there were 26 train stations in Iraq. However, the harsh conditions experienced in Iraq, represented by the successive wars of 1988, 1991, and 2003 and the last battle against outlaws groups from 2014 until now prevented the development of the railway network and train stations. In addition, some stations have been destroyed, such Ramadi, Fallujah, Mosul, and Salah Din, during the most recent battles in those cities **[3]**.

All the existing stations in Iraq are located within the city centers. For example, in the province of Babylon, the train station is in the city of Hilla, which is the center of Babylon province, because when these stations were established the population density was mainly in the city centers, as shown in Figure 5.

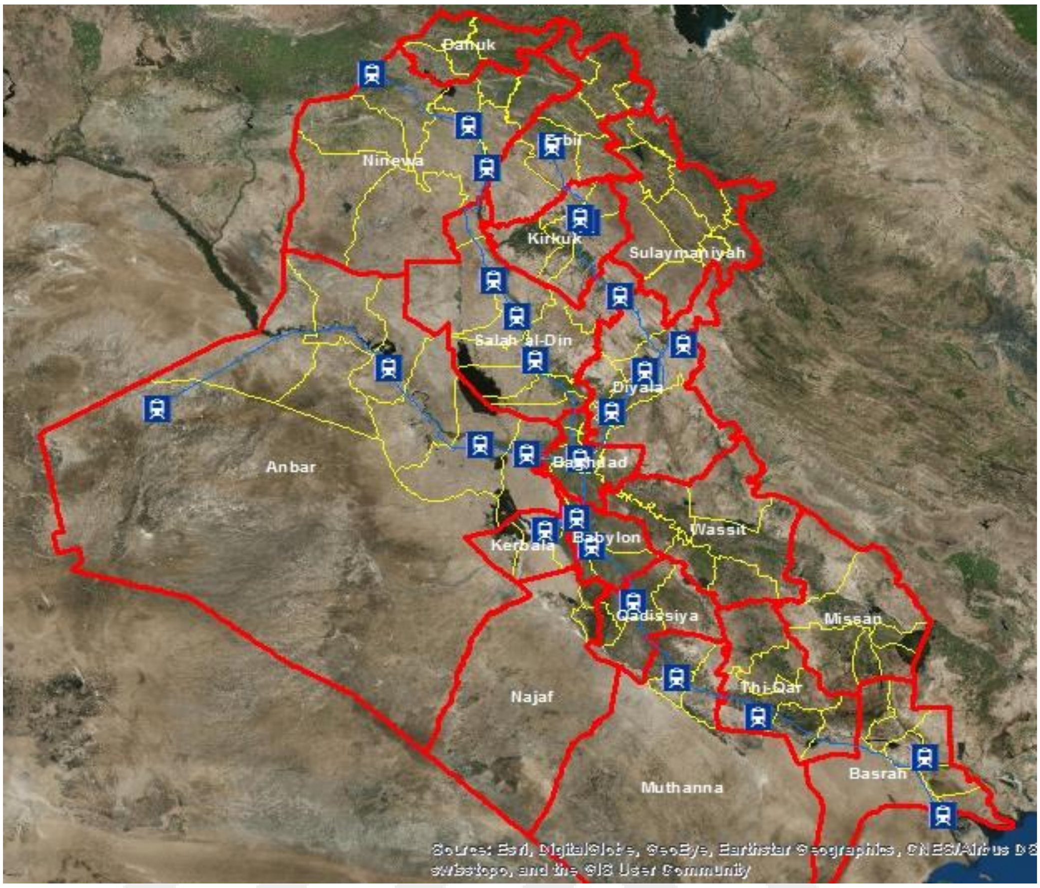


Figure 5 Train stations in Iraq

This study has two parts. The first part aims to analyze the current train stations in Iraq to determine the size of the problem by using network analysis to measure the access time from population density points to train stations depending on the existing road network. Then, the second part of this study aims to determine the best locations for new train stations that can be accessed by people within a walking time of 20 minutes **[4].**

1.2 Problem Statement

There are many reasons why train stations are a big and real problem in Iraq. First of all, the last census showed that Iraq has a population of approximately 32 million people. So, establishing new train stations is very important in Iraq because the number of people is increasingly continuously every year while the train stations remain the same and without new upgrades. All of those people need transportation. In addition, they need goods and other services. So, it is necessary to upgrade the

Iraqi railway network and to predict new train stations that can be used in daily life instead of the road network **[5]**.

Secondly, in the last four years, the average quantity of petrol consumed in Iraq was 20 million liters per day. So, the emissions of pollutants resulting from the use of this petrol are huge and dangerous for people, animals, and even plants. In addition, this problem will affect people's budgets because they need to use their cars every day. To conclude, this problem has a big impact on people and will even affect the government, because the government should be able to provide this large amount of petrol **[6], [7]**. Figure 6 shows one of the crowded streets of Baghdad.

Figure 6 Congestion on the roads in Baghdad province

Thirdly, what about traffic jams on the road network? Upgrading the Iraqi railway network and locating new stations depending on some criteria will decrease the congestions on the streets network. For example, the maximum carrying capacity on the roads in Iraq is 60 tonne, but on the railways, it is possible to carry more than 100 tons on the goods transport network lines **[8]**.

All in all, locomotion by train is safe and good for people and can also save time and money for those people because locomotion by train depends on scheduled times. Also, using the train is better for the environment because all new trains work using electric power. So, there are no emissions of pollutants. Finally, using trains will enable people to save money. Also, it will enhance the country's economy **[9]**.

For all the above reasons, the railway network is not adequate for today's life and today's requirements. Studying this network and planning to upgrade it by using traditional methods is very difficult and too complex because a very large amount of data are related to this railway network, but it is easy when using GIS techniques and accurate results will be obtained through the analysis and other techniques to achieve the predefined aim **[10]**.

1.3 GIS for Railway Network.

GISs are computer-based systems with the ability to capture, store, display, retrieve, and analyze data. GIS are depending on both spatial and historical data, to perform any of these functionalities, which mentioned above. In addition, there are five components of a GIS, namely data, hardware, software, people, and the method. The most critical part is the data, because the data are the key to starting working with a GIS. Railway projects are infrastructure projects and all of the infrastructure projects have a spatial representation on the real earth's surface. So, studying, analyzing, and upgrading the railway network by using GIS functionalities is the best method of obtaining accurate and efficient results. In railway projects, geographic analysis is the key to making better decisions. For example, in this study, the best locations for new train stations were determined accurately because these locations result from analysis depending on predefined criteria **[11].**

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. In addition, the road network should be considered when we want to decide on a new location for a train station because the accessibility value of that location depends on 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 **[12]**.

Figure 7 shows the railway network analysis by using the network analysis technique in GIS.

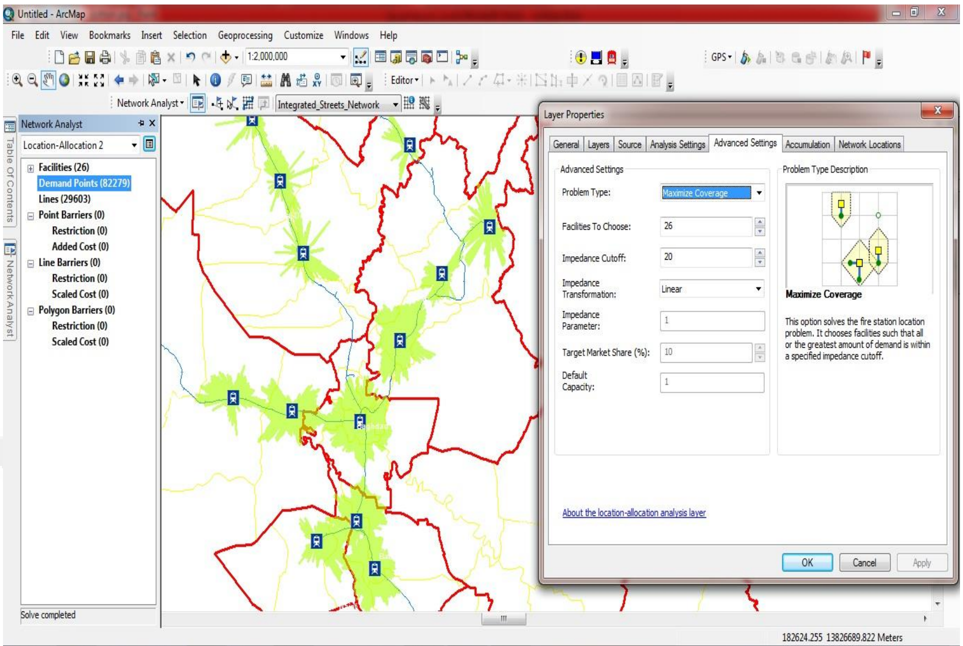


Figure 7 Railway network analysis

1.4 Aim and Scope

The main aim of this dissertation is to use the GIS functionalities to study and develop train stations in Iraq. To achieve that aim, the work was divided into two stages: analysis of the current train stations and prediction of the best locations for new train stations. The first part 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 and also to know the numbers of people who can reach those stations within a walking time of 20 minutes. The analysis of current train stations depends on the road network, because people use roads to reach train stations.

The second part aims to determine the best candidate locations for new train stations, and these locations result from the application of some criteria. In addition, the new locations should serve people within 2 km or a walking time of 20 minutes. Therefore, the new locations can achieve the aim of this study.

This study aims to build an integrated environment so the user can deal with and upgrade the railway system by the easiest method. The new system is a hybrid system because combines the ArcGIS® application, PYTHON™ programming language, and ASP.NET (C#) programming language.

The ArcGIS® application was used to manage and prepare spatial data for the Iraqi railway network and to analyze all current train stations in Iraq. This analysis using the existing road network aims to show all stations that people can access from their residences within a walking time of 20 minutes.

In addition to the ArcGIS® application, a new tool was built on top of ArcGIS® by using Python™ language. The purpose of this tool is to find the candidate locations for new train stations depending on the distance between the density points of the population and the new chosen sites and also taking into consideration the number of people in the surroundings of the chosen location.

Furthermore, the new toolset contains three new tools that have been developed on top of ArcGIS® by using Asp.Net(C#) programming language in order to manage and view the results and navigate between the resulting layers. Nevertheless, the user can preview the results and see both the serviced areas and the number of people served by current stations and candidate stations; also, the user can discuss and print any of the results.

1.5 Research Questions

An attempt was made to answer these questions, which represent the aim of this thesis:

- Do Iraq's railroads play a good role in transport and can they meet the requirements of the Iraqi people?
- Can the current train stations in Iraq cover all areas with high populations?
- 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?

1.6 Motivation

I live in the province of Babylon in Iraq and work at the University of Babylon, which is approximately 18 km from my home. When I want to reach my workplace, there are no other choices aside from using my private car every day. This is the main issue that motivated me to carry out this study. Furthermore, the GIS course was one of the study courses I took, and after studying this course, I wanted to search for solutions to the transportation problem in Iraq. In addition, when I came to Ankara to study for my Master's degree, I saw the big role played by trains in the transportation system.

1.7 Software Used in this Research

Mainly the ArcGIS® package was used in order to manage spatial layers and prepare the data for use. In addition, ArcGIS® was used to analyze the train stations. Furthermore, PYTHON™ programming language was used to build a new tool on the top of ArcMap to determine the best candidate locations for new train stations. Also, extra tools were built on top of ArcMap to manage the results and represent maps by using Asp.Net (C# 2010) programming language, as shown in Figure 8.

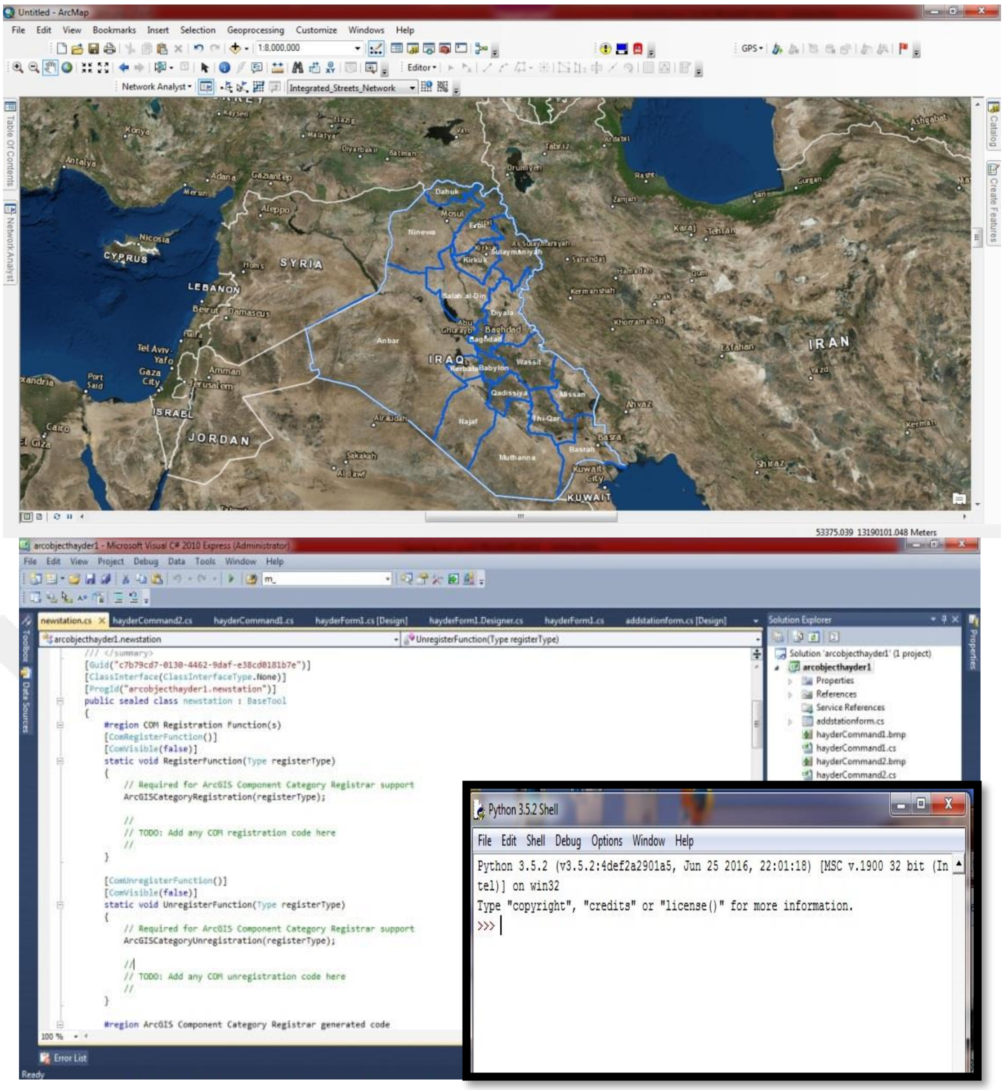


Figure 8 Software used

1.8 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 Figure 9.

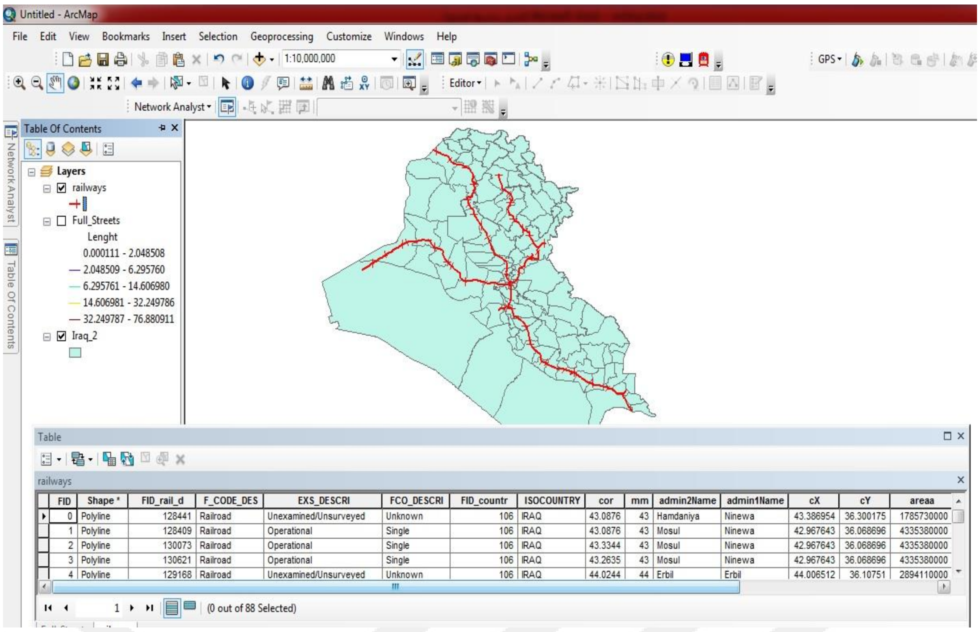
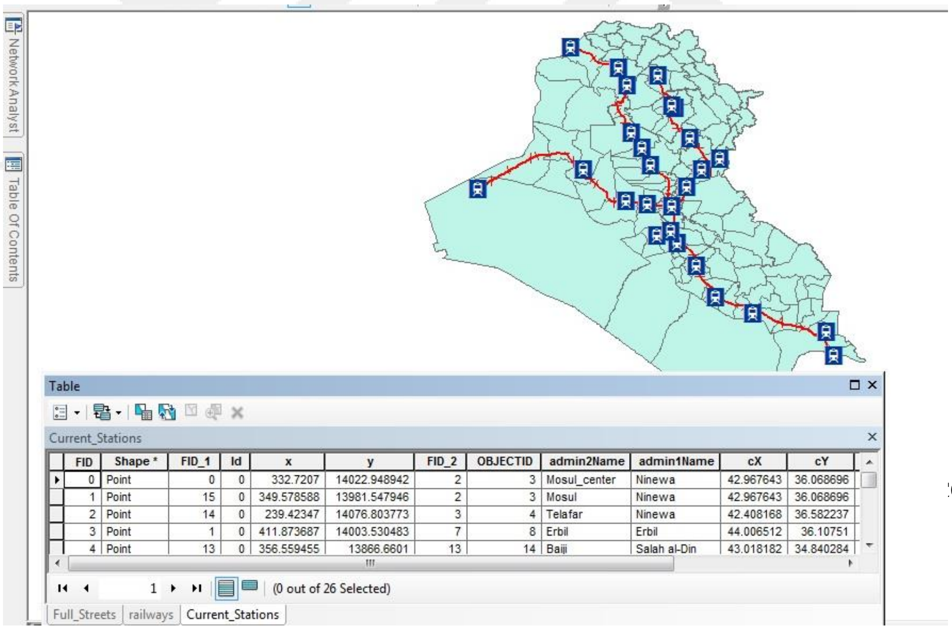


Figure 9 Iraqi railway layer

- Figure 10 shows the layer of current train stations in Iraq, which contains 26 records of train stations in the Iraqi provinces.



ords of

Figure 10 Iraqi train station layer

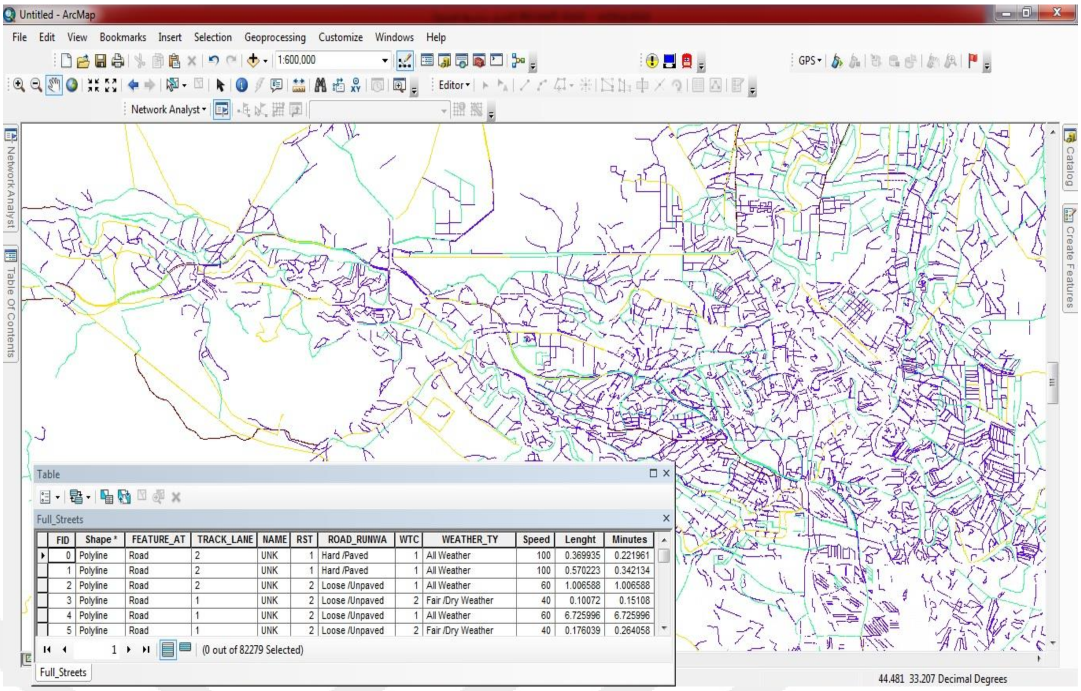


Figure 11 Road network layer

- The population density layer which it is a point layer containing information about the population density of each city in all Iraqi provinces, as shown in Figure 12.

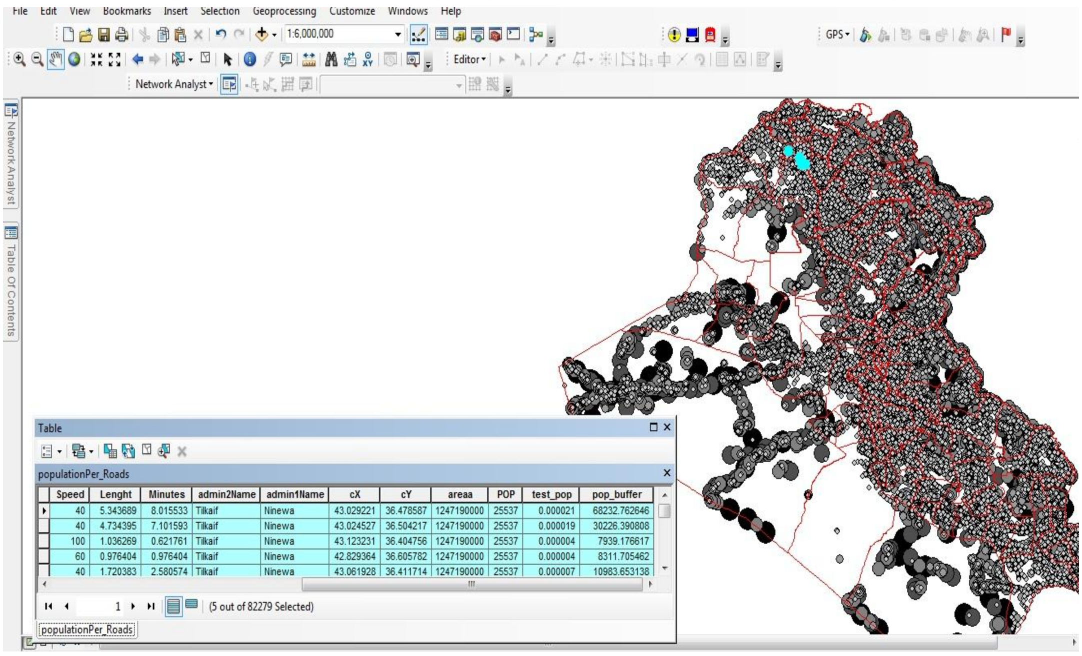


Figure 12 Iraqi population density layer

These are the main raw data used in this research. In addition, these raw layers were used to generate new layers by using GIS techniques, which will be mentioned in the coming chapters.

1.9 Research Method

Firstly, a lot of time was spent collecting all the data, which are related with the Iraq railways network, because without data it is not possible to work with GIS. Therefore, all data were collected in order 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.

Secondly, 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.

Thirdly, a new tool was built in the ArcMap environment by using PYTHON™ programming language. This new tool is able to determine the best candidate locations for new train stations depending on some criteria.

Fourthly, by using ASP.Net (C#) programming language, a new toolset containing three tools was built. This new tool was built on top of ArcMap. Each of these tools was built for a specific purpose, as follows:

- Showing information about tools;
- Obtaining the X and Y coordinates anywhere on the screen by using the mouse and opening a new form in order to add a new candidate location;
- Navigating between results and presenting any of these results as a map as well as enabling the user to see records for any result. In addition, by using this tool we can print any of these cartographic results.

Figure 13 shows a diagram of the methodology followed in this research.

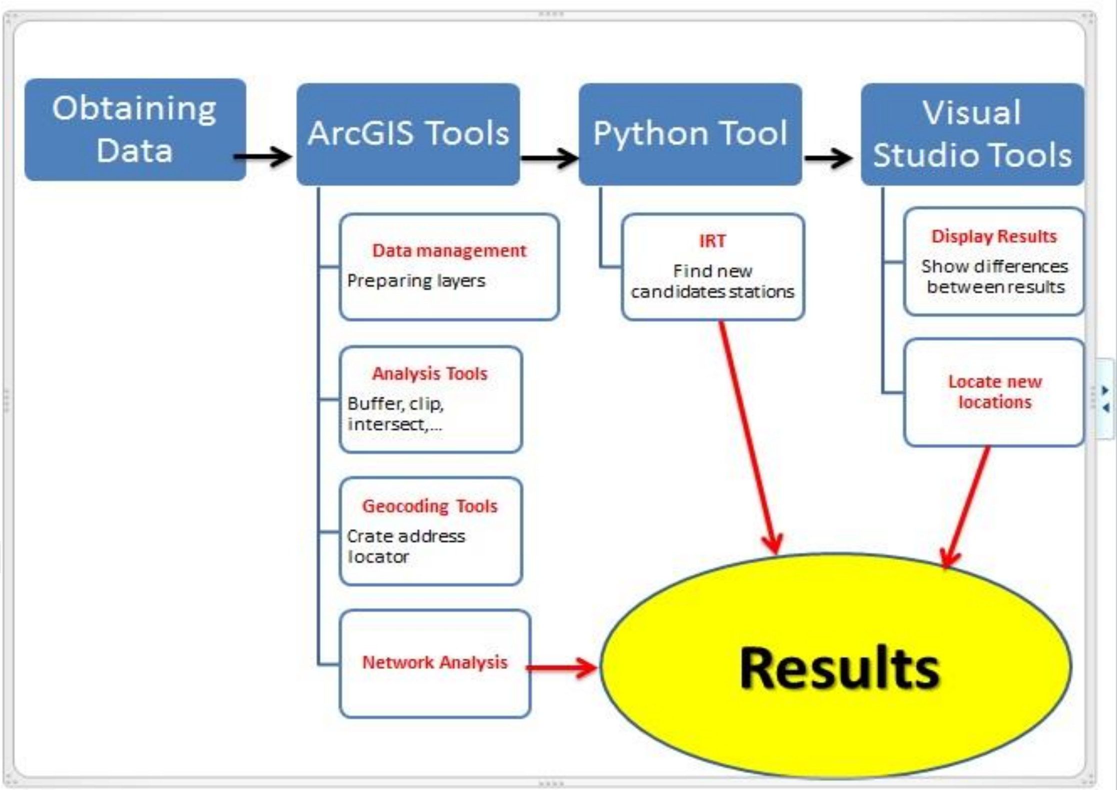


Figure 13 Diagram of the research methodology

CHAPTER 2

Background and Literature Review

This research focuses on GIS and the Iraqi railway network in order to determine the best locations for train stations in Iraq, as mentioned in the first chapter. So, it is necessary to present the main concepts of GIS techniques and the railway network. Therefore, studies in the literature will be reviewed in this chapter and the problems addressed in this research will be mentioned in this chapter.

2.1 Geographic Information Systems

What is a GIS? A GIS is a computer-based system consisting of a collection of integrated tools that represent the GIS functionalities, which are as follows:

- **Capturing data.** There are two types of geographical data: spatial and tabular. For example, a hospital can be represented by using a polygon but its name and other features are stored as tabular data. There are some different resources for data, as follows:
  - **X and Y coordinates**, using specific devices, for example, GARMIN;
  - **Digital data** [global positioning system (GPS) and remote sensing (RS)];
  - **Digitized maps**.
- **Storage.** GIS data are stored in two main formats:
  - **Raster**. This type is based on images that are represented as cells on the computer screen to reflect a specific location on the earth’s surface with its features.
  - **Vector**. This type is based on coordinates that reflect the earth’s surface. In this type, the earth’s features are represented by a series of points that represent the (X, Y) coordinates.

- **Spatial analysis.** GIS is used to answer questions depending on analysis of the relationships between shapes on the maps. Three kinds of analyses are used to solve spatial problems:
  - **Network analysis**, carried out between groups of objects such as roads, railways, sewers, and so on;
  - **Proximate analysis**, carried out between objects such as distances, buffers, and so on;
  - **Overlay analysis**, carried out between map layers, such as clip, intersect, merge, and so on.
- **Retrieval**. Queries can be used to determine specific features. They can be complicated or simple depending on the capability of the GIS software, available data, and query type.
- **Displaying data**. There are some different kinds of data that are displayed by GIS but basically all of these kinds are displayed as maps' format or graph tables.
- **Production of output**. This includes both soft and hard copy such as tables, images, digital maps, paper maps, documents, and files that can be used in other applications, such as internet services, databases, and so on **[13]**.

  GIS comprises a map and the dataset behind that map. By using GIS, we can solve and analyze many problems that have spatial references. For example, if we are looking to create a new bank, looking for the best soil for growing apples, or looking for the shortest way to the shopping center, all of these problems have a geographic component, so we can use the GIS to find the best solution to each question. In addition, GIS can be used to support scientific queries on the maps in order to understand the relations between shapes on the maps that reflect the real earth's surface by relying on the data behind those shapes **[14].**

The GIS solves the spatial problems depending on the available data related to these problems. Thus, the available data determine the types of problems that can be solved with GIS. Mainly, GIS helps to answer many questions pertaining to locations (what is at ...? where is the capital city of …?), measurements (distances, areas), conditions (which cities that have populations of more than 100,000 people?), the typical distribution of infrastructures (what is the relationship between the distribution of schools and the population in a specific area?), changes (what changes have happened in the city of … since 1980?), scenarios (what happens if the number of residents in the city is above 1000000?), and finding the shortest path (what is the most suitable route between the city center and …?), as shown in Figure 14.

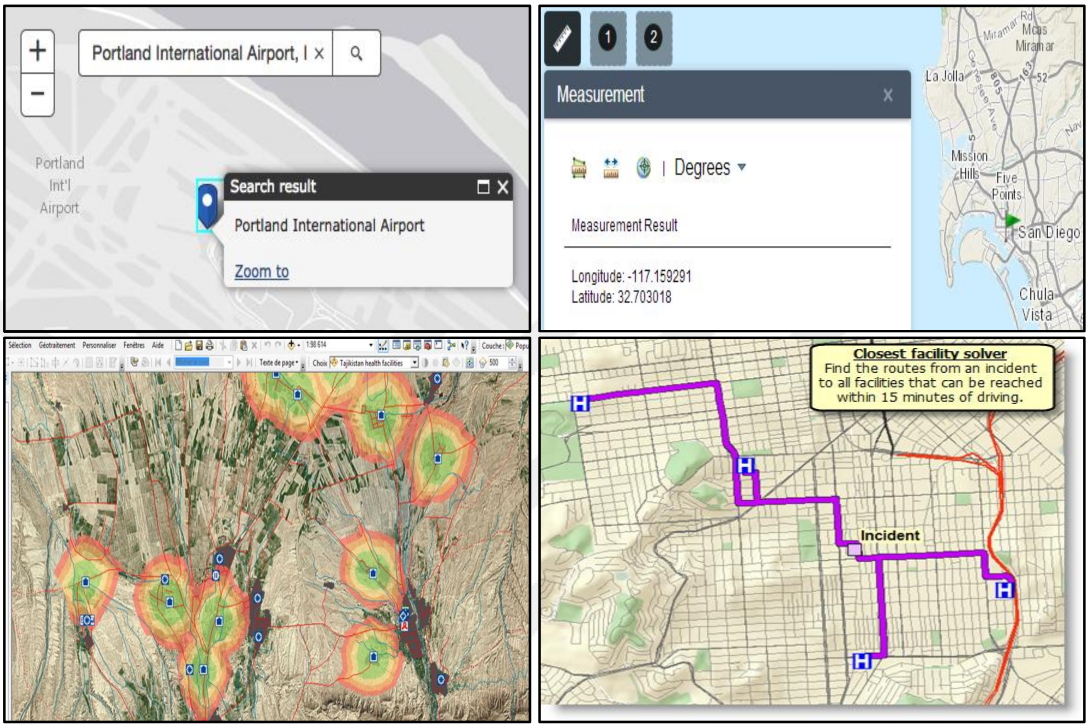


Figure 14 Samples of GIS uses

GIS depends on both spatial and tabular data to solve problems that have spatial references on the earth's surface. The GIS is a virtual representation that reflects the real earth's surface on a computer screen. GIS is also used as a decision support system to monitor ongoing projects on the earth's surface **[15].**

2.1.1 Basic Components of GIS

There are five main components of a GIS, as follows:

- **People.** A GIS, like any information system, needs people to deal with it and to use its functionalities (techniques). People are the most critical part of the GIS components because people are the ones who benefit from GIS techniques. There are three kinds of people who deal with GISs:
    1. **Viewer users**, who use GIS just for viewing maps and browsing the datasets related to these maps, for example, browsing Google maps;
    2. **General users,** who use GIS to set up new businesses or to improve decision making, such as managers and engineers;
    3. **Specialist users,** who are able to solve spatial problems and who should have the ability to administer databases and GISs. These users are able deal with all GIS tools or to develop new GIS tools in order to make a good environment that is able to cover all the parts of the problem that we want to handle, such as programmers, urban planning engineers, and computer engineers.
- **Method**. This is the procedure used to produce the final solution. The method consists of some steps to capture, store, and analyze data and display the results. The steps of the procedure should be well defined before starting in order to find a good solution to achieve the desired aim. The selection of the procedure depends on the available data, problem type, and available hardware and software.
- **Data**. Data are the most important component of GIS, because without data there is no GIS. Both spatial and tabular data are important because we need coordinates and attribute data that belong to these coordinates. For example, with regard to a street, we need its name and width in addition to its coordinate points. Data type and data accuracy determine the types of problems that the GIS can deal with. There are different resources for GIS data. As mentioned before, there are two main data types in a GIS:

1. **Spatial data**, comprising all data with spatial references. These data reflect the real earth's surface with its infrastructure on the computer screen. The spatial data are categorized into two sub-types, namely:

   - **Raster data**. This type is based on raster images and represents the earth's surface features using a grid of cells. The cell size determines the resolution of the data. The raster images are obtained from photographs, scanned maps, satellite images, and so on and are often useful to represent continuously changing attributes like terrains, as shown in Figure 15.

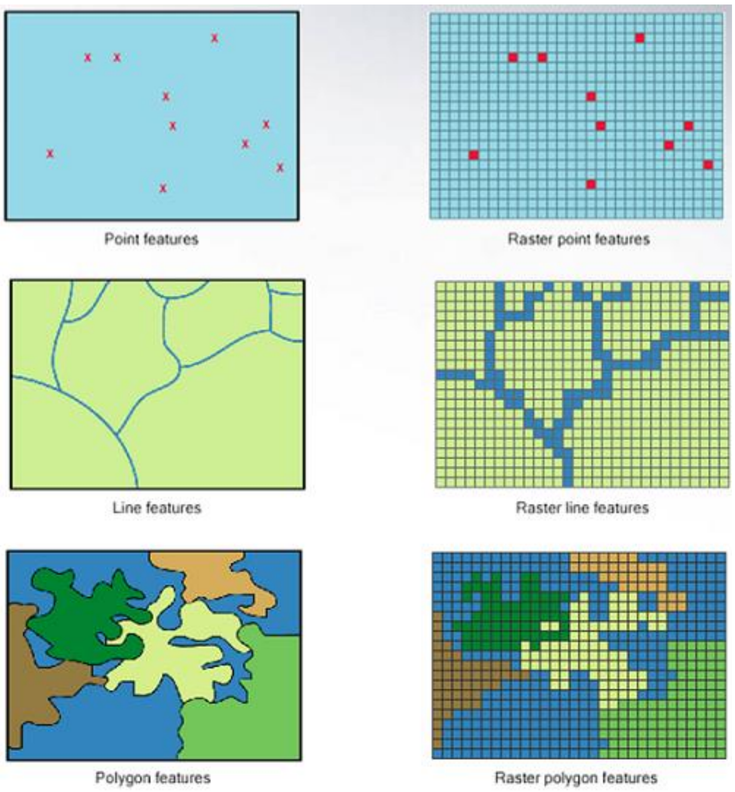


Figure 15 Representation of earth's surface features to raster image

   - **Vector data**. Data of this type are presented and organized as layers, which reflect the earth's surface features with their explicit locations and coordinates. Features are represented by a series of coordinate points. The vector type is useful for reflecting clearly defined and static features like roads, rivers, railways, and so on. Also, with this type of data, all the spatial relationships between objects (features) can be defined, as shown in Figure 16 **[16]**.

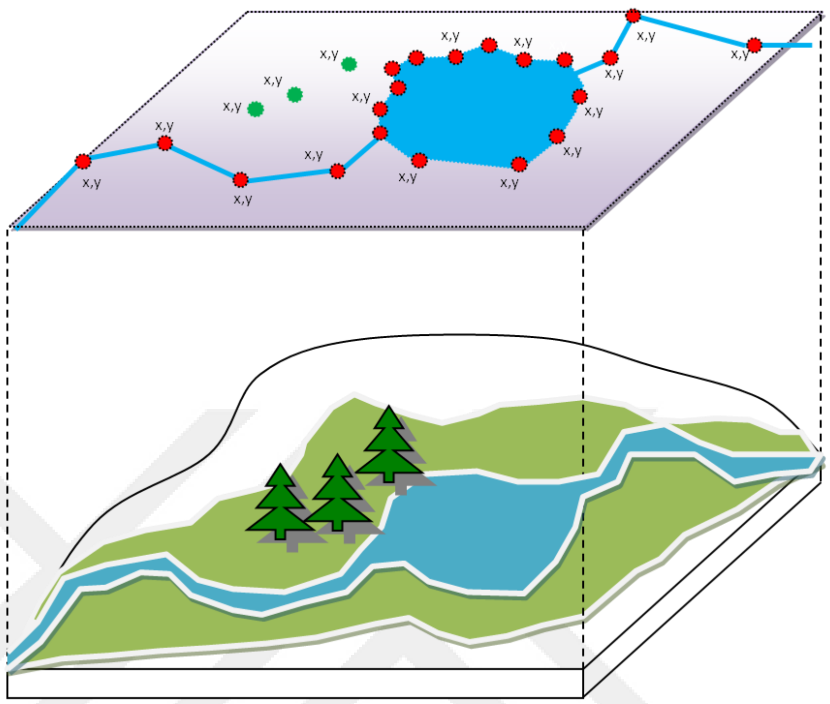


Figure 16 Representation of earth's surface features to vector layer

There are three types of Vectors layers, as follows:

- Points. For example, trees can be represented by points.
- Polyline. For example, railways can be represented by polylines.
- Polygon. For example, schools can be represented by polygons, as shown in Figure 17 **[17]**.

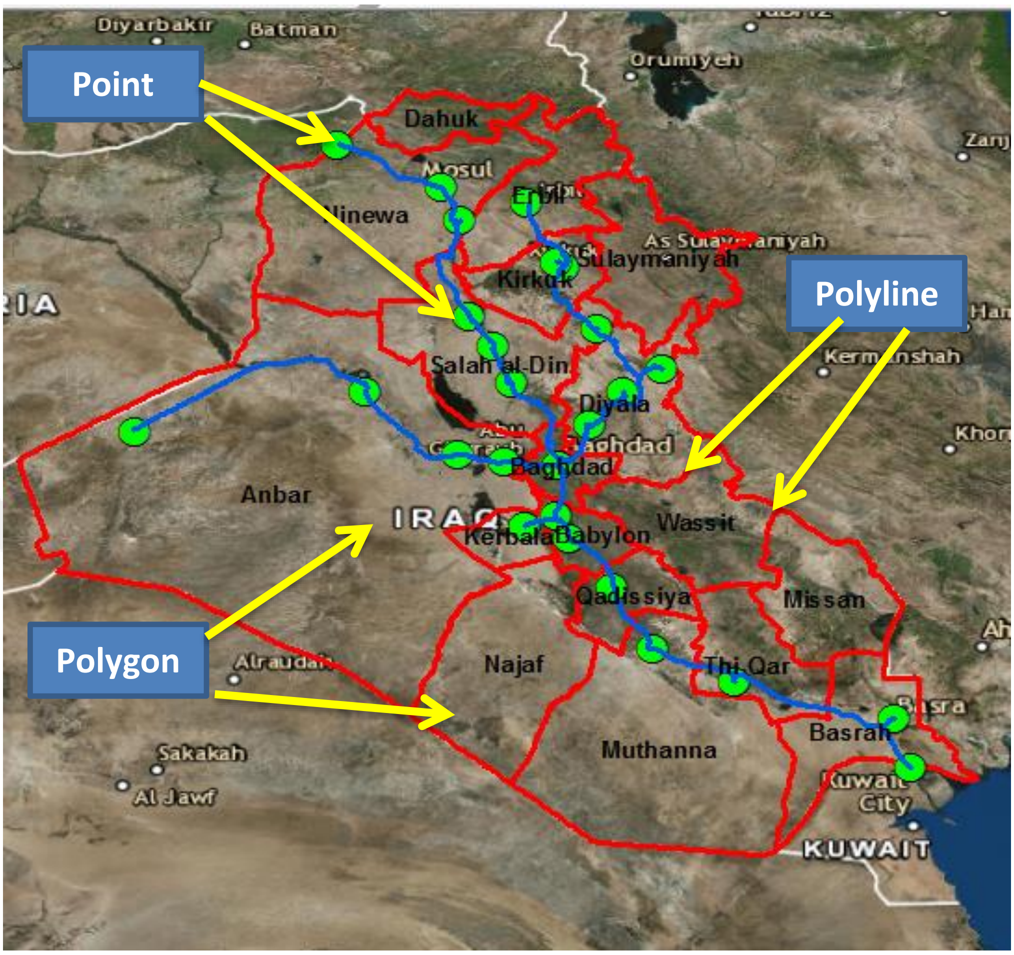
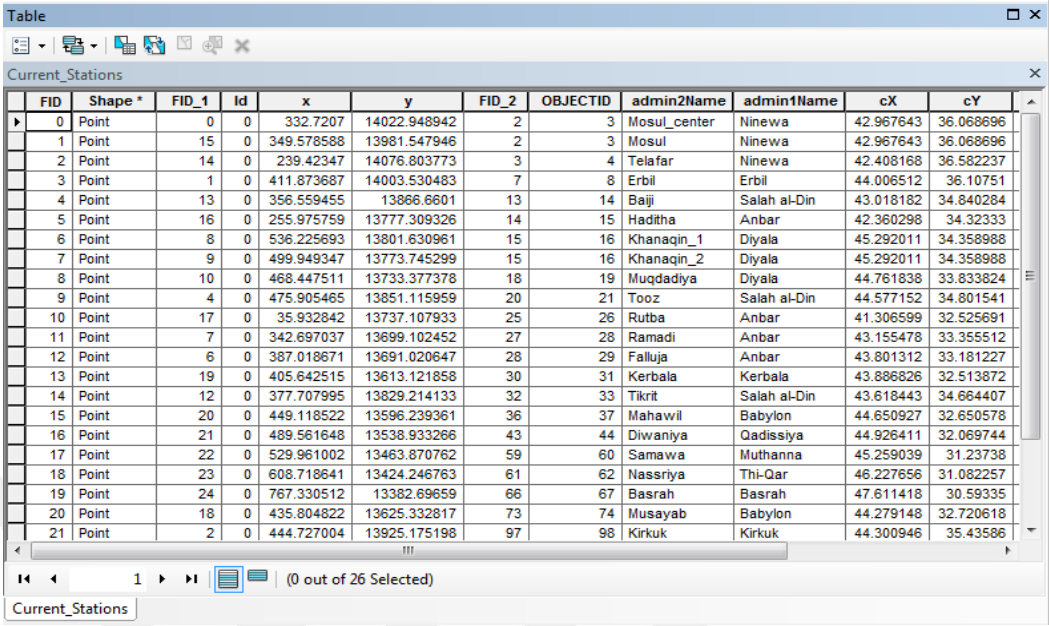


Figure 17 Layer types

In this thesis, all data that will be used is a Vector data.

2. **Tabular data.** Non-spatial data means all data that do not have any spatial references but it represent the attributes of those spatial objects. Non-spatial data are also called tabular data. Tabular data are very important for solving problems and retrieving data. To solve any problem with GIS, both spatial and historical data related to these spatial data are required, for example, if one needs to find cities with populations of more than 100000. There are different resources for tabular data such as Excel, SQL, MySQL, Microsoft Access, and so on. Moreover, it is easy to link these data with the spatial data. Figure

18 shows a sample of tabular data, the attributes table for the train station layer.



Table

Current_Stations

FID	Shape *	FID_1	Id	x	y	FID_2	OBJECTID	admin2Name	admin1Name	cX	cY
0	Point	0	0	332.7207	14022.948942	2	3	Mosul_center	Ninewa	42.967643	36.068696
1	Point	15	0	349.578588	13981.547946	2	3	Mosul	Ninewa	42.967643	36.068696
2	Point	14	0	239.42347	14076.803773	3	4	Telafar	Ninewa	42.408168	36.582237
3	Point	1	0	411.873687	14003.530483	7	8	Erbil	Erbil	44.006512	36.10751
4	Point	13	0	356.559455	13866.6601	13	14	Baiji	Salah al-Din	43.018182	34.840284
5	Point	16	0	255.975759	13777.309326	14	15	Haditha	Anbar	42.360298	34.32333
6	Point	8	0	536.225693	13801.630961	15	16	Khanaqin_1	Diyala	45.292011	34.358988
7	Point	9	0	499.949347	13773.745299	15	16	Khanaqin_2	Diyala	45.292011	34.358988
8	Point	10	0	468.447511	13733.377378	18	19	Muqdadiya	Diyala	44.761838	33.833824
9	Point	4	0	475.905465	13851.115959	20	21	Tooz	Salah al-Din	44.577152	34.801541
10	Point	17	0	35.932842	13737.107933	25	26	Rutba	Anbar	41.306599	32.525691
11	Point	7	0	342.697037	13699.102452	27	28	Ramadi	Anbar	43.155478	33.355512
12	Point	6	0	387.018671	13691.020647	28	29	Falluja	Anbar	43.801312	33.181227
13	Point	19	0	405.642515	13613.121858	30	31	Kerbala	Kerbala	43.886826	32.513872
14	Point	12	0	377.707995	13829.214133	32	33	Tikrit	Salah al-Din	43.618443	34.664407
15	Point	20	0	449.118522	13596.239361	36	37	Mahawil	Babylon	44.650927	32.650578
16	Point	21	0	489.561648	13538.933266	43	44	Diwaniya	Qadissiya	44.926411	32.069744
17	Point	22	0	529.961002	13463.870762	59	60	Samawa	Muthanna	45.259039	31.23738
18	Point	23	0	608.718641	13424.246763	61	62	Nassriya	Thi-Qar	46.227656	31.082257
19	Point	24	0	767.330512	13382.69659	66	67	Basrah	Basrah	47.611418	30.59335
20	Point	18	0	435.804822	13625.332817	73	74	Musayab	Babylon	44.279148	32.720618
21	Point	2	0	444.727004	13925.175198	97	98	Kirkuk	Kirkuk	44.300946	35.43586

1 (0 out of 26 Selected)

Current_Stations

Figure 18 Attributes table for current train stations

It can be concluded that non-spatial data can be incorporated with its spatial references easily even if it were not ready, or they were in the form of paper documents. Non-spatial data can be entered manually by adding the required fields in the attributes table for any spatial data and then entering the data. Also, these data can be added by linking to spatial features. Spatial data, however, cannot be entered manually but must be entered by using dedicated hardware such as GARMIN.

Consequently, spatial data remain the most important part of the GIS.

- **Hardware.** As mentioned before, a GIS is a computerized system, which means there should be computer units to operate and deal with it. The type of available hardware determines the GIS software that will be used. Different hardware components are used for GIS, such as computer units (i.e. RAM, CPU, etc.), retrieval units (i.e. GPS, remote sensors, camera, etc.), and data portrayal units (i.e. monitors, printers, plotters, etc.).
- **Software.** GIS software is a full package that should able to perform all of the GIS functionalities such as drawing, displaying, and analyzing data,

dealing with datasets, storing data, and so on. The GIS software and its options determine the types of output results. The most popular GIS software is ArcGIS®, because this software has a large number of tools. Also, there is specific GIS software that was built for specific purposes such as the EGO system, which manages movement and routes of buses in Turkey **[17].** Figure 19 shows the main components of the GIS.

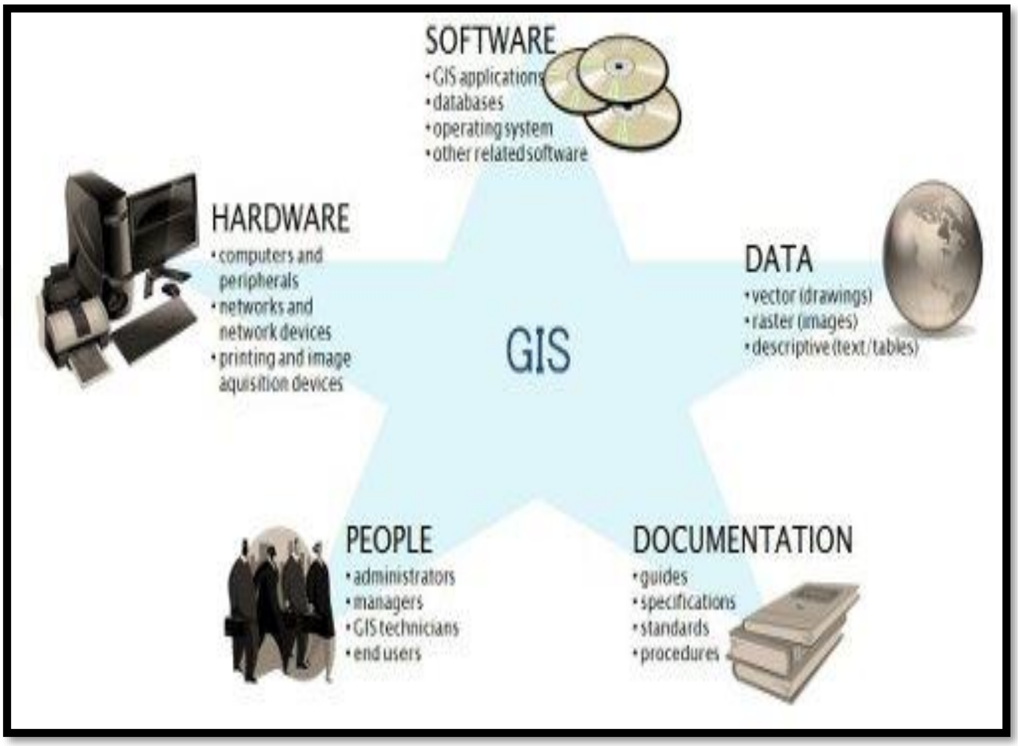


Figure 19 GIS components

2.2 Railway network in GIS

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 **[18].**

2.3 Criteria Used in this Study to Determine the Best Locations for New Train Stations in Iraq

Some criteria that were applied in this thesis 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
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.
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 them.
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.
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 the 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.

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.

2.4 Network Analysis

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

Network analysis depends on two algorithms, DIJKSTRA and VORONOI, to solve the problem, calculate the service areas, find the shortest paths, and so on.

In this study, we will use new-location allocation because the aim of this study is to determine the best locations for new train stations **[19].**

2.5 Problems

The problems covered in this thesis are related to Iraqi railway lines and train stations, as follows:

1. The problem of Calculation the population density rate on all urban roads around Iraq. A specific formula was used to calculate the approximate population density for every road because, as mentioned before, there are no accurate data on the populations of Iraqi cities. The formula used will be mentioned in the next chapter.

Population per road is important because the network analysis depends on the existing road network to solve problems. Figure 20 shows one of the highways in Iraq and the empty area around it.

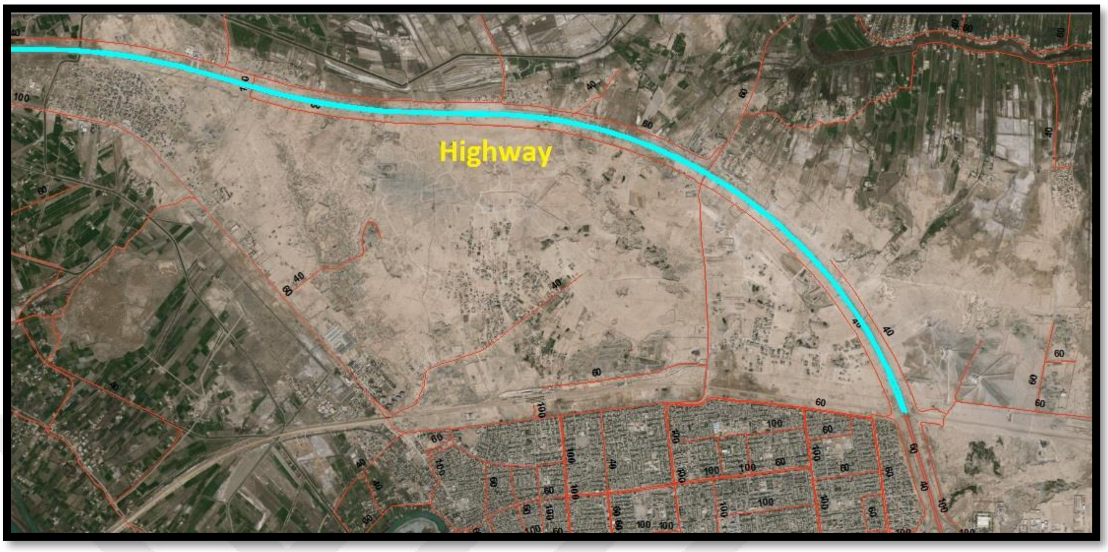


Figure 20 Population density problems

2. Measuring the accessibility value for current train stations. The network analysis technique in GIS was used for this purpose. The network analysis was performed by applying some criteria that will be mentioned in the next chapter (Figure 21).

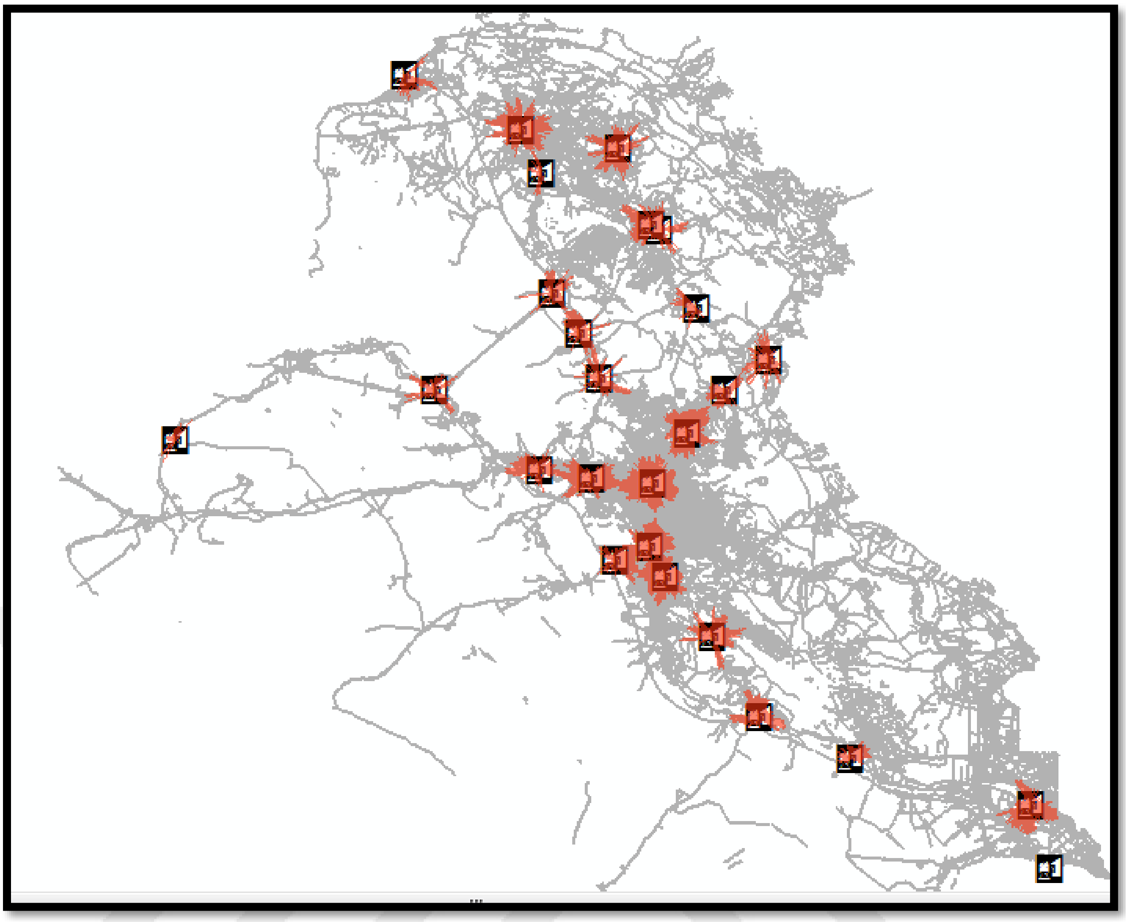


Figure 21 Sample of the results of analysis, current train stations

As can be seen, there are many locations that are more than 20 minutes away from those stations.

3. Determination of the best locations for new train stations. To achieve this goal, a new tool was built on top of ArcGIS® software by using the PYTHON™ programming language. This tool determines candidate locations based on the distance between demand points (population points, which represent the central points of the roads, with each point taking the same attributes of the represented road. Put differently, the population points result from converting the roads to points, which are the centroids of the roads) and the new location. Furthermore, the new locations can be selected depending on the population density values around the new candidate locations, as shown in Figure 22.

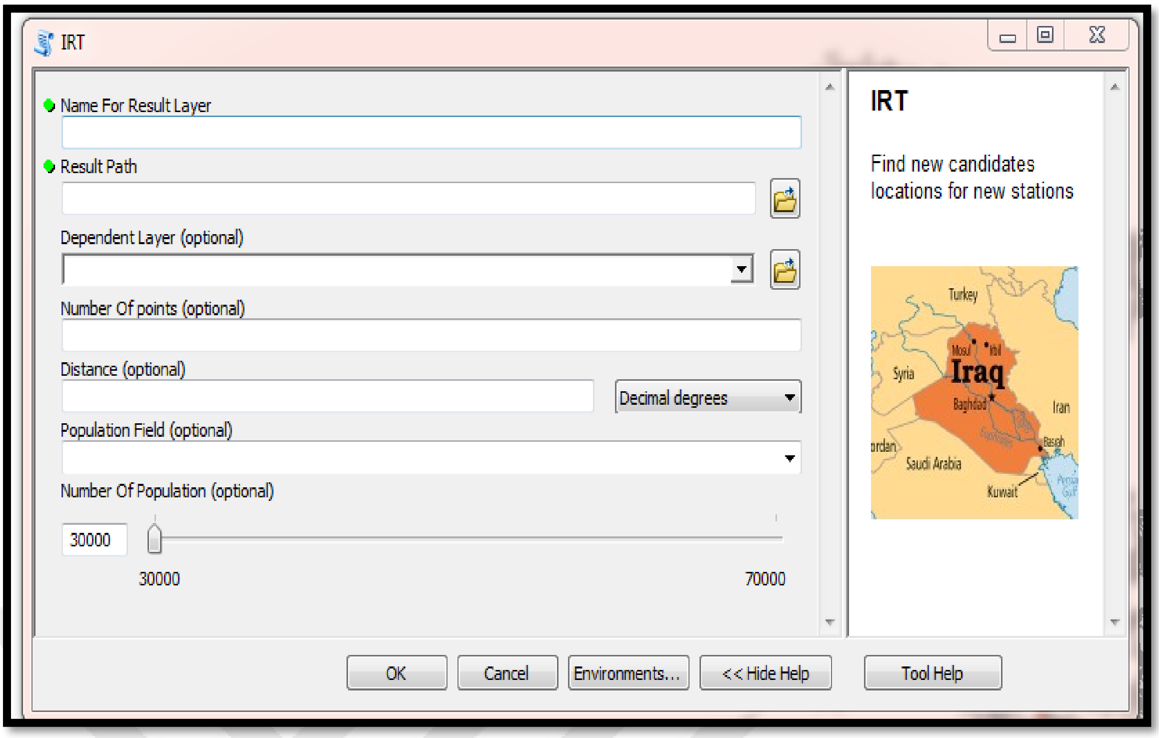


Figure 22 The new Python tool

4. Browsing and extraction of the results. For this purpose, a new toolset was developed using Asp.Net (C#). This toolset was built on top of ArcMap 10.2. In addition, by using this tool, the user can add new train stations as appropriate. Figure 23 shows the new toolset, which was developed on top of ArcMap 10.2.

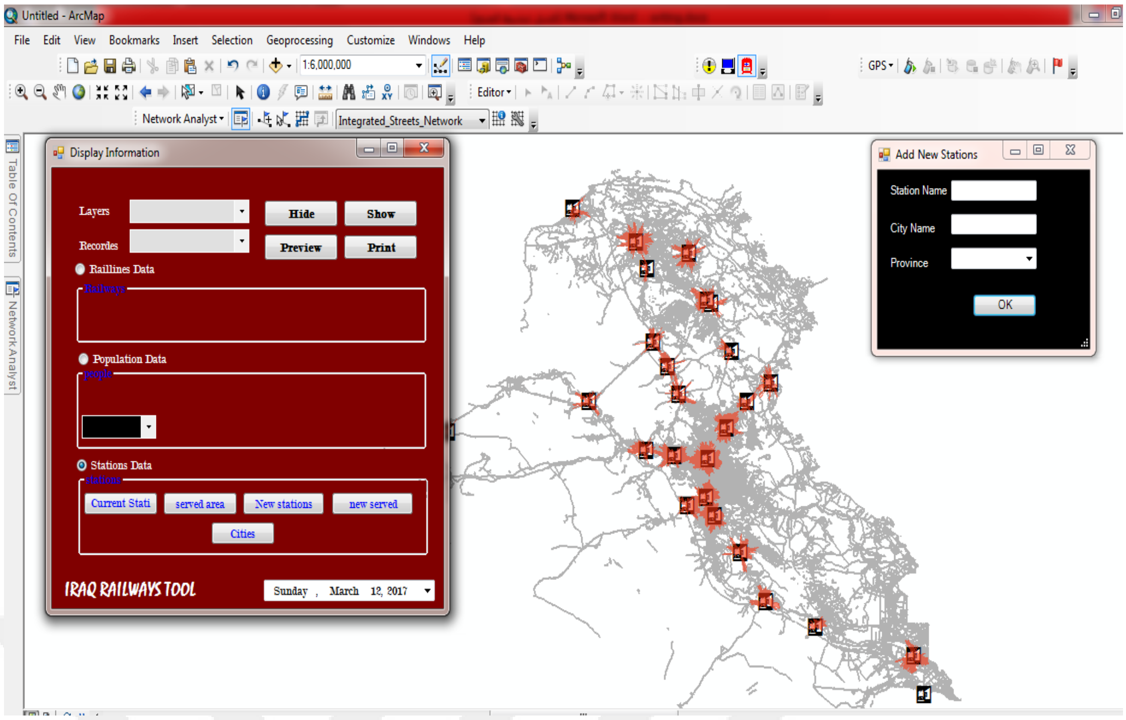


Figure 23 New toolset to browse and manage the results

2.6 Literature Review

Sjimmie (2012) aimed to measure the flow of passengers to some new train stations in the Netherlands. For this aim, the author 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 Sjimmie has applied these two methods in order to compare them. In addition, this is considered a good way to see which method is the best **[20]**.

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.

Dongwei and Qinghuai (2009) aimed to determine new locations for new railway lines. They used GIS with the ANT algorithm in order to achieve the study's aim. In order to locate new railway lines, some factors taken into consideration were the construction cost, earth surface type, surface topology, length of railway line, and environmental influence. The authors used these factors as limitations for the ANT algorithm. The factors were measured by using buffer analysis, overlay analysis, and hierarchical analysis, and all of these analyses were performed by using GIS. The ANT algorithm was used to find the best path that has good factors. In addition, the Dongwei and Qinghuai did not take into consideration the numbers of people who will use these new train lines. However, we are thinking in another way because the aim of this research is to find new train stations that are able to serve as many people as possible. Also, the earth's surface in Iraq is the flat type, so there is no need to take into account the surface topology for the railway lines. **[21]**.

Another study was conducted in Guangxi region, China, by Rong, Yingjie, Hongsheng and Zhuoyuan (2010). This study concerns 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 **[22].**

In **[23]**, Qingming, Xingang, and Yinghui (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, they 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.

Another study was conducted by Liu (2016) in the Beijing area. The aim of this study was to analyze the train stations and railway lines in order to find out the influence of the railway network in urban areas. In addition, the author wanted to show the affected areas around each train station. The author used spatial analysis to achieve the aim of the study. Spatial analysis was used in order to show how the railway networks contribute to the development of cities and to show how the area around each station (metro or train) was influenced. The spatial analysis was done by using the distance parameter, which represented the radius of the influenced area around each station. The author used 0–15 km as the distance parameter to analyze the influenced areas around metro stations and 15–30 km for train stations. However, in the current research, another method was used to analyze train stations in Iraq, namely network analysis, in order to show the areas around each train station that have good accessibility values. Also, time was used as a cost factor in the network analysis, instead of distance factor **[24]**.

Furthermore, another study was carried out in India using a new method to determine the numbers of people who could use these stations. This method entailed putting electronic sensors near the candidate locations for the new train stations. These electronic sensors were linked with a control center by wireless devices and when using this method continuously, maintenance and monitoring are required, so this will lead to spend more money and time. Sensing technology is a type of fast processing that can be used to collect reliable data, but it is more expensive and takes more time. In the opinion of the author of this thesis, this method is reliable and good and the data will be more accurate because, as is well known, there are no accurate data of population density with 100% percentage. However, it costs more money and consumes more time **[25].**

Quinn (2012) aimed to show the relationship between population density and the road network in Canada. The author used Saint Lucia city as a case study for this research. In Quinn's study, Quinn used GIS to calculate the total length, denoted as **L**, to represent the road network in Saint Lucia city. Then the author also calculated the population density, denoted by $\mathbf{D_P}$**,** by using GIS in order to obtain the population density on the roads, $\mathbf{D_R}$, given by $\mathbf{D_P/L}$. The results showed that the relation between population density and the length of the road network in Saint Lucia city is $\mathbf{D_P = \sim 10–30\ D_R^2}$**.** This method is a general method of calculating the proportion of the population in a determined area. For example, when we want to find the population density in Iraq for each square meter, we can use the formula of total population divided by total area, expressed in square meters, in order to find the number of people in each square meter. In this thesis, the main idea of how to calculate the population density on the road network was taken from Quinn's study. Then this formula was developed to make it more accurate and to calculate the data more accurately because it is well known that there is a negative relationship between highways and population density, as mentioned before **[26]**.

Research was also conducted by Diaz Roderick, Allen Booz, and Hamilton Inc. (1999) in North America. The goal of this study was to find the impact of the train stations on the surrounding areas. The authors used the property value and accessibility time as analysis factors. The relationship between property value and accessibility value is negative. That means that when the accessibility value decreased, the property value increased. The distance used by the authors for examining the impacted areas was 500 m around the train stations. The authors used the GIS technique in order to achieve the aim of the study. The same idea was used here in order to measure the serviced area around train stations in Iraq but by applying different factors. In addition to the network analysis, we used the service area analysis in order to obtain more accurate results **[27]**.

Ahsan (2001) aimed to determine the domain area for the train stations. This research examined Dhaka city in Bangladesh. The station domain defined in Ahsan's study is the areas around the stations that mostly attract passengers to use the train's services within those areas. The author used two methods to achieve the aim of this study. The first method used the VORONOI algorithm to determine the domain for each train station by taking 500 meter as the affected area around each station. The second method assumed that the domain area is the shared area between train stations that lie on the same railway line. Then the author used a specific formula to calculate the population density in the areas that were planned as a domain. This formula is as follows:

Total population in the domain area = total area of the planned station * planned population density in the planned areas.

The idea of using the VORONOI algorithm and the possibility of applying it to determine the shortest path between candidate train stations was taken as a one of the future works for this thesis **[28]**.

Another research was conducted by AASHTO GIS for the Transportation Symposium (2010) in the USA in Los Angeles city. The aim of this study was to analyze and measure the accessibility values of the train stations. The authors used network analysis, which is one of the GIS techniques, in order to fulfill the aim of this study. In this research, the authors used two different factors to analyze the accessibility values of train stations. These factors were a walking time of 20 minutes and a walking distance of 1.0 miles. The authors used these factors because, as they mentioned in the same research, "the average walking time is 20 minutes for the normal person". Furthermore, they used other input factors of 10 minutes and 0.5 miles in order to present another analysis level and to show the difference between the results. The same method was used in this research to measure the accessibility values of the train stations in Iraq and to find the number of people who could reach those stations within a walking time of 20 minutes **[29]**.

Thevenin, Mimeur, Schwartz, and Sapet (2016) performed a study in France to determine the difference between the train stations' accessibility and changes in population density. The authors used historical data in order to calculate the data for this study. The first step was linking the historical data with their geospatial locations in order to use GIS techniques to achieve the goal of this study. Then, the processing of the analysis involved the following steps:

- Both historical and spatial population data were displayed for a specific period, such as six years.
- The data were divided into two parts: normal data and dubious data.
- Train station data were used in order to draw a comparison between populations before and after the construction of stations.
- The variance rate between normal and dubious means the change in the rate of population density.

In the author's opinion, this is a good method if we want to depend on historical data. However, this method costs more time as well as more money **[30].**

Extracting a geo-schematic model from the same spatial data is a method that was applied by Samanah Seyedi (2014) in Sweden in order to analyze the railway network. In this research, the author generated a schematic model from a geographical dataset of Swedish railroads. The main factor used as the analysis parameter was the kilometer, which means the impacted area around a train station. The author used Avesta Krylbo, the central train station, as a case study. In addition, according to this research, the locations for new train stations can be determined by the same schematic model. The main idea of using a geo-schematic model is to analyze complex networks such as railways and make them easier to study. This research was done by using a schematic map extension with the ArcGIS® program **[31]**.

Another research was conducted in the Netherlands, specifically in Amsterdam, by Debrezion, Pels, and Rietveld (2007). This study aimed to determine the impacted areas around train stations in order to measure the accessibility value. To fulfill the aim of this study, the authors analyzed train stations by using meta-analysis. This analysis mainly depended on two parts: walking time and distance. The author used 20 min as time required to walk to the train stations. In addition, they used the distance factor in order to examine the distances from population density points to the train stations. For that purpose, the authors applied a multi-level method to analyze up to 2 km surrounding each train station using multi-distance values. Multi-distance values of 1/4, 1/2, 3/4, 1.0, 1.25, 1.50, 1.75, and 2 were used in order to examine the accessibility value per level. On the other hand, the author used a second factor to measure the accessibility value of each train station, which is the property value in the area surrounding the train station. The results of the second method show that for every **250 m** from the train station, the property value decreased by **2.3%**. Therefore, we used this research in order to learn the limitation of the walking time and the multi-level analysis method **[32].**

Guler, Akad, and Ergun (2004) aimed to show the benefits of using GIS in order to manage and develop transportation in Turkey and especially the railway network. Also, they wanted to show how it is possible to transform the work from the traditional methods to GIS methods in order to develop the railway network. In addition, with GIS, the goals can be easily defined and the achievement of these goals depends on the available data (spatial and tabular data). Also, by using GIS, the results will be accurate because they are obtained by applying specific criteria in order to meet the defined aims. In the study mentioned above, the authors analyzed the train stations by using GIS techniques. According to this research, GIS is the key for dealing with railways because of the huge amount of data related to it. Furthermore, a GIS can be used to determine the appropriate locations for new buildings such as train stations by analyzing the relationship between the new locations and their surroundings **[11]**.

On the other hand, De Luca, Dell'Acqua, and Lamberti (2012) used another analysis method that is a multi-criteria method but is based on spatial analysis. The aim of this study is to determine the best locations for the new high-speed railway lines in Italy. Two analysis levels were used in this study: cost–benefit and spatial analysis. The best locations were determined in dependence on the results of the analysis such as construction cost, environmental conditions, earth surface type, and social characteristics. The aim of that research was the opposite of the aim of the present paper, because whenever the population density was less, this means this location is the better, because the goal of the study was to determine the best locations for high-speed railway lines and not train stations. The research was accomplished by using GIS **[33].**

Wei (1996) aimed to determine the best locations for new railroads in China. In this research, the author used spatial analysis in GIS in order to accomplish the study. The spatial analysis in the research was based on satellite images collected by remote sensing devices because satellite images can provide rich information about the earth's surface. Then, the author used a CAD program in order to draw the new lines in the appropriate areas. However, the new lines were drawn based on a specific formula to measure the degree of elevation. After that, the authors used the VORONOI algorithm to determine the shortest paths in the determined areas. The same idea of the VORONOI algorithm can be used to determine the shortest paths between train stations as a one of the future works of the current thesis **[34].**

CHAPTER 3

Thesis Methodology

In this chapter, all steps of the methodology followed in this thesis will be presented. Furthermore, the problems presented in the previous chapter will be addressed in this chapter.

The methodology of this thesis consists of three main sections, as follows:

- **ArcGIS® 10.2**
- **PYTHON™ 2.7.3 (GUI)**
- **Microsoft Visual Studio (C#) 2010 express**

3.1 ArcGIS® 10.2

The free trial copy of ArcGIS® software was used. The ArcGIS® package consists of five main programs. In this thesis, ArcMap® and ArcCatalog® were used from among these programs.

3.1.1 ArcMap Tools

In order to open the ArcMap program and use its functionalities, the following steps should be followed:

Start → all programs → ArcGIS® → ArcMap 10.2.

3.1.1.1 Data Management Tools

As mentioned in the first chapter, the data were collected from the Internet and the Iraqi Railways Company. The data management tools can be used to prepare the data layers before they are used by other ArcMap® tools. Data layers are prepared as needed in order to meet definite aims, such as providing buffers, calculation of geometry, intersection, union of two layers, and so on.

The first case is the railway layer. In this layer, there is no information about the provinces and cities where those railways are located. In addition, in this study, that information is needed for each railway line in Iraq in order to analyze the train stations in all cities, as shown in Figure 24.

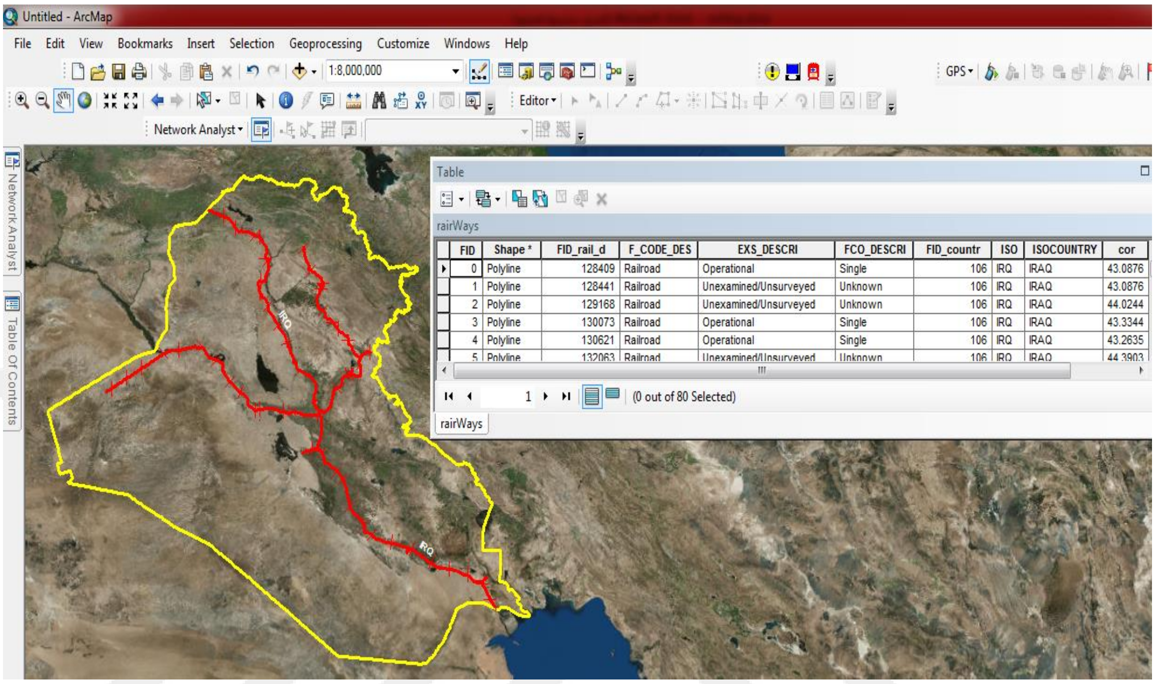


Figure 24 Railway layer and its attributes table

On the other hand, the province layer contains all the information about provinces and their cities. Therefore, the "join" tool was used, which is one of the data management tools. By using this tool, it is possible to join two layers depending on the unique fields or spatial data. In this case, the two layers will be joined based on spatial locations, because it is necessary to link the railways to the cities where those railway lines are located, as shown in Figure 25.

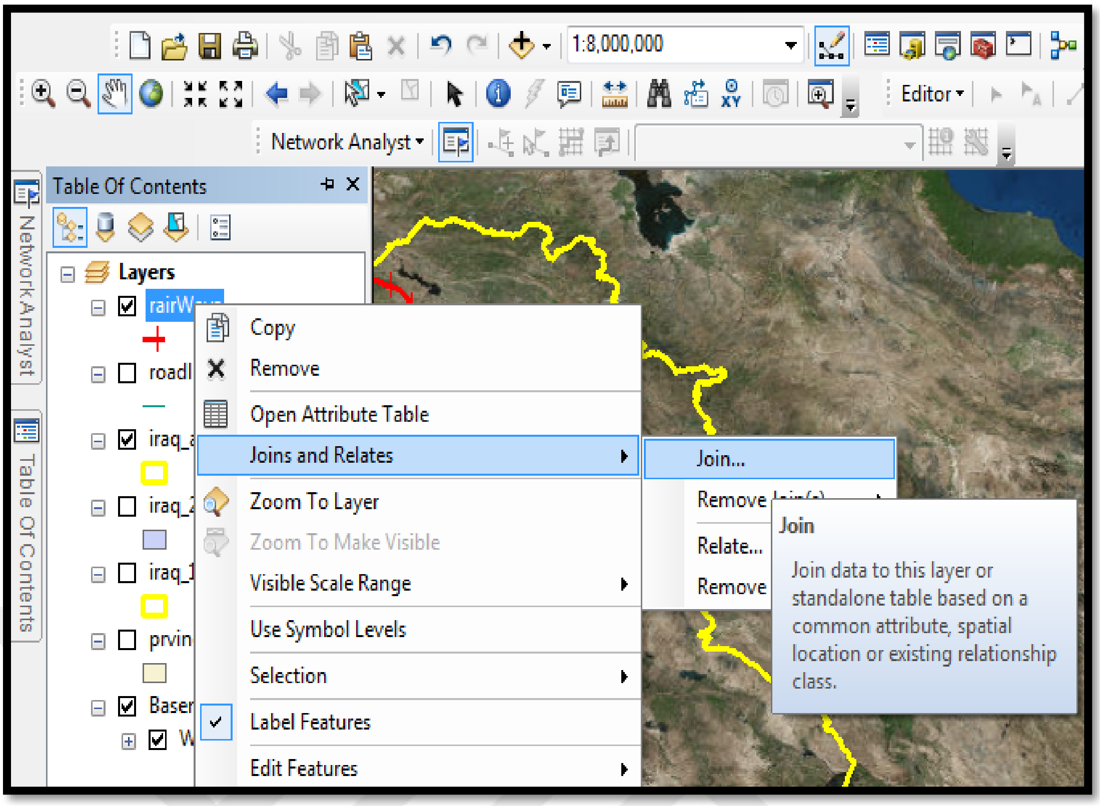


Figure 25 Tool for joining railway and province layers

Then, the option "each line will be given all the attributes of the polygon" should be selected, which means the layers will be joined according to the similar spatial locations between these layers. Next, the name and path for the output layer should be determined, as shown in Figure 26.

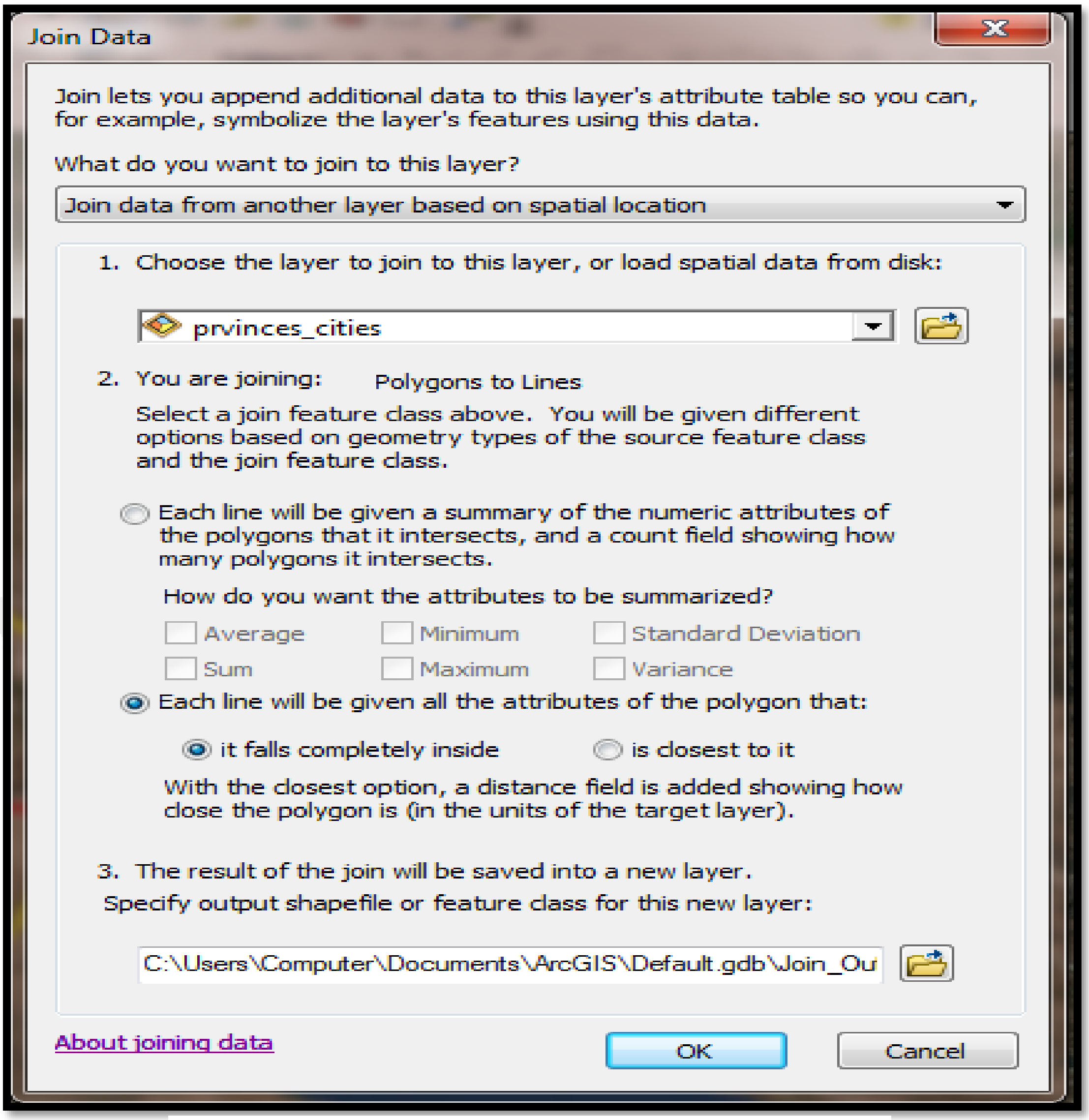


Figure 26 Parameter setting for the "join" tool

Also, the road network layer does not contain information about cities. So, it is necessary to join the road layer with the city layer based on spatial location. The joining process was done by using the same steps as previously and just changing the layers. The aim of this step is to extract roads inside each city (each polygon) in order to calculate the population density on the roads, which will be calculated depending on a specific new formula that will be mentioned in the next sections of this chapter. Thus, we need we need to know the population density points on each road because those points represent the demand points in the network analysis, as will be used later (Figure 27).

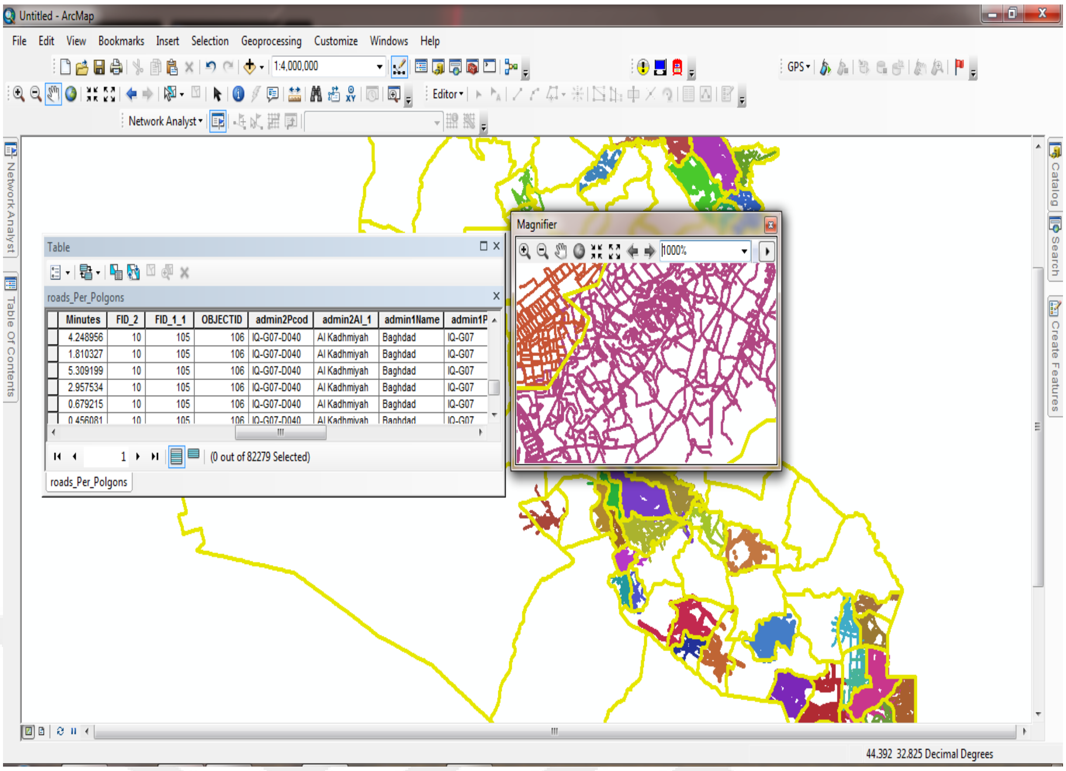


Figure 27 The resulting new road layer and its attributes table

Next, we need to join the population layer with the road layer that finally resulted from the previous step, because we need to reflect the population density information of each city on the roads that lie within that city. In order to extract the population density on those roads. The population density on roads will be obtained by applying a specific formula, as mentioned in Section 3.1.1.4 of this chapter. This formula is based on the relationship between the populations of cities and the properties of the roads inside those cities. The population density layer used here contains general information about the population density of Iraqi cities but does not contain detailed information such as the approximate density number of people who are living around each street. However, in this step, the joining process will be based on attributes tables and specifically the column showing the city names in these layers, because this field is similar in both of these layers. Firstly, the joining type should be determined. Then, as the basis of the joining process, the joining column for each layer should be selected, which is the column listing the city names for each layer because the columns of city names are similar for both layers., as shown in Figure 28.

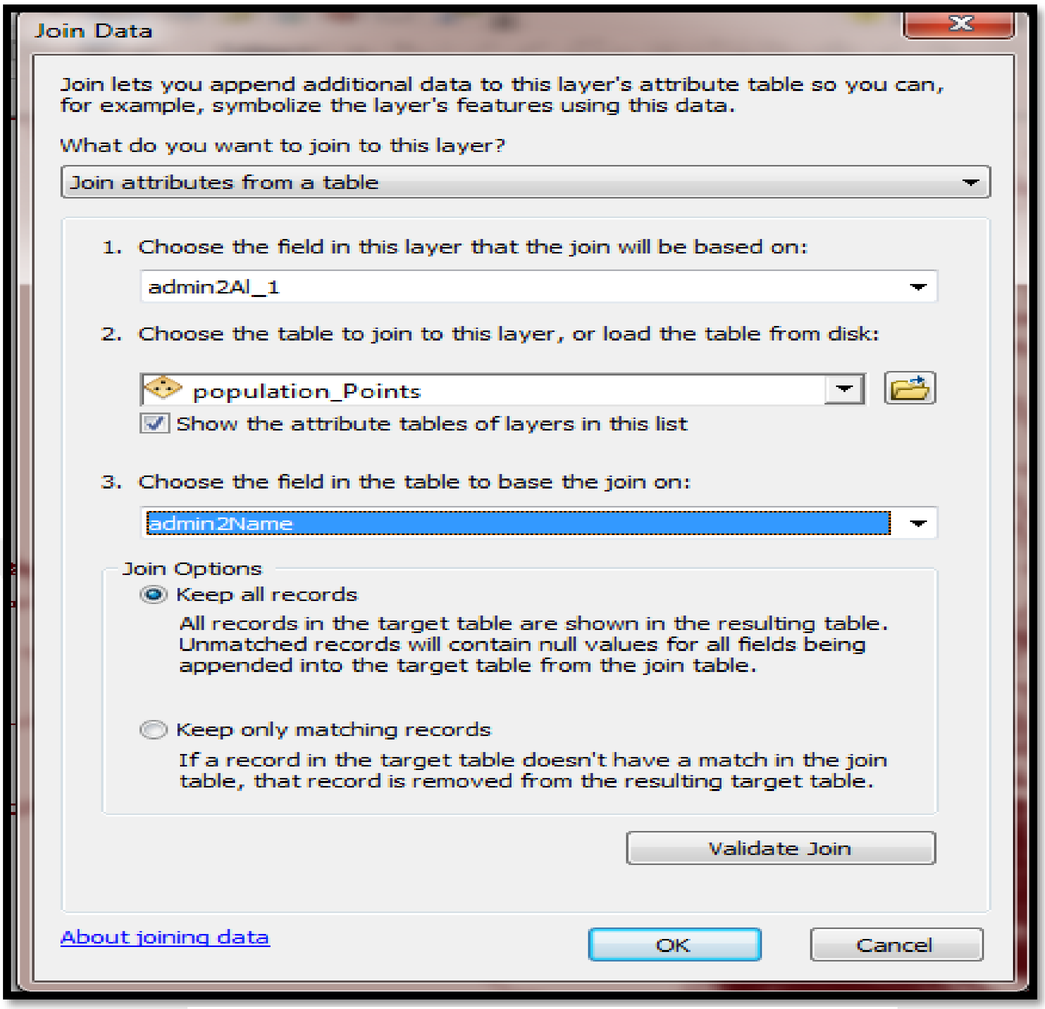
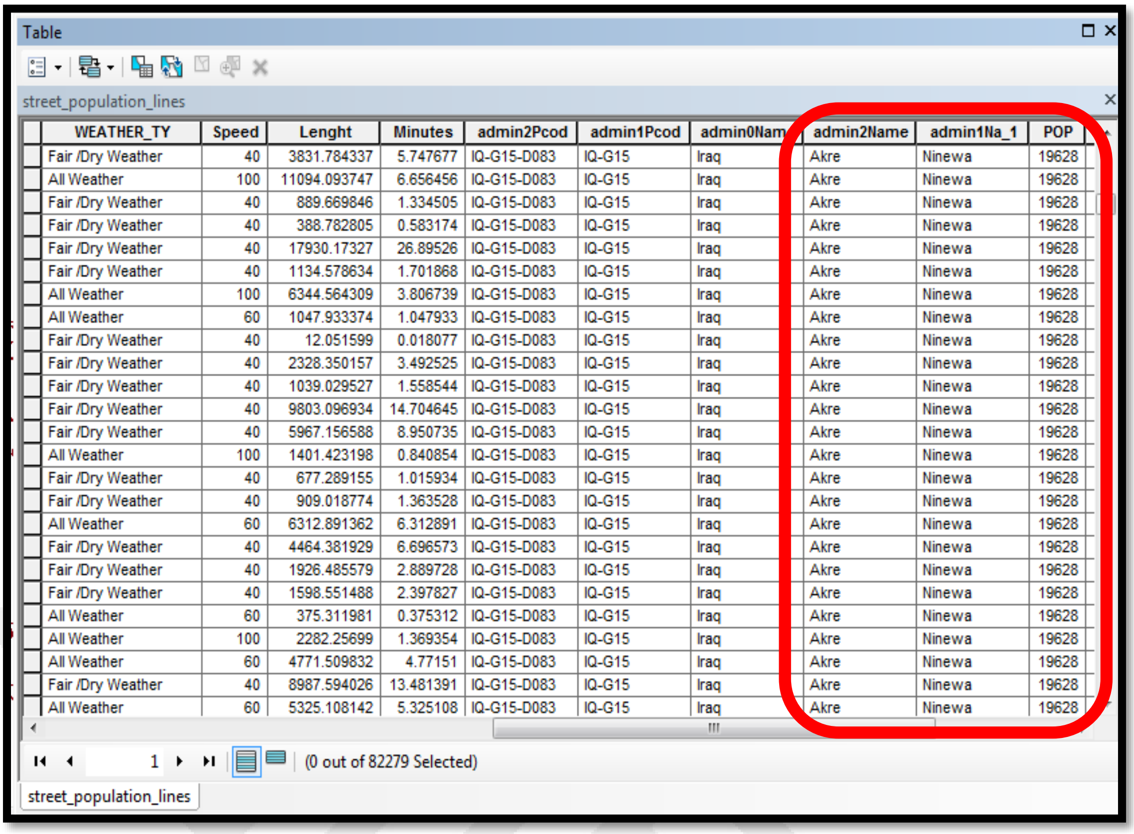


Figure 28 Setting the parameters for joining

The result is a polyline layer that represents the road network. This layer contains all information about roads but the population number in this layer represents the population density of cities within which those roads lie. The aim of this step is to prepare the population field in the road layer in order to calculate the approximate population density per road. The population density on the roads will be calculated according to the population density of cities and the length, number of lanes, and traffic speed of each road in those cities (Figure 29).



WEATHER_TY	Speed	Lenght	Minutes	admin2Pcod	admin1Pcod	admin0Nam	admin2Name	admin1Na_1	POP
Fair /Dry Weather	40	3831.784337	5.747677	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
All Weather	100	11094.093747	6.656456	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	889.669846	1.334505	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	388.782805	0.583174	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	17930.17327	26.89526	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	1134.578634	1.701868	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
All Weather	100	6344.564309	3.806739	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
All Weather	60	1047.933374	1.047933	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	12.051599	0.018077	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	2328.350157	3.492525	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	1039.029527	1.558544	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	9803.096934	14.704645	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	5967.156588	8.950735	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
All Weather	100	1401.423198	0.840854	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	677.289155	1.015934	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	909.018774	1.363528	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
All Weather	60	6312.891362	6.312891	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	4464.381929	6.696573	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	1926.485579	2.889728	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	1598.551488	2.397827	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
All Weather	60	375.311981	0.375312	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
All Weather	100	2282.25699	1.369354	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
All Weather	60	4771.509832	4.77151	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
Fair /Dry Weather	40	8987.594026	13.481391	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628
All Weather	60	5325.108142	5.325108	IQ-G15-D083	IQ-G15	Iraq	Akre	Ninewa	19628

Figure 29 The final resulting road layer

There are other problems in the road layer, which are the gaps between streets. As mentioned before, we need the road layer in the network analysis for the train stations because this analysis depends on the existing road network in order to measure the accessibility values of those stations. There are two causes of these gaps. The first cause is the accuracy of the data. Sometimes, the map scale is the main factor that affects the accuracy of the data. For example, data are collected by using a specific map scale and then used with a different map scale. This difference generates many mistakes and gaps between objects in the map because whenever the drawing scale is bigger, the gaps become larger. Figure 30 shows an example of gaps in the road layer.

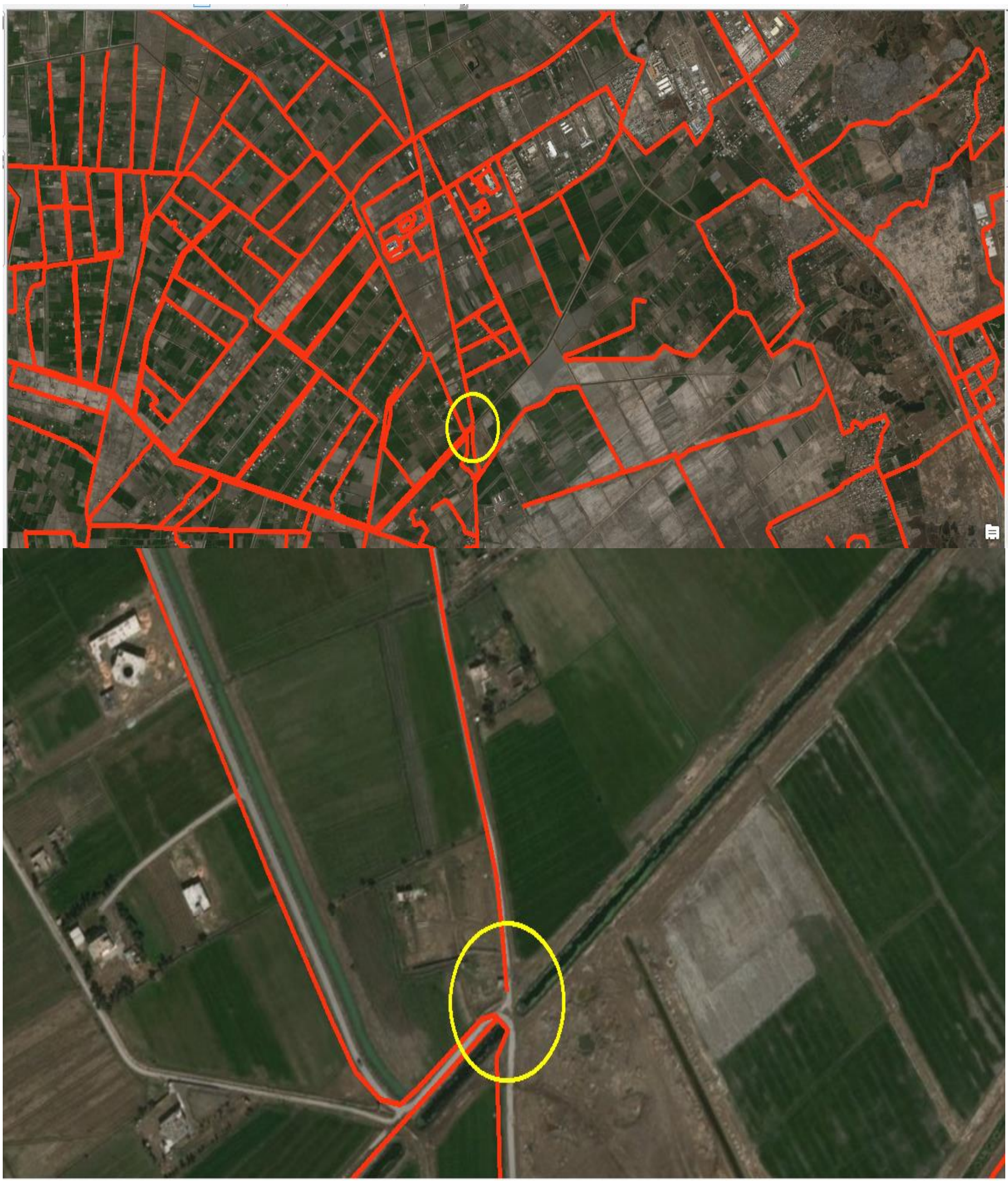


Figure 30 Gap problem when the map scale was changed

The second cause is the reality of the earth's surface. Sometimes there are minor roads linking other routes, for example, a small bridge connecting two roads. Cases such as these are often not represented in the data of roads layer.

In order to use the road layer in the network analysis, this problem should be addressed, because the network analysis depends on the integrated polyline network. The "integration" tool was used to solve this problem. This tool is one of the data management tools in ArcMap 10.2. The “integration” tool is used to solve the shared features boundary problem and the gaps problem **[35].**

We can use this tool easily by selecting the road layer as an input in the tool configuration window. The result will be the same road layer but integrated polylines, as shown in Figure 31.

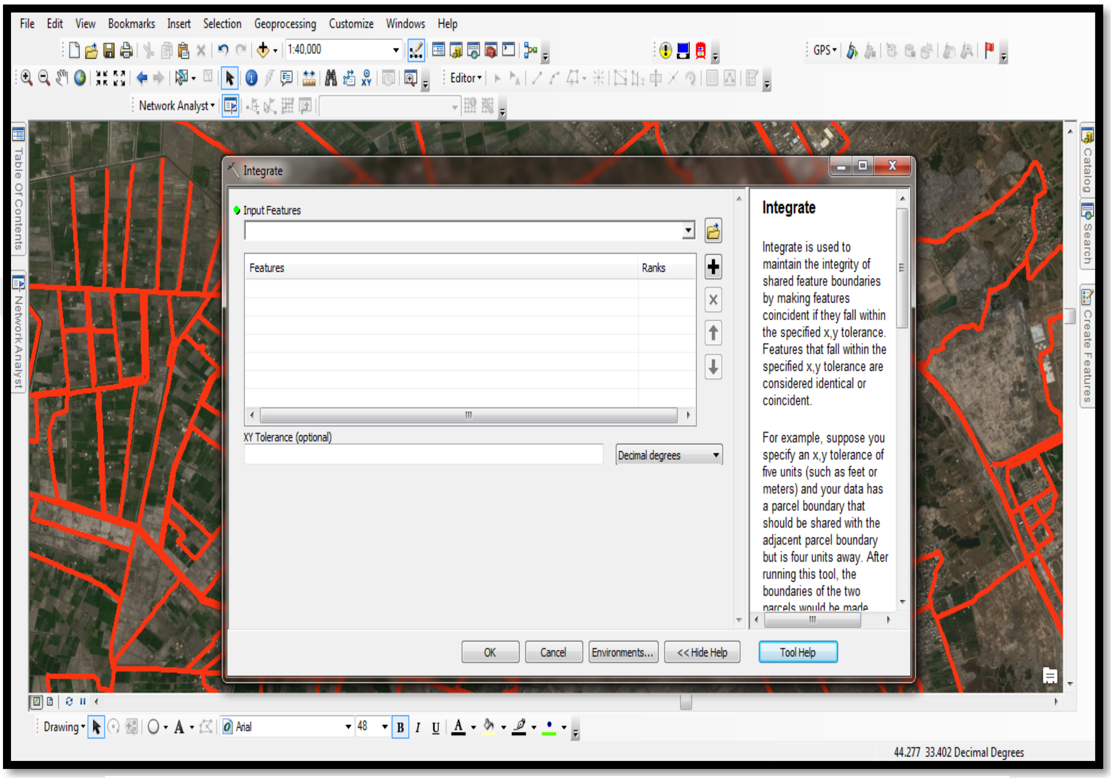


Figure 31 Use of “integration” tool

3.1.1.2 Geocoding Tools

The geocoding toolset contains seven tools. From these, the tool “create address locator” was used in order to create a new address locator for Iraq. The aim of using this tool is to create a reference for Iraq's cities. This reference can be used to find a location by searching. In addition, this tool makes it possible to select the appropriate style for the new address locator, such as cities, streets, ZIP codes, and so on. The “general-city-state” was used as a style and the province layer, which contains the province’s names and cities, was used as a reference layer. Then, as seen in Figure 32, the reference columns were selected according to the information matched. By the way, the default address locator in the ArcGIS® program is the USA.

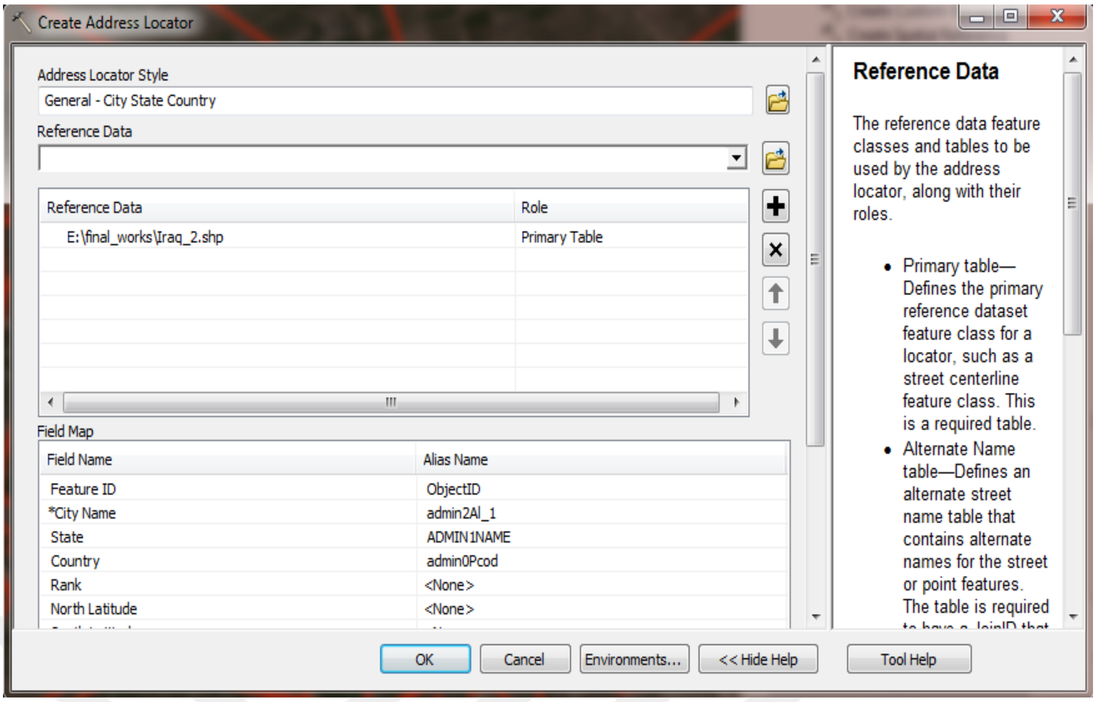


Figure 32 Use of "create address locator" tool

3.1.1.3 Projection and Transformation Tools

The purpose of the use of this tool is to change the coordinate system, which is used to present the data layers (maps) on the screen. In addition, if we want to carry out some geometry calculations, we must use "projected coordinate systems". Then, the coordinate system that is appropriate for Iraq, namely "WGS_1984_UTM_Zone_38S", is selected. It is necessary to change the coordinate system in order to get accurate results that reflect the reality of the earth's surface (Figure 33) **[36]**.

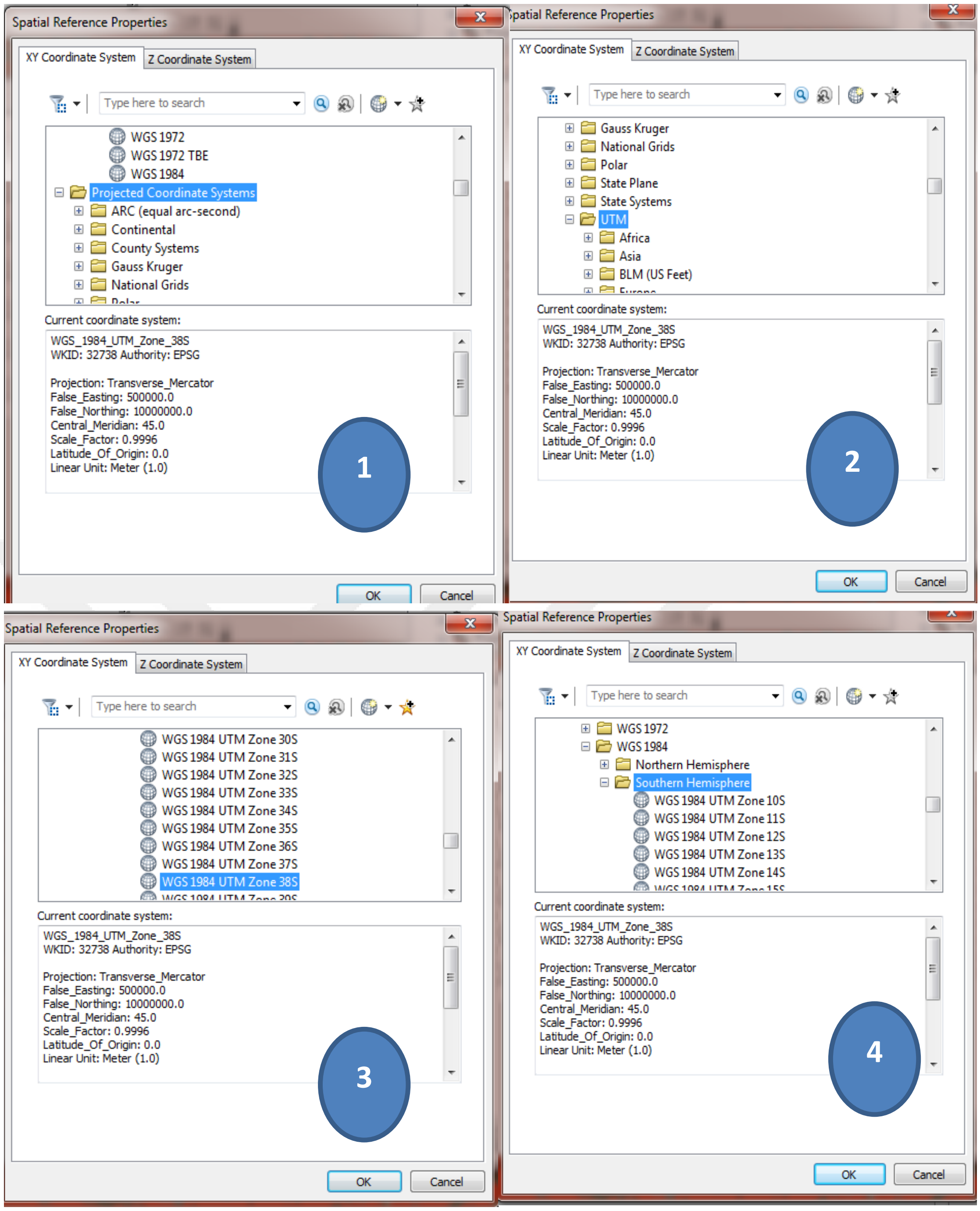


Figure 33 Use of “projections and transformations” tool

3.1.1.4 Field Tool

This tool is used to modify the attribute tables. By using this tool, new fields can be added to the attributes table and geometry calculations such as distance, area, coordinates, and so on can be carried out for fields. In addition, mathematical calculations can be done on any field in the attributes table by using the options provided by the field calculator, such as /, *, -, +, Cos (), Abs (), Log (), and so on. Furthermore, the field tool can be used to find the statistics for the fields.

This tool was used to modify the attributes table for the road layer. Firstly, a new field was added, called “minute”. This new field represents the appropriate time required to cross each road, as will be mentioned later in this chapter. It is necessary to add and calculate this field, because the network analysis depends on the time to calculate the accessibility values of train stations. The steps required to add this new field are as follows:

1. Open the attributes table
2. Open the table’s “options” menu
3. Select “add field”
4. Write the name of the new field
5. Select the field type (integer, string, float, double, date), as shown in Figure 34.

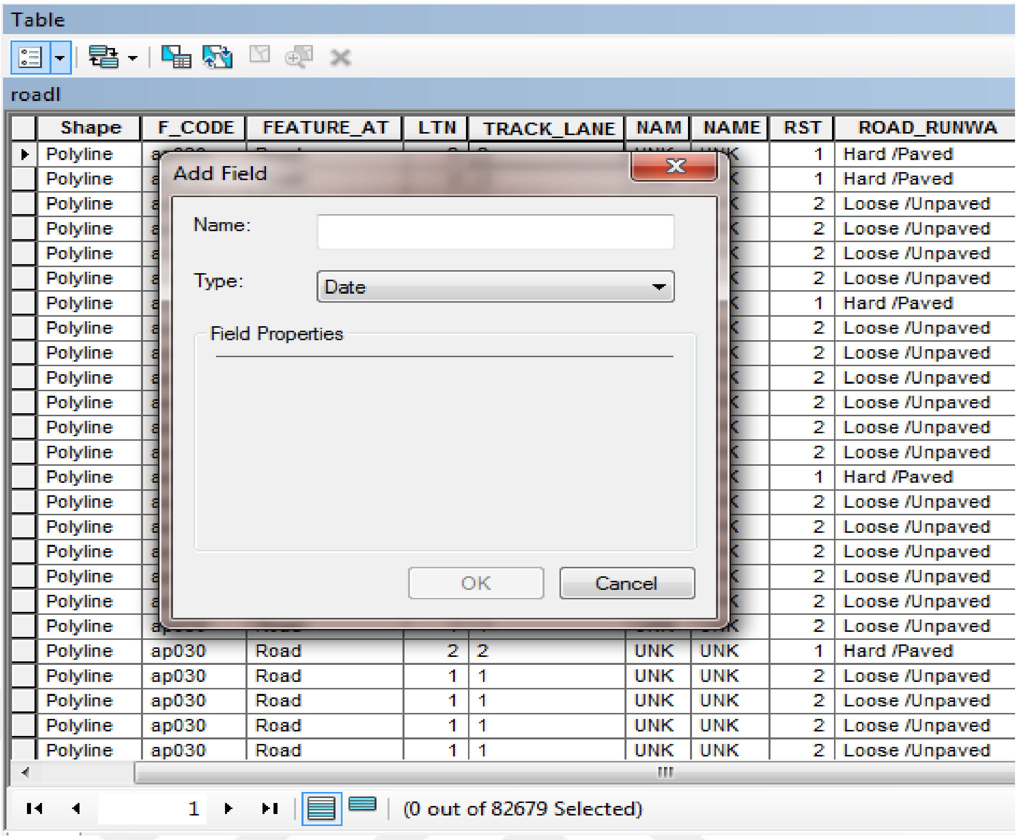


Figure 34 Steps required to add a new field

Secondly, the length of each road in the road layer will be calculated by using the geometry calculations as below:

1. Right click on the header of the length column
2. Select "calculating geometry"
3. Select "length" as the geometry type
4. Click "OK" (Figure 35)

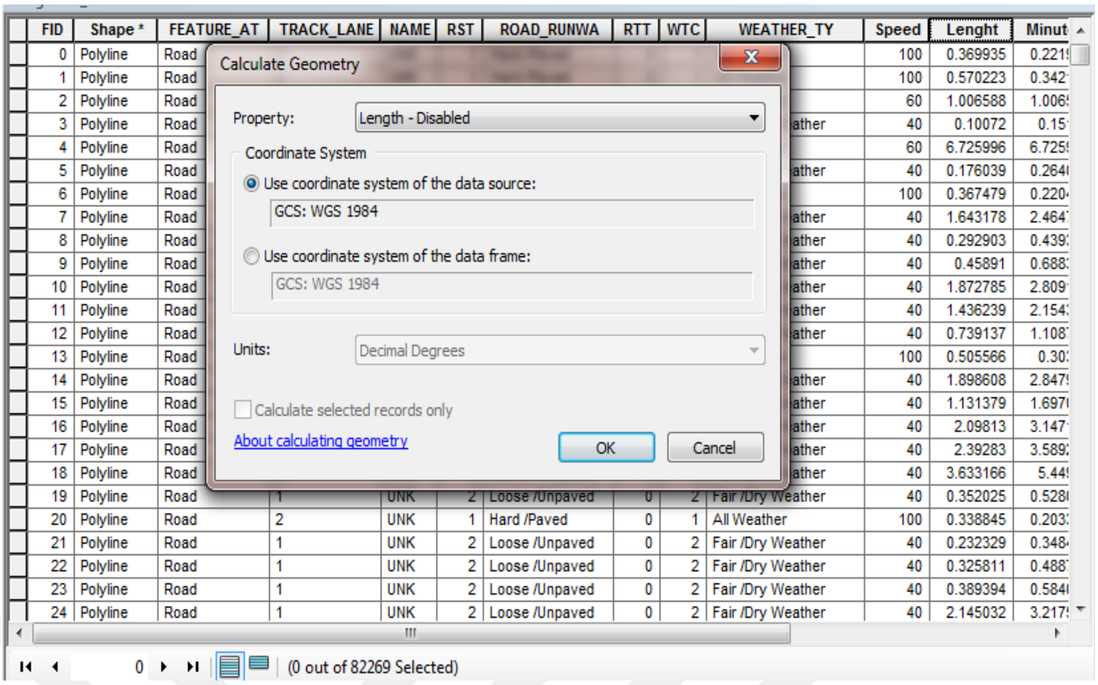


Figure 35 Calculation of lengths of roads

After that, the values for the minutes column should be calculated by using field calculator method because by using field calculator option the column can be calculated either by entering the values or applying mathematical formulas. So, the minutes column will be calculated by applying a specified formula that will be mentioned next. This can be done by right clicking on the header of the new column and clicking on "Field Calculator" then writing the 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 **[37]**. Figure 36 shows the calculation window used to write the needed formula in order to calculate the minute field.

$$\textbf{Time of Travel} = \frac{\textit{Distance Travelled}}{\textit{Average Speed}} \qquad \textbf{(1)}$$

$$\textbf{Driving Time (minutes)} = \left(\frac{\textit{Length}}{\textit{Speed}}\right) * 60 \qquad \textbf{(2)}$$

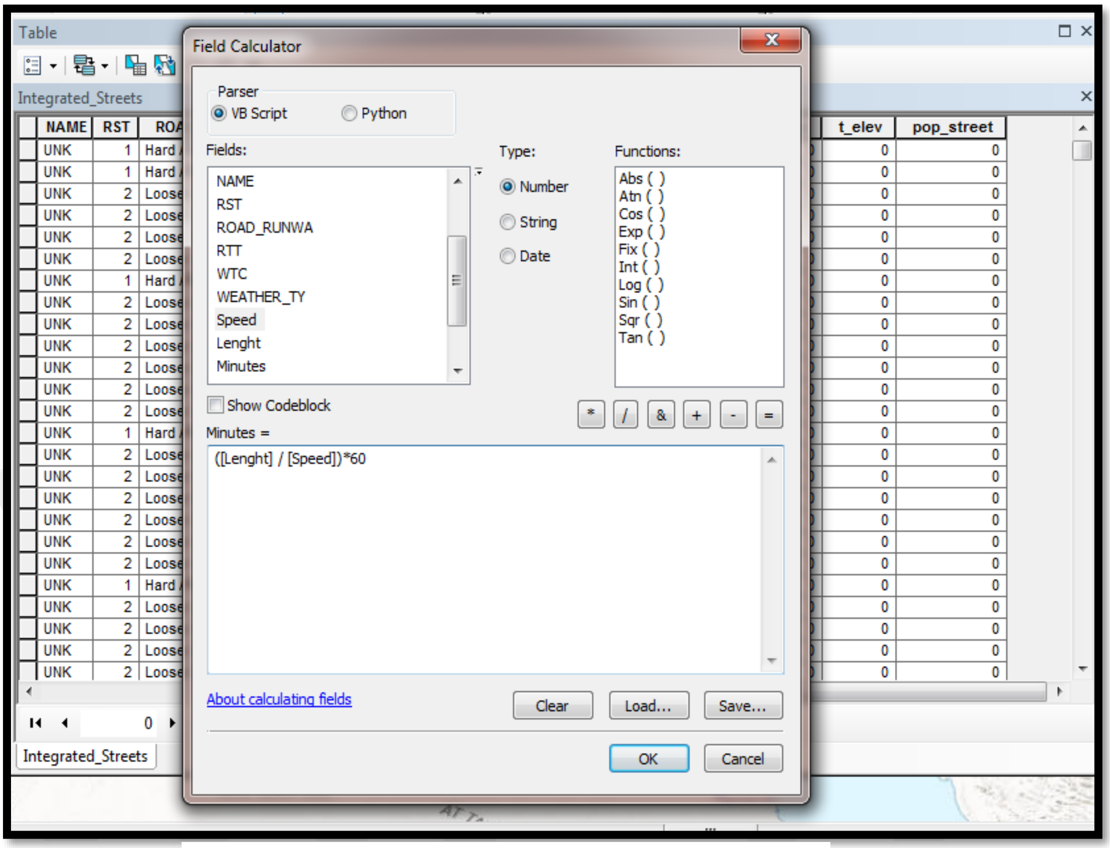


Figure 36 Calculation of the "minute" field

Next, we will add a new field to calculate the pedestrian's walking time. 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 expressed in minutes), as shown in Equation 3 (Figure 37) **[30]**.

$$\text{Pedestrian time } \mathbf{Minutes} = \left(\frac{\mathit{Length}}{0.1}\right) \qquad \mathbf{(3)}$$

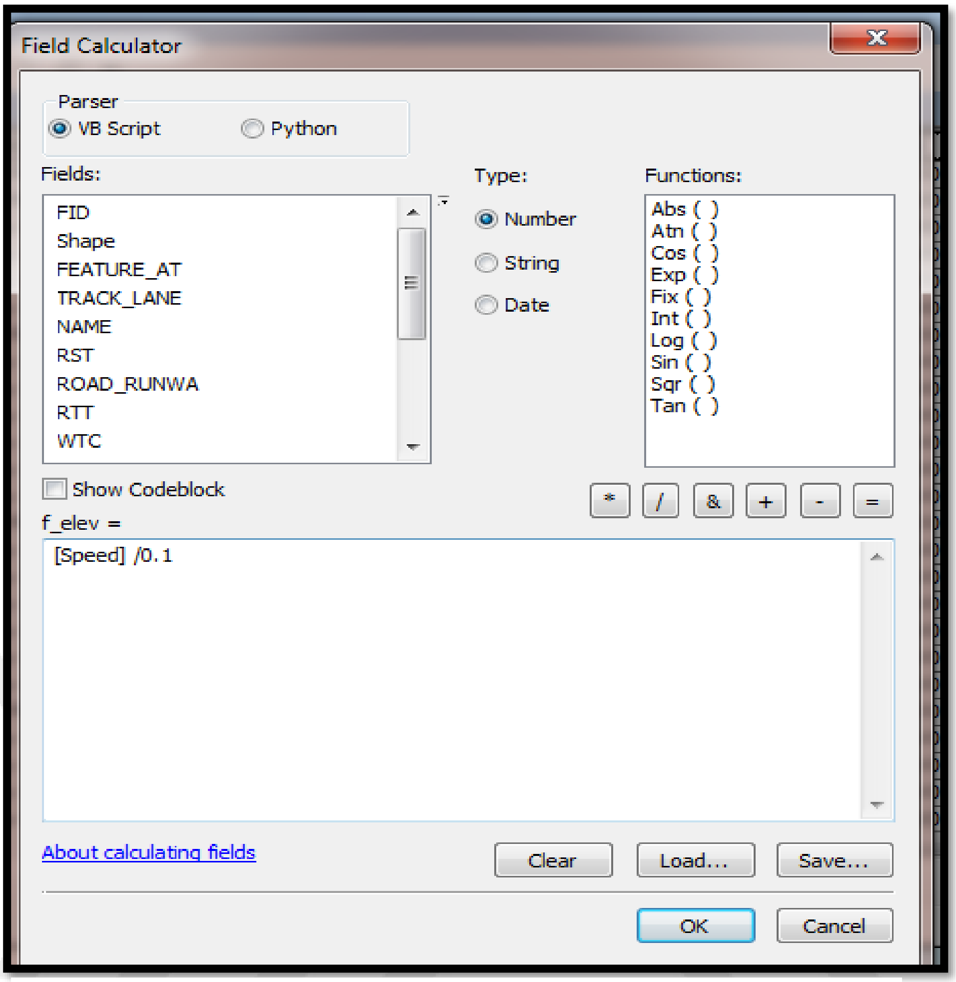


Figure 37 Calculation of minutes spent walking

There is another issue in the road layer that should be addressed. This issue is the calculation of the population density numbers on the roads. So firstly, we should add a new field to the table, which is "population_per_road", by using the same method as previously. Next, the values for the new column should be calculated by using the "field calculator" option. The values for this field will be calculated by applying a special formula proposed in this work, as shown in Equation 4

$$\textbf{Population}\ \boldsymbol{per\ roads} = \frac{\textbf{Population per city}}{\textbf{Traffic speed}\times\textbf{number of lanes}\times\textbf{length of road}} \qquad \textbf{(4)}$$

This formula was used because there is a negative relationship between population density and highways, because when roads are longer, faster, and have four or more lanes, that means those roads are external (outside cities). For example, the population density around a short road with a one-track lane in Ankara-Kizilay is higher than that of Eskişehir Road, which is a long high-speed road with four lanes (Figure 38).

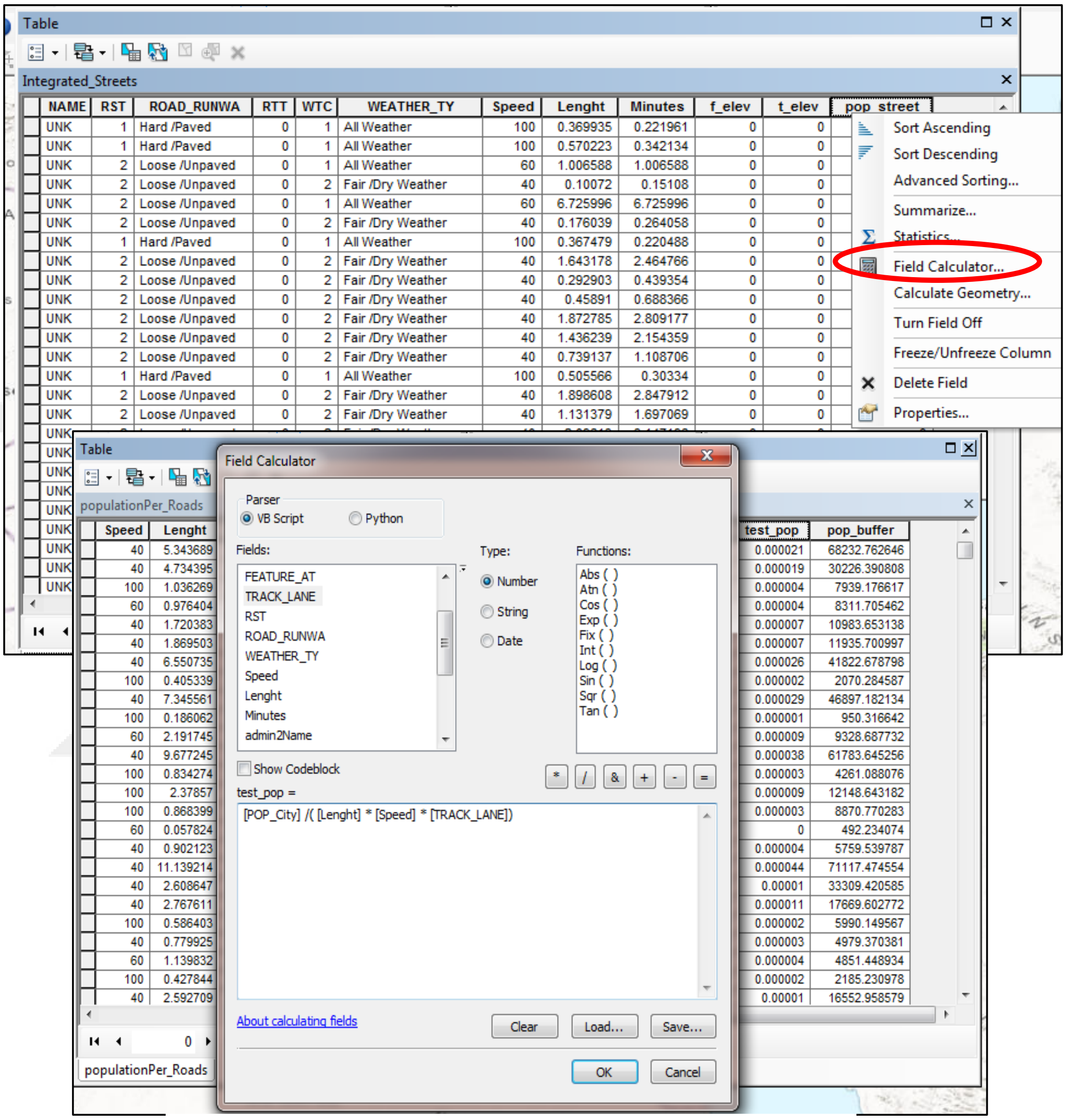


Figure 38 Calculation of population per road

Now, the road layer is ready to use in the network analysis. The next step is to convert the population density values from the attributes table of the road layer and place them as points on the map. This step aimed to create a layer of population density points, which are the centroid points of the roads, in order to use those points as a demand point layer later in the network analysis. In order to do so, the steps are followed:

- Add two columns to the attribute tables for the road layer. These columns are **cX** and **cY.**

  These new fields represent the center of the X-axis and the center of the Y-axis for roads. Then, these values were calculated by using geometry calculations. The main idea here is to convert the polylines (road layer) to points (population density point layer), as shown in Figure 39.

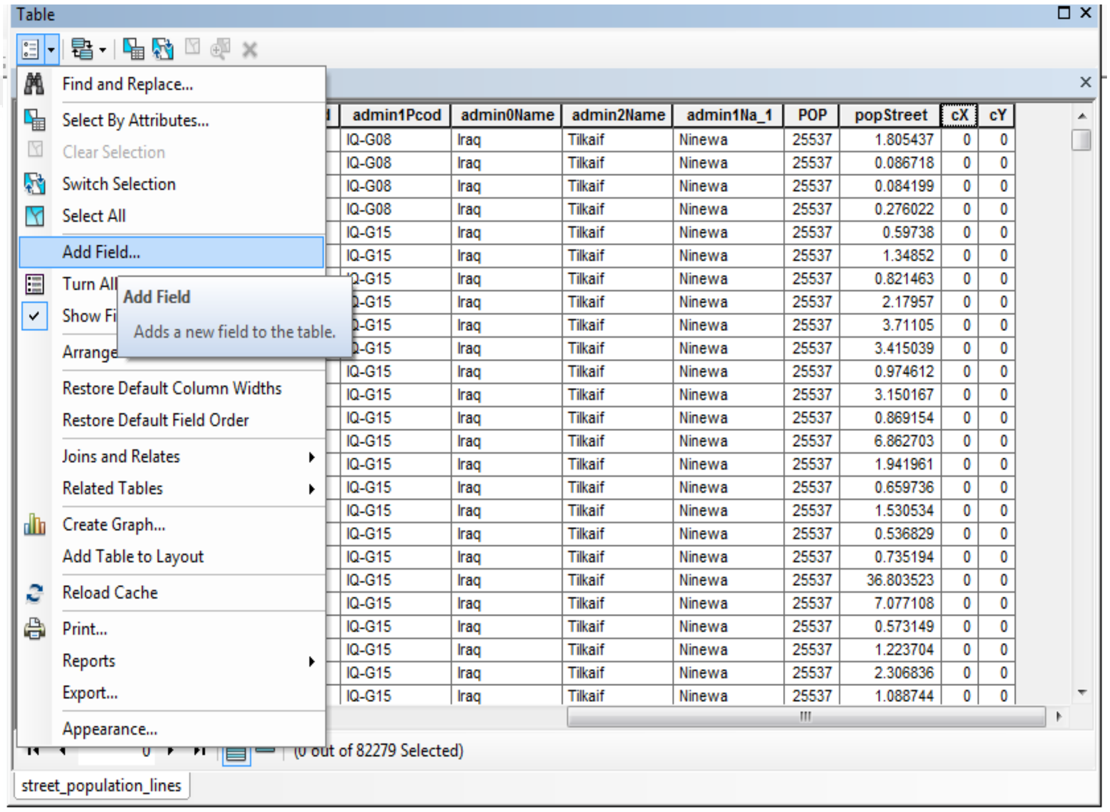


Figure 39 Addition of (cX) and (cY) fields

- Calculate the values for the cX and the cY fields by using geometry calculations, as below:
  - Right click on the (cX) column's header.
  - Select "calculate geometry".

- Select “X coordinate of the midpoint”. The purpose of this step is to represent the X-axis midpoint of the line (road).

  The same steps are used to calculate the (cY) field (Figure 40).

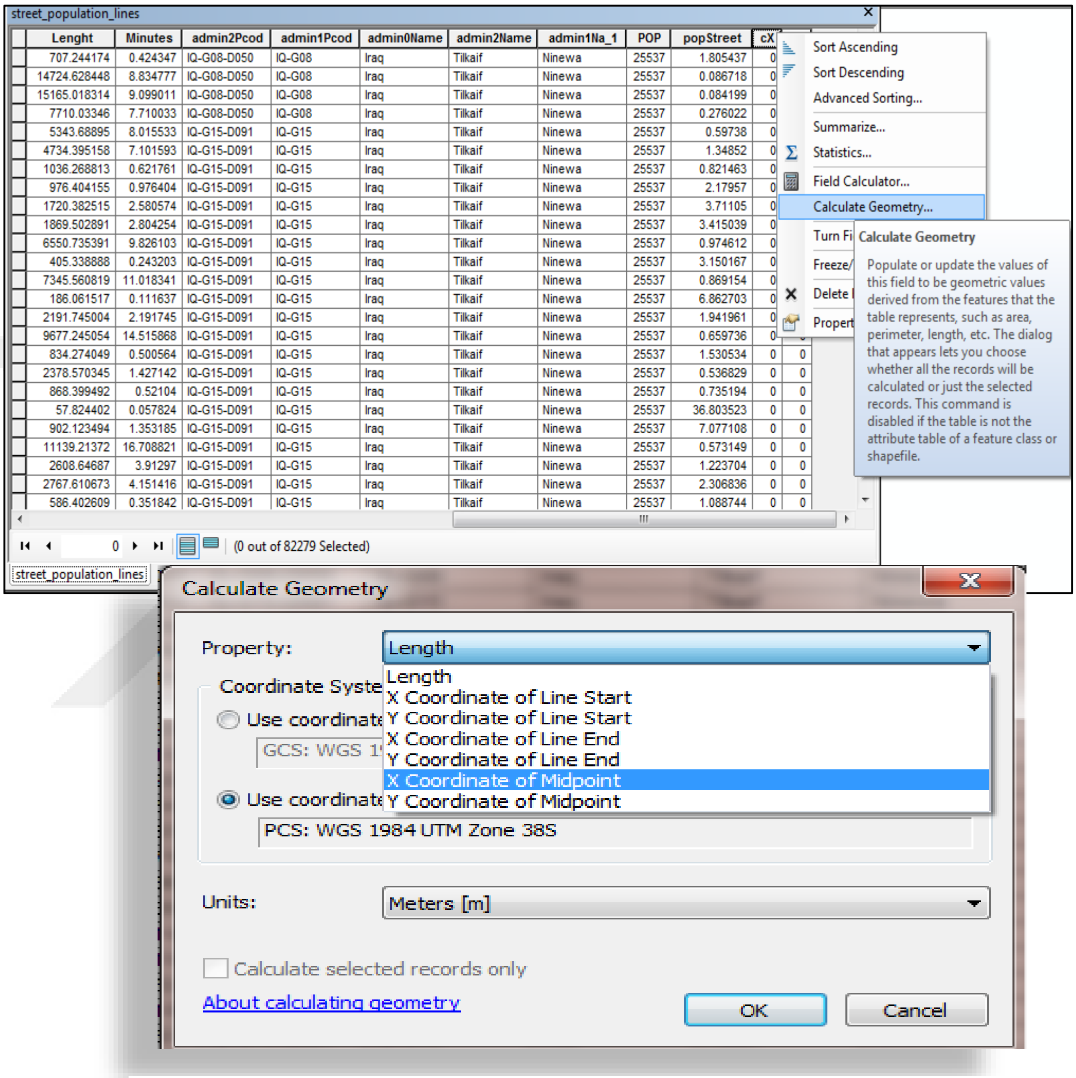


Figure 40 Calculation of cX and cY fields

Now, the attributes table for the road layer has become contains all the necessary fields needed by the network analysis. Therefore, the next step is to extract the population points depending on the spatial locations of the cX and cY fields and to locate those points on the map in order to use them later in the network analysis.

The steps below were followed in order to create a new point layer for the population density on the roads below:

1. Export the attribute table for the road layer, which now contains the cX and cY fields. The exportation steps are as follows:

   Open the attributes table → table options → export → all records → select the output path → OK (Figure 41).

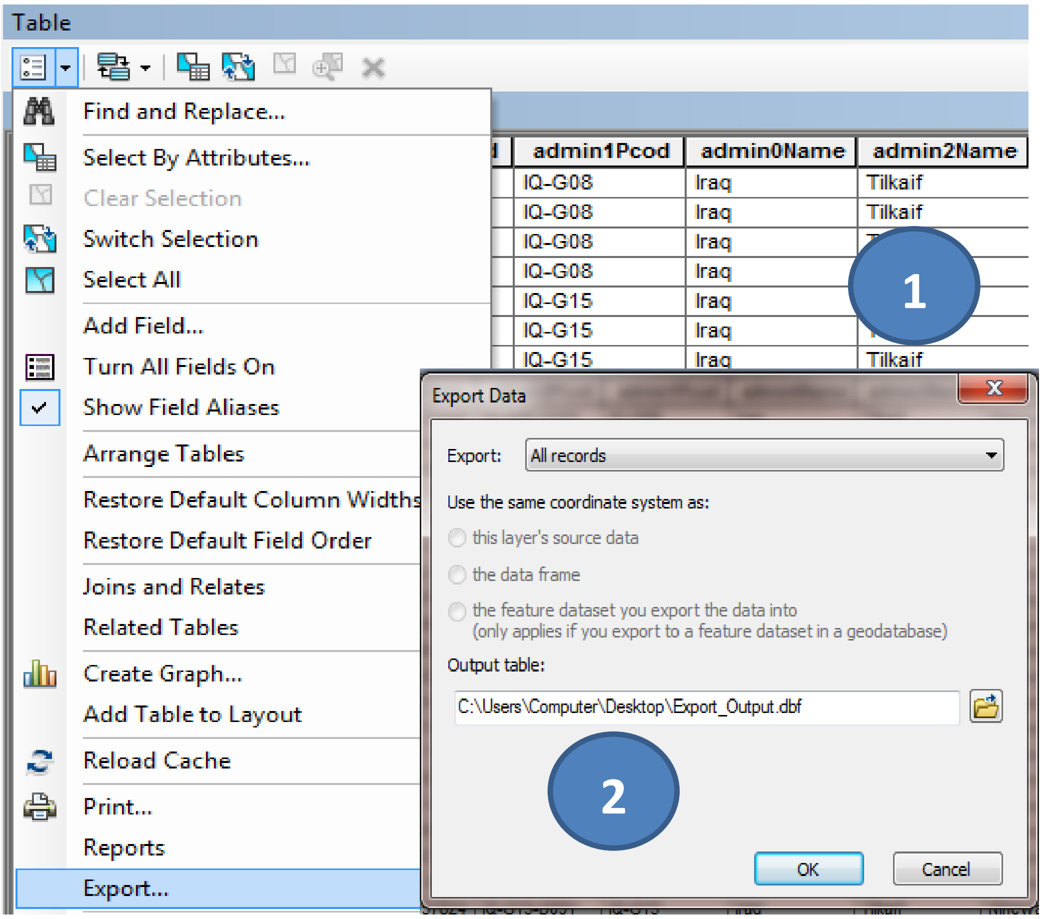


Figure 41 Steps for exporting the attributes

2. Import the attribute table that resulted from the first step by following these steps:

   ArcMap → file → add data → determine the data path → add (Figure 42).

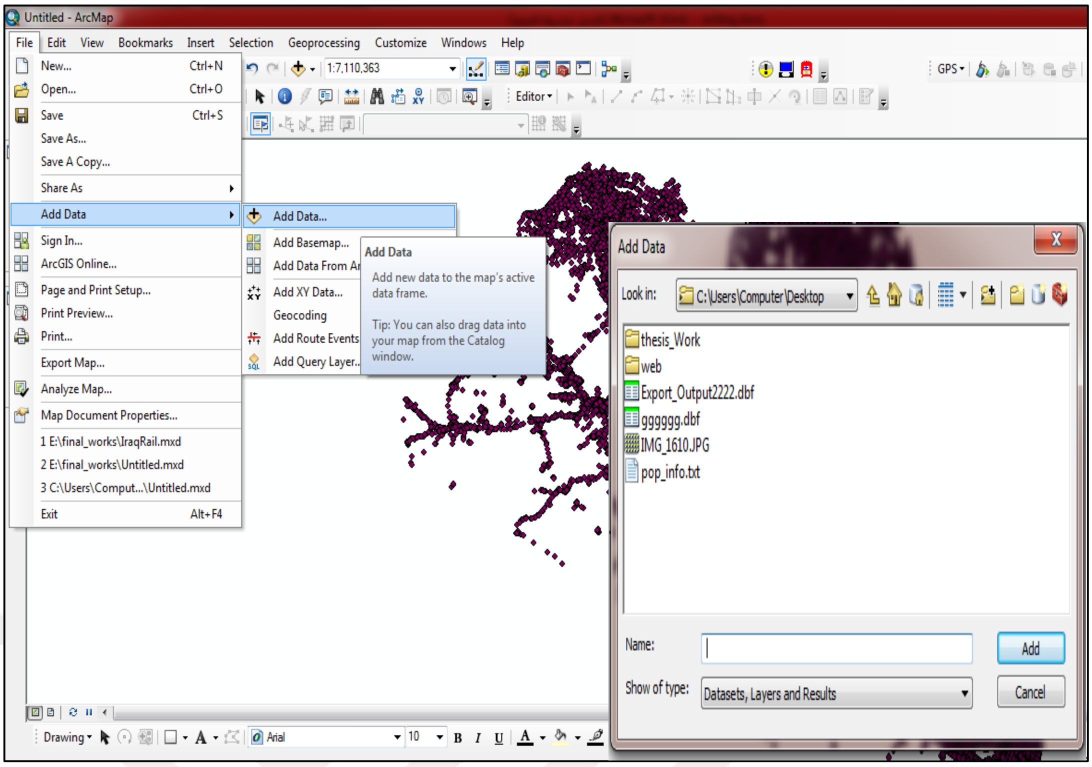


Figure 42 Importing the attributes table

3. Display the population density points as a layer on the screen. Now, we have the attributes table and it contains all the needed columns. Nevertheless, there is no spatial representation of these columns. Therefore, the following steps were used to present those data as points on the map to represent the approximate population density on the roads:
   ArcMap → table of contents → right click on the table → display XY data → select the X field in the table → select Y field in the table→ OK, as shown in Figure 43.

4. Export the population point layer and save it in order to use it later in the network analysis. The export steps are as follows:

   ArcMap → table of contents → right click on the new layer (point layer) → data → export data → all features → set the name and path for the new layer, as shown in Figure 44.

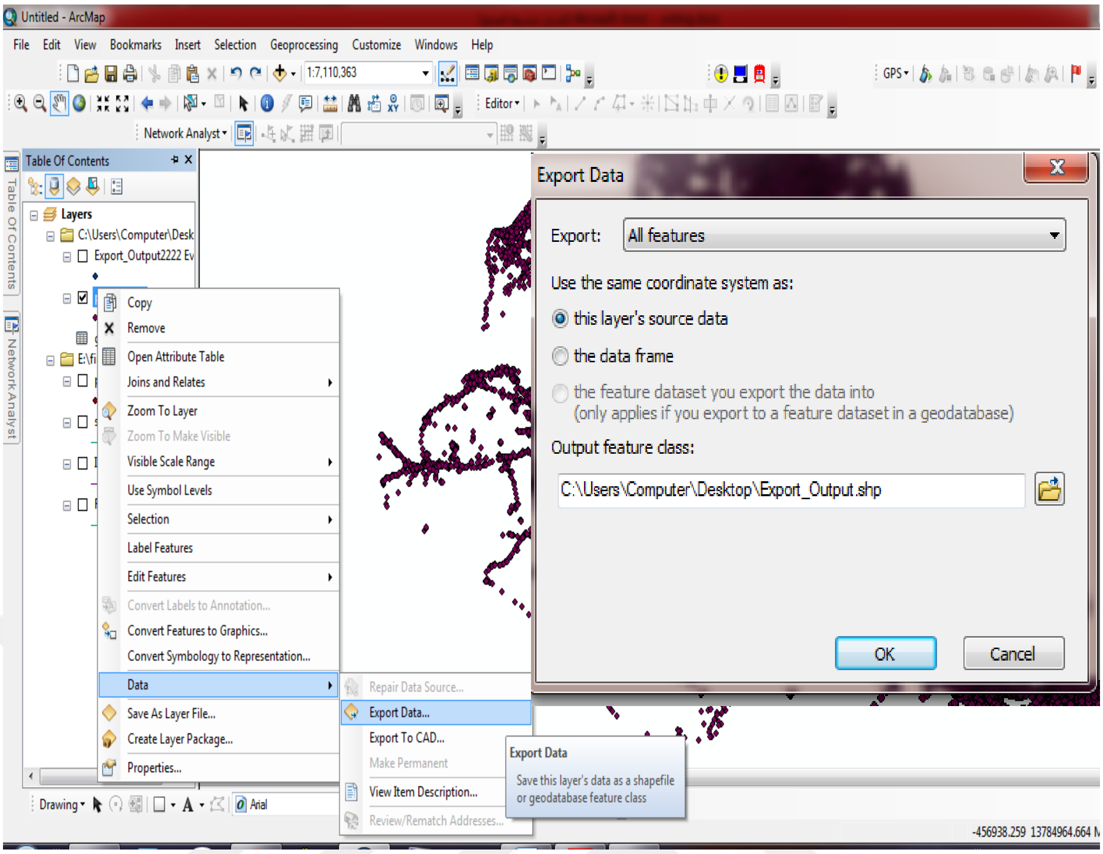


Figure 44 Exporting the new layer

3.2 Arc Catalog 10.2

By using the (ArcCatalog) program, a new network dataset can be created. This network dataset (ND) will be used as a base for the network analysis because the network analysis mechanism depends on the network dataset to perform the analysis of railway network. The following steps are used to open the Arc Catalog program:

Start → all programs → ArcGIS® → ArcCatalog 10.2

In the next step, a network dataset will be created for the road network, as below:

ArcCatalog 10.2 → catalog tree→ right click on the road shape file → new network dataset (Figure 45).

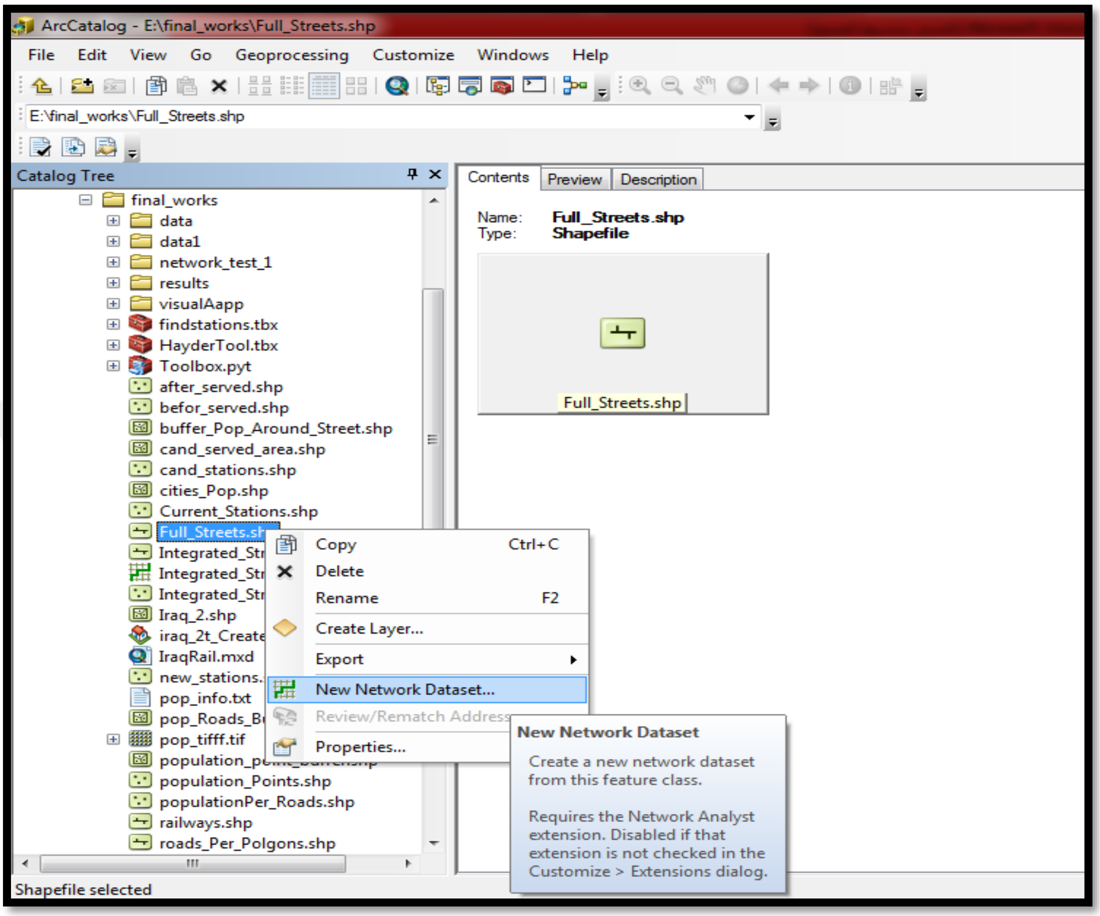


Figure 45 Creation of a new network dataset

In the next step, the connectivity type between vertexes on the road network should be set because the analysis depends on those roads to measure the accessibility values of the train stations. Then, the cost field for the network analysis must be determined while creating the network dataset. Firstly, type "any vertex" was used as a connectivity type between vertices in the network dataset in this thesis. The "Any Vertex" type could be used as a connectivity type between vertices in this research because in the road network any vertex (end of the each road) is considered as a connection point between roads, as shown in Figure 46.

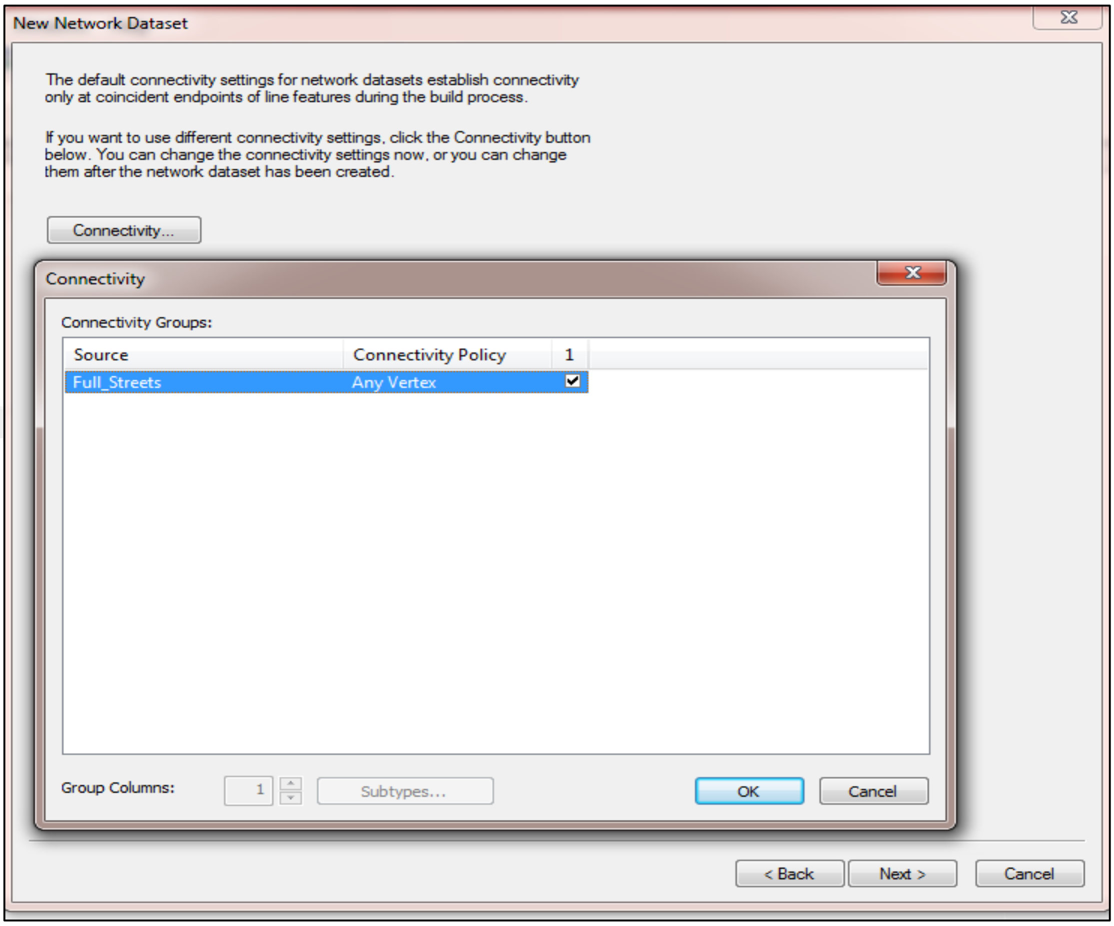


Figure 46 Setting the connectivity type

Secondly, in this research, the "minute" field, which was calculated in Section 3.1.1.4 of this chapter, was used as a cost type for the network dataset to allow analysis of the train stations according to the accessibility times, as shown in Figure 47.

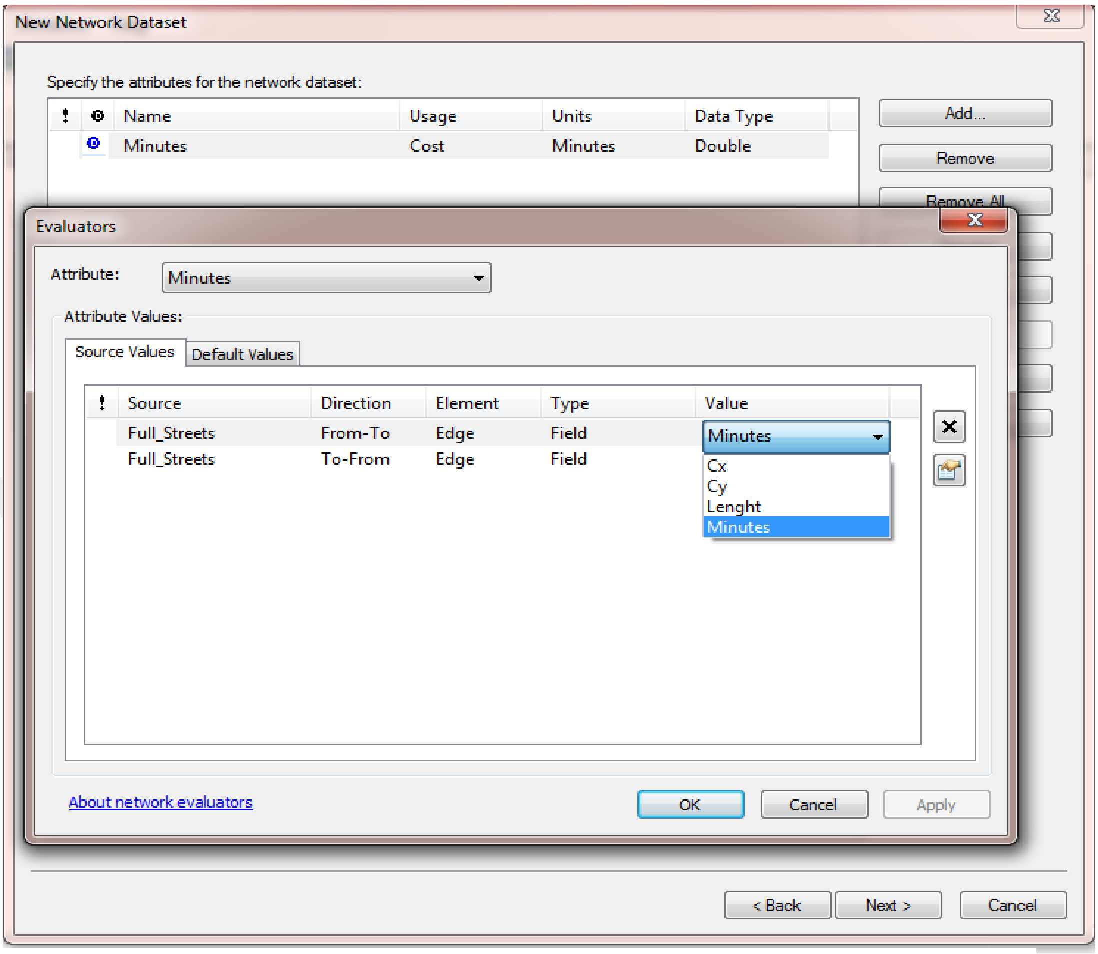


Figure 47 Selection of the cost type and setting the field

Then, the type of "no driving directions" is selected for the analysis direction in this dataset because there are no walking directions for pedestrians. Thus, the steps required to create the new network dataset can be summarized as follows:

ArcCatalog 10.2 → catalog tree → right click on the roads shape file → new network dataset → naming the dataset → select connectivity type → select cost type → determine the cost field → no-driving directions → finish.

3.3 Network Analysis (NA)

1. The network analysis extension should be added to ArcMap in order to use the network analysis tools. It is possible to add this extension by following the steps below:

ArcMap → customize → extensions → network analysis [20], as shown in Figure 48.

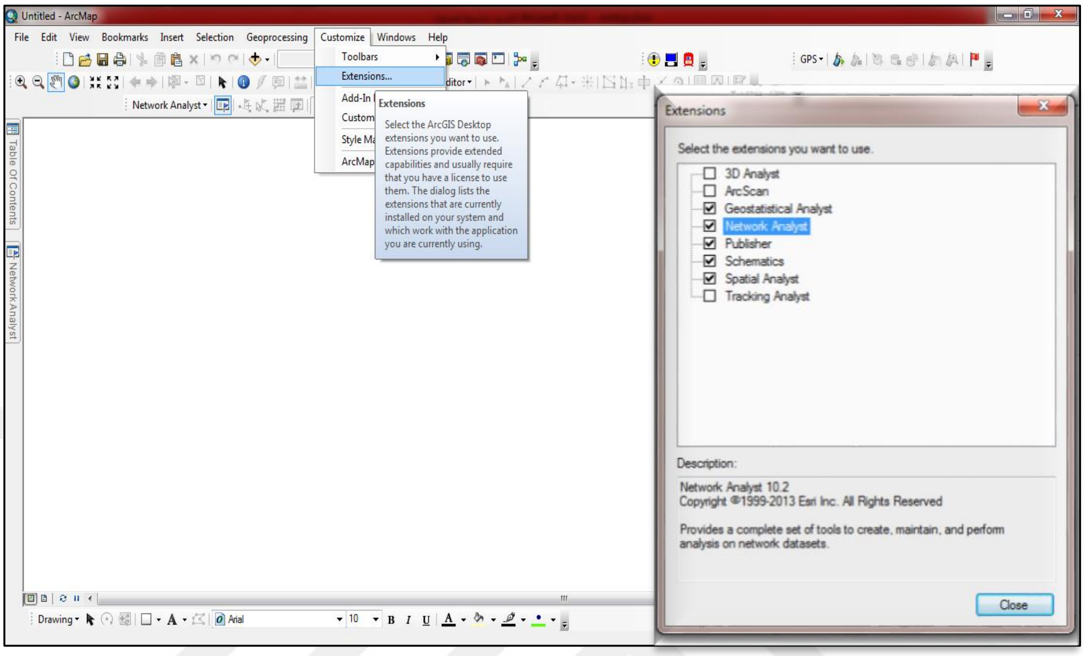


Figure 48 Addition of network analysis extension

1. The new network dataset created in Section 3.2 is added to ArcMap to become the base for the network analysis. The dataset can be added by using these steps:

   ArcMap → add data → select the network dataset **(**the file with the extension “**ND**”) → add, as shown in Figure 49.

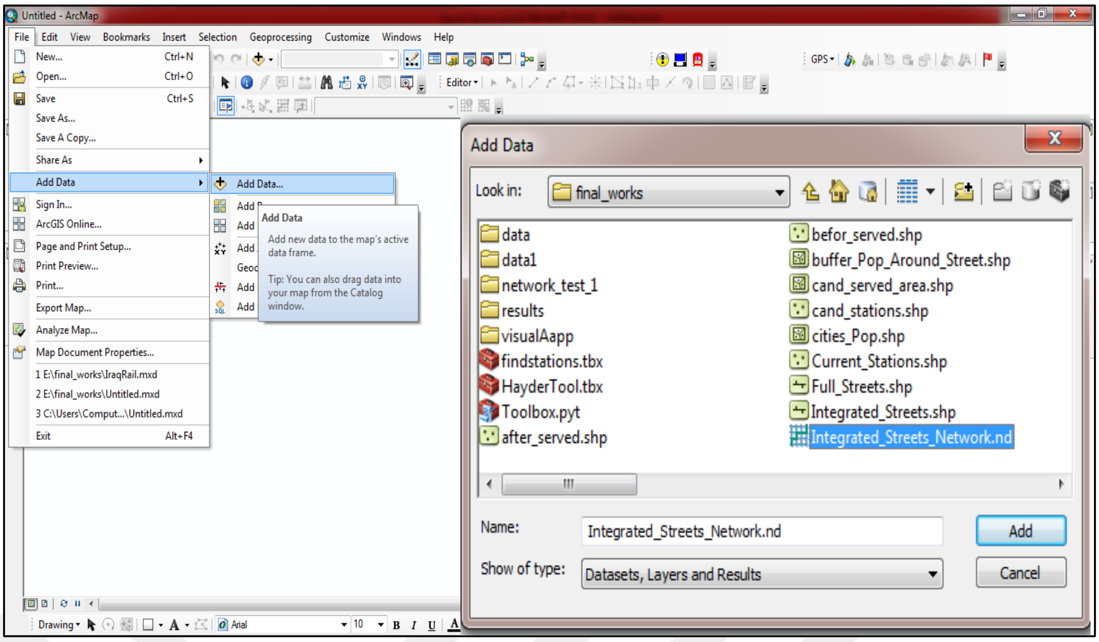


Figure 49 Addition of the network dataset

3. The analysis type is selected for the network analysis. As mentioned in the first chapter, the aim of this research is to find the best locations for train stations. Therefore, the best analysis type is the new-location allocation. These steps were followed in order to perform this analysis:

   ArcMap → network analyst → new-location allocation → OK, as shown in Figure 50.

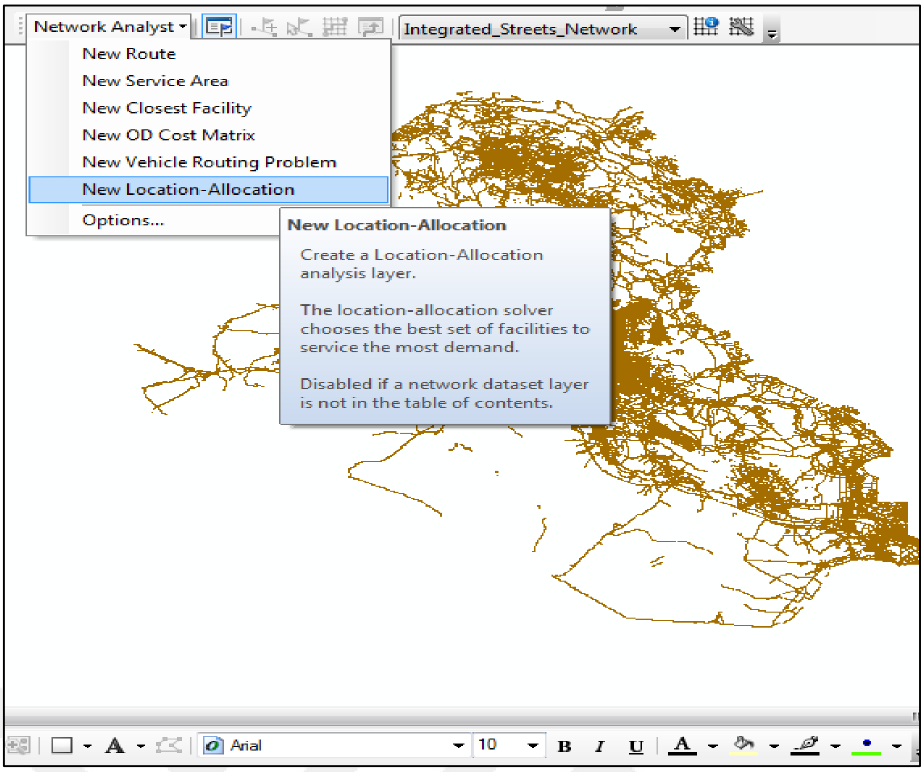


Figure 50 Selection of the analysis type

4. The layer of the population per road, which is the point layer obtained in Section 3.1.1.4–4, is added in order to use it as a demand layer in the analysis. In order to load this layer, these steps were followed:
   New-location allocation → OK → network analyst window → right click on the demand points → load locations, as shown in Figure 51.

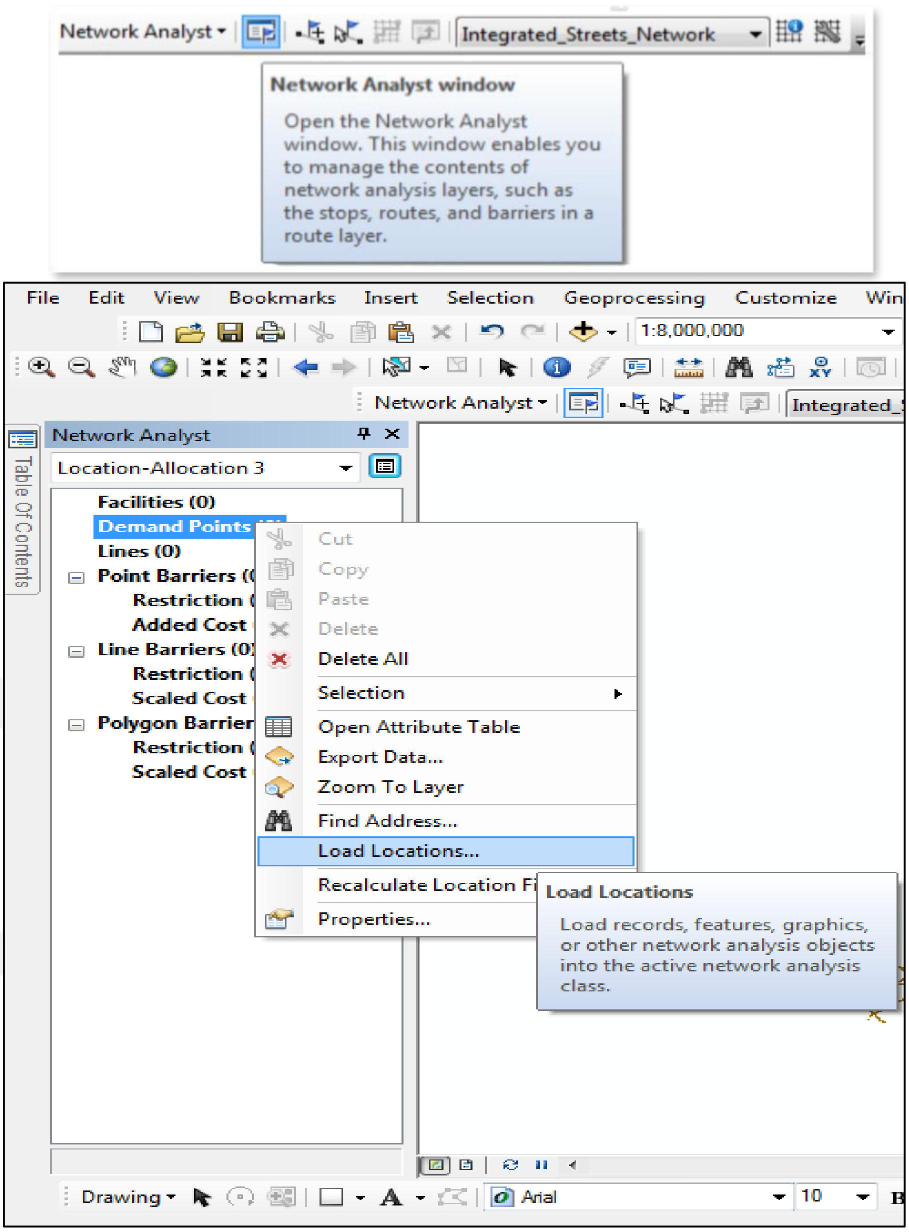


Figure 51 Addition of the demand layer

5. The parameters of the demand layer are set (population density point layer). Then, the parameters required for the network analysis should be set too. The population-per-road field was selected as a weight for this analysis. These parameters were set by following the steps below:

   Load locations → select the layer (must be a point layer) → select the name field → select the weight field → leave the rest as default values → OK, as shown in Figure 52.

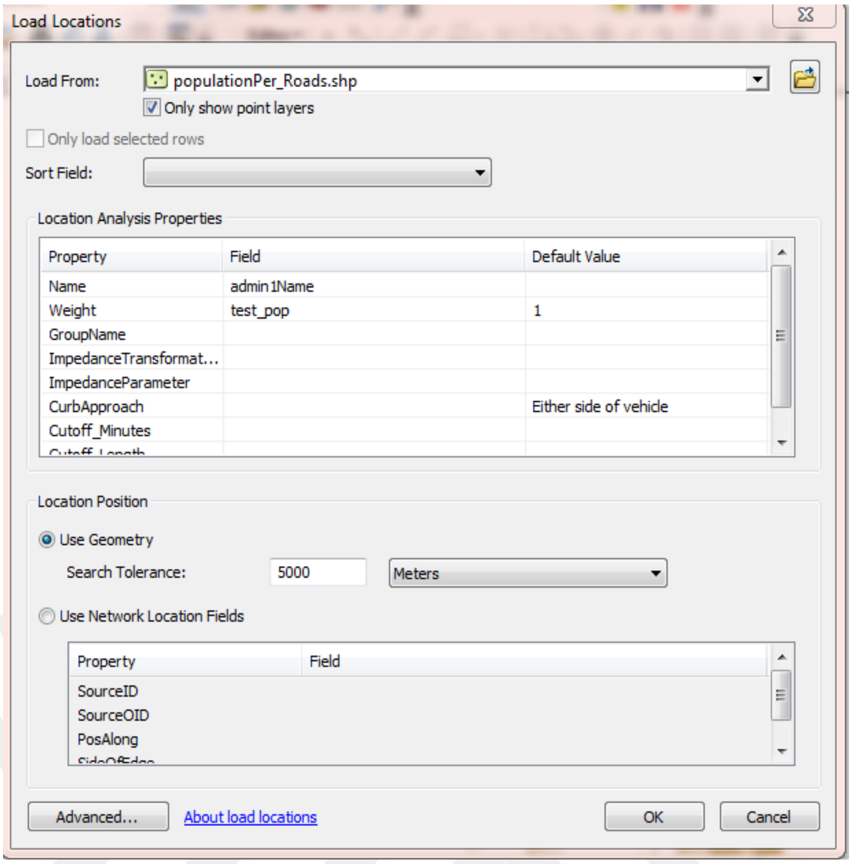


Figure 52 Setting the parameters of the demand layer

6. The layer for the current train stations in Iraq, which is a point layer, is loaded in order to use it as a facilities layer in the analysis. In order to load this layer, the steps below were followed:

   New-location allocation → OK → network analyst window → right click on the facilities points → load locations.

7. The parameters for the facilities layer were set. The current train stations were used as a facilities layer. The steps below were followed:

   Load locations → select the layer (which must be a point layer) → select the name field → select the facility type as "chosen"→ leave the rest as default values → OK, as shown in Figure 53.

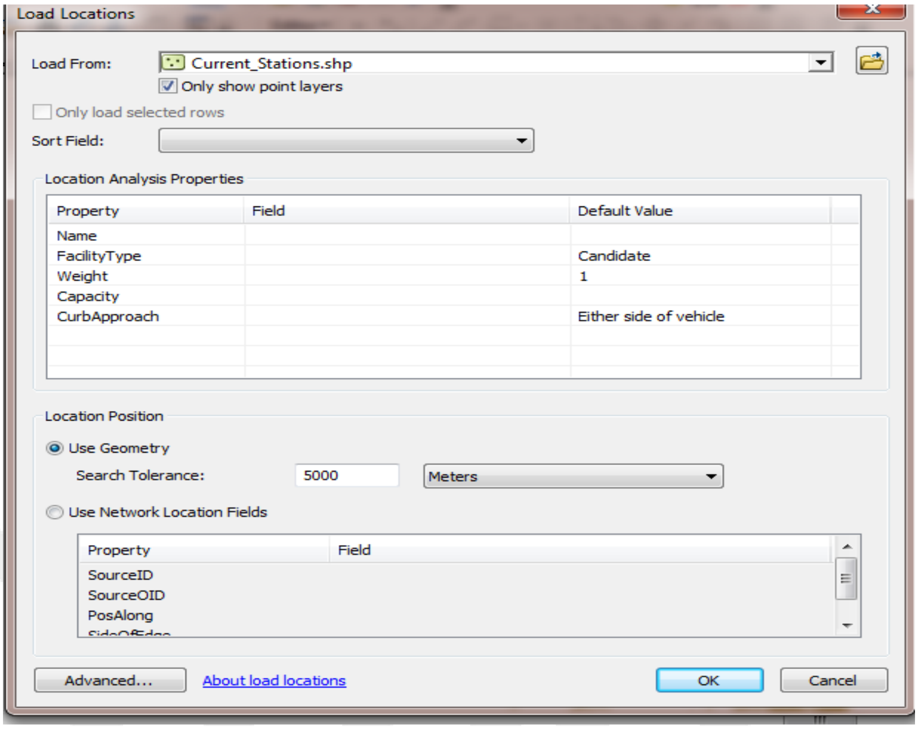


Figure 53 Setting the parameters for the facilities layer

8. The analysis parameters are customized according to specific criteria to achieve the aim of this study. These parameters can be set by following these steps: open network analyst window → select analysis properties → select analysis setting. The criteria are as follows:
   - Minutes as the analysis **impedance** (cost for analysis)
   - **Travel from** demand to facility (from population density points to train stations)
   - **Output shape type** as straight lines (The results will be shown as straight lines but actually the analysis is based on the existing roads network to perform the analysis, but show the results as straight lines to become more clarity), as shown in Figure 54.

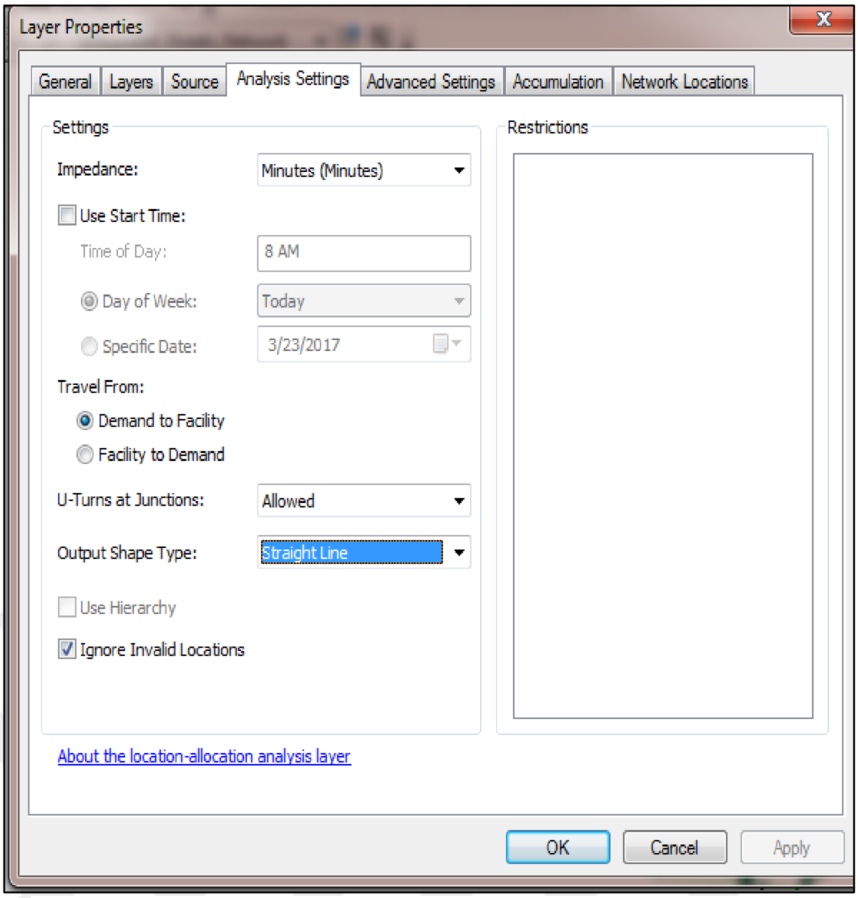


Figure 54 Analysis setting

9. The advanced analysis settings are customized. These settings can be made by using the steps: network analyst window → analysis properties → advanced settings. These settings were chosen as follows:
   - Maximize coverage was chosen as the **problem type** (we want the maximum area to be served around train stations)
   - All facilities were chosen in the field "**facility to choose**" (all current train stations should be analyzed)
   - A limited walking time of 20 minutes was set (from population points to the train stations) in the field "**impedance cutoff**"
   - For the **impedance transformation,** "linear" was selected because the analysis was based on the roads, which were linear (Figure 55).

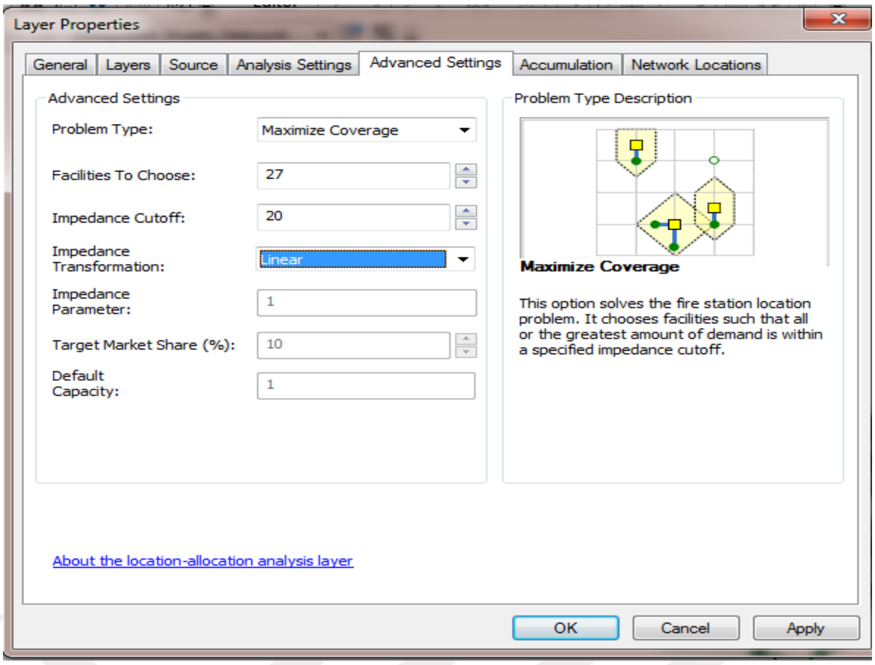


Figure 55 Setting the advanced settings

10. The network analysis was run to solve the problem based on layers and settings that had been introduced. The network analysis can be done by following the steps below:

    Network analysis window→solve, as shown in Figures 56 and 57.

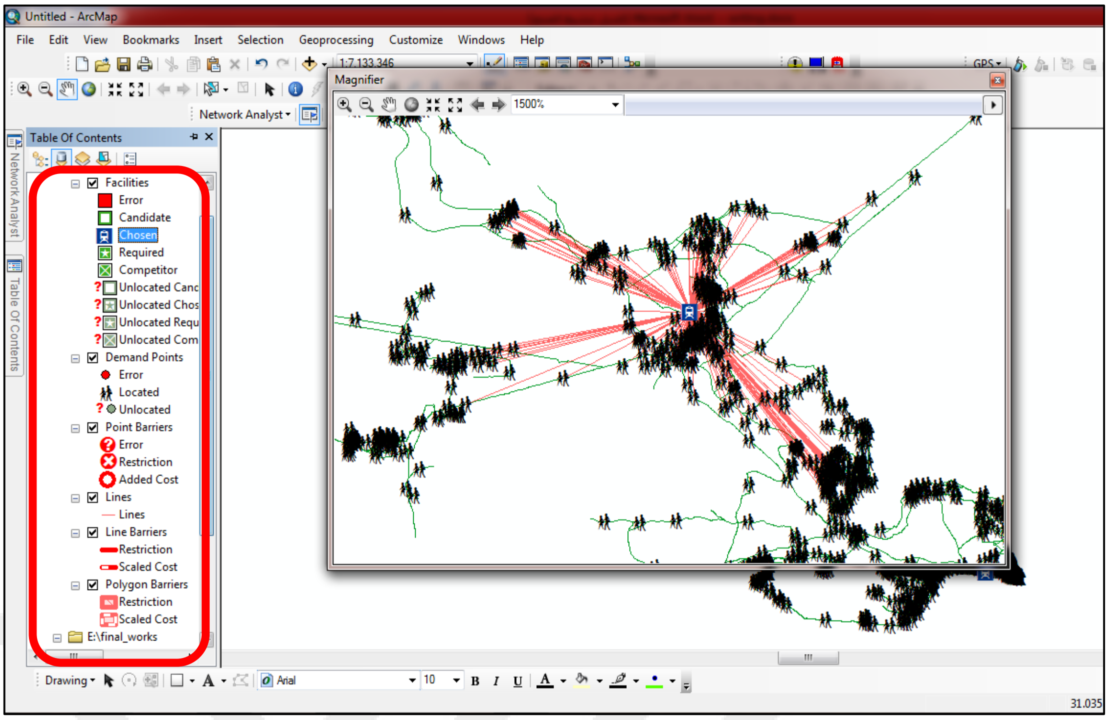


Figure 57 Network analysis results

3.4 PYTHON™ Tool (IRT)

A new custom tool that works in the same environment as ArcMap 10.2 was developed. This new tool was programmed by using PYTHON™ 2.7 programming language, which exists in the ArcGIS® package by default. The purpose of creating this tool is to determine the best candidate locations for new train stations based on the distance between those candidates and population density points. In addition, by using this tool, the candidate locations can be found depending on the population density surrounding those candidate locations **[38].**

This new tool was developed by following these steps:

1. The code was written by using PYTHON™ 2.7 GUI and saved by following the steps below:

   Start → ArcGIS® → PYTHON™2.7 → idle PYTHON™ (GUI) → writing code → file → save as → enter a name for the file → select PYTHON™ as a file type → OK, as shown in Figure 58.

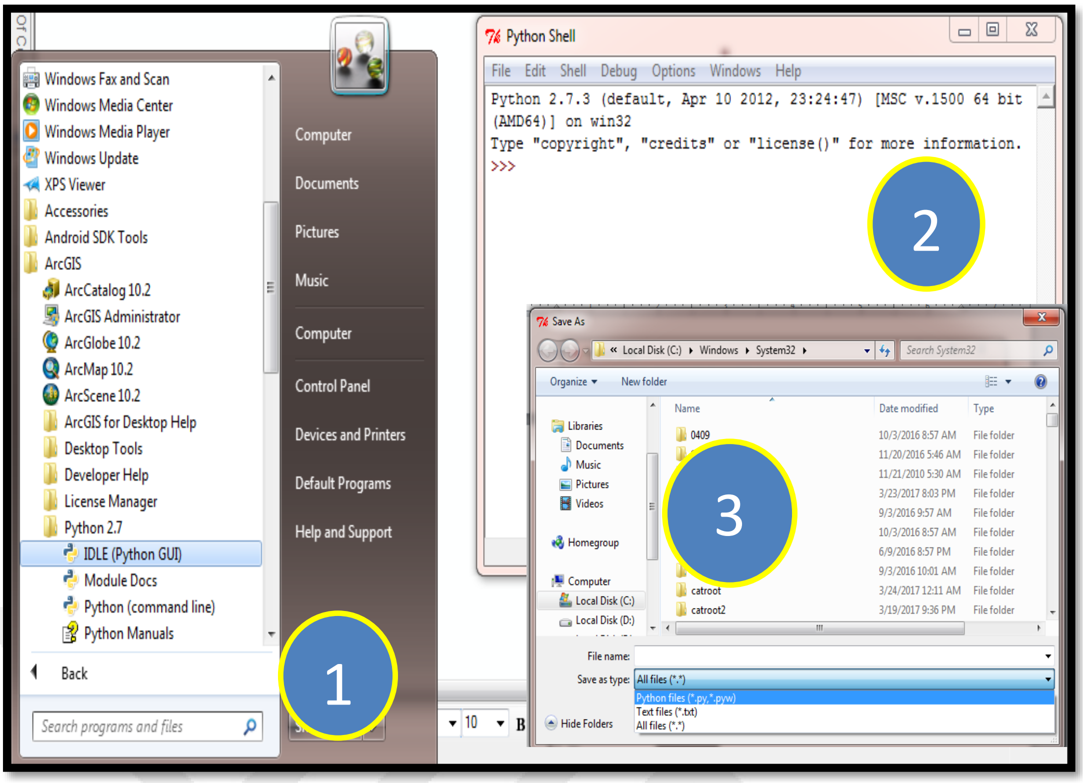
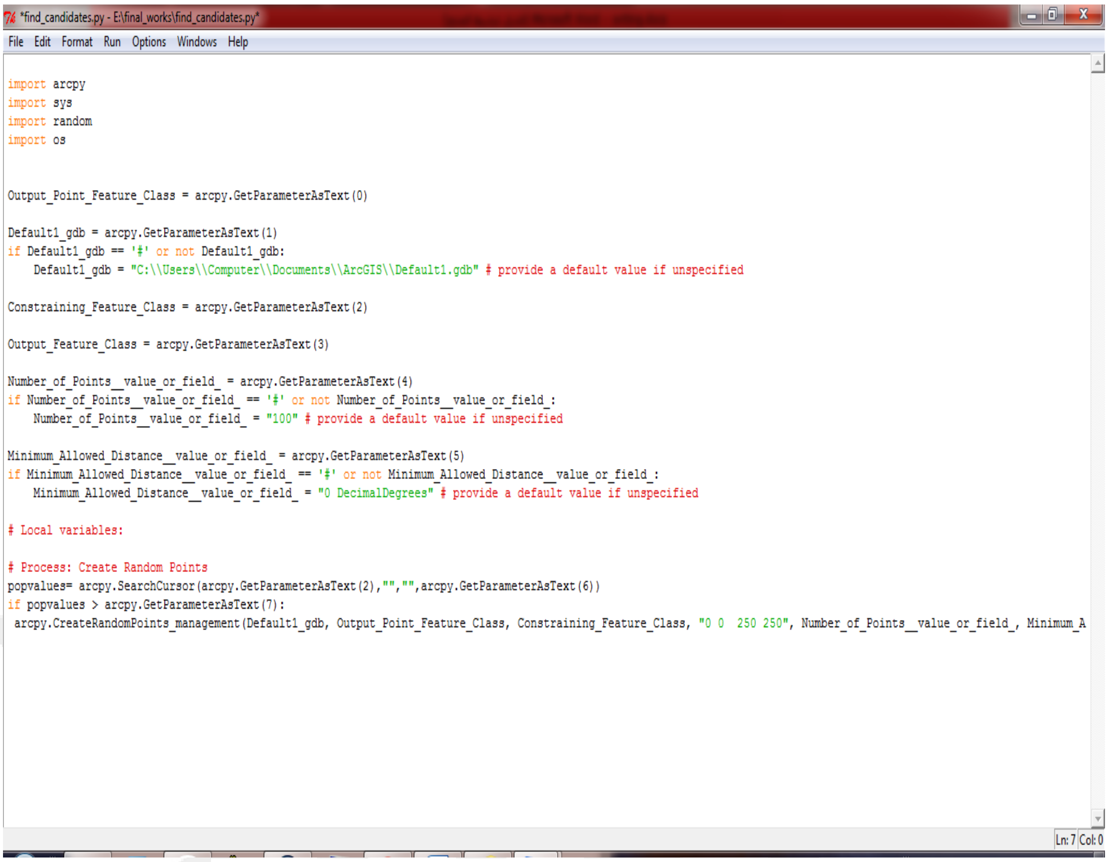


Figure 58 Opening and writing code and saving it as a Python file

2. Figure 59 shows a sample of code for the new tool by using the PYTHON™ coding window.



```
*find_candidates.py - E:\final_works\find_candidates.py*
File  Edit  Format  Run  Options  Windows  Help

import arcpy
import sys
import random
import os


Output_Point_Feature_Class = arcpy.GetParameterAsText(0)

Default1_gdb = arcpy.GetParameterAsText(1)
if Default1_gdb == '#' or not Default1_gdb:
    Default1_gdb = "C:\\Users\\Computer\\Documents\\ArcGIS\\Default1.gdb" # provide a default value if unspecified

Constraining_Feature_Class = arcpy.GetParameterAsText(2)

Output_Feature_Class = arcpy.GetParameterAsText(3)

Number_of_Points__value_or_field_ = arcpy.GetParameterAsText(4)
if Number_of_Points__value_or_field_ == '#' or not Number_of_Points__value_or_field_:
    Number_of_Points__value_or_field_ = "100" # provide a default value if unspecified

Minimum_Allowed_Distance__value_or_field_ = arcpy.GetParameterAsText(5)
if Minimum_Allowed_Distance__value_or_field_ == '#' or not Minimum_Allowed_Distance__value_or_field_:
    Minimum_Allowed_Distance__value_or_field_ = "0 DecimalDegrees" # provide a default value if unspecified

# Local variables:

# Process: Create Random Points
popvalues= arcpy.SearchCursor(arcpy.GetParameterAsText(2),"","",arcpy.GetParameterAsText(6))
if popvalues > arcpy.GetParameterAsText(7):
 arcpy.CreateRandomPoints_management(Default1_gdb, Output_Point_Feature_Class, Constraining_Feature_Class, "0 0  250 250", Number_of_Points__value_or_field_, Minimum_A

Ln: 7 Col: 0
```

Figure 59 Python code

3. A new empty toolbox was added to ArcMap in order to add the new tool inside this toolbox. The program ArcCatalog 10.2 was used to add this new toolbox by applying these steps:

   Start → ArcCatalog → catalog tree→ right click → new → toolset (Figure 60).

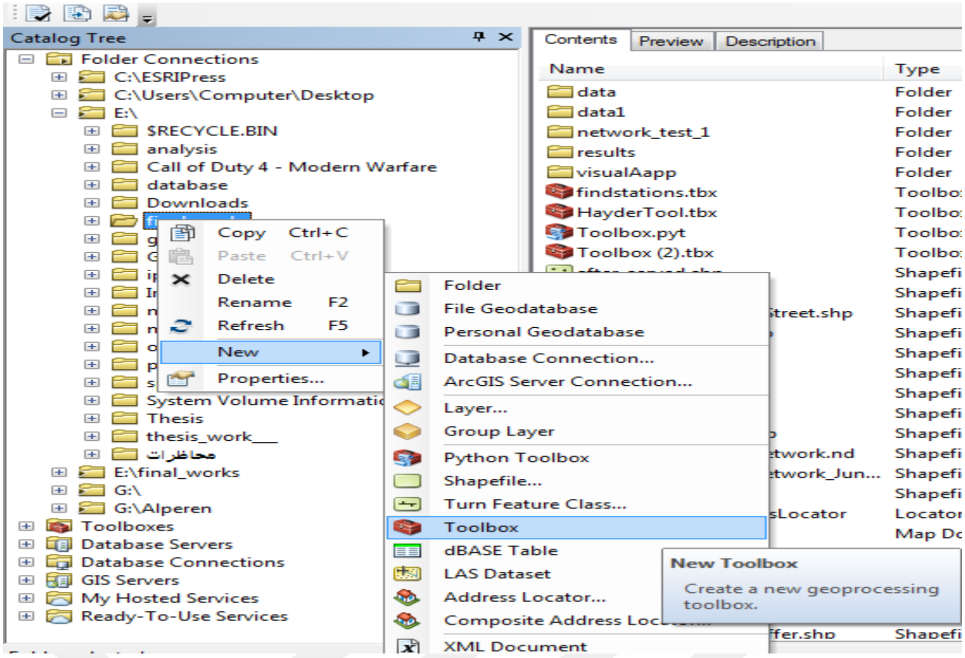


Figure 60 Addition of new tool to the

4. The PYTHON™-scripting file was added with the empty tool. The PYTHON™ file that was created in the previous step was added to the new tool by using these steps:
   Right click on the new tool → add → script → next → determine the path of the scripting file → set the input parameters for the new tool (**u**ser **i**nterface **w**indow) → finish, as shown in Figure 61.

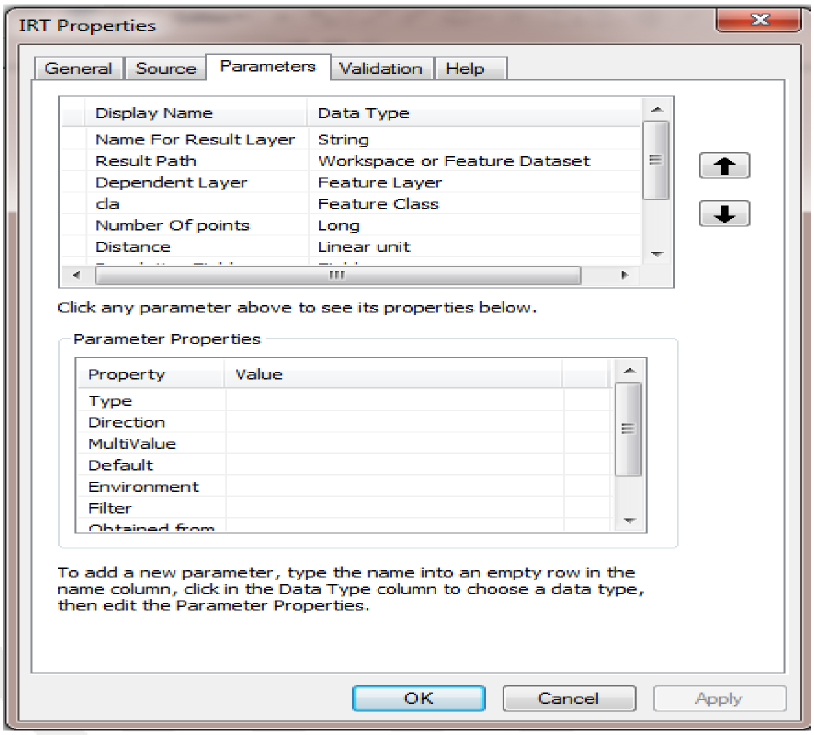


Figure 61 Setting parameters for the new

Note: The parameters that were used with the new tool are listed in Table 1:

Table 1 Parameters of the Python tool

Parameter	Type	Purpose of parameter
Name of the result layer	String	Name of the output layer
Result path	Workspace	Path to save the output layer
The layer on which the new tool depend on to locate the candidates	Feature class	Finding candidates depending on the distance to this layer
Number of candidates	Long	Number of candidates generated
Distance	Linear unit	the distance Between population density points in dependent layer and the new candidates
Population field	Field	Select population field in the dependent layer
Population number	Long	Exclude all points with populations below this number.

5. The description and help feature for the new tool (IRT) were written. Also, some pictures can be added in order to help the user or to describe this tool. This was done by using the following steps:

   ArcCatalog → right click on the tool → description → write the description (Figure 62).

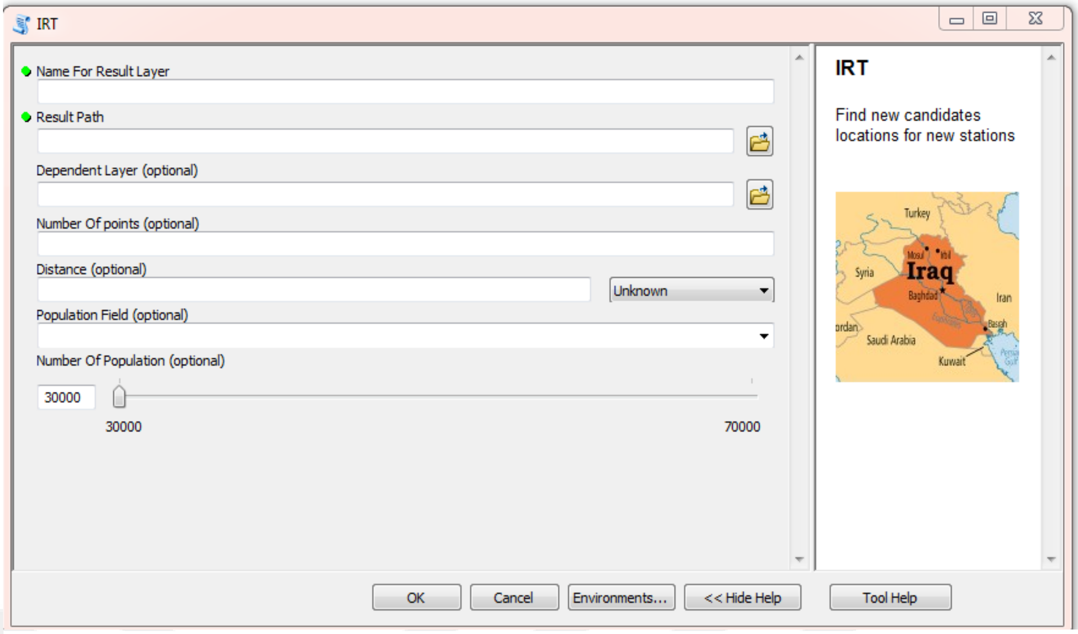


Figure 62 New tool (IRT) created by using Python

3.5 Visual Studio Toolset

A new custom toolset (consisting of three tools) was developed by using Asp.Net (C#) programming language, and it works in the same environment as the ArcMap program. In other words, these tools can be used through the ArcMap10.2 program. ASP.Net(C#) was used to program these tools. In addition, ArcObject 10.2 was used as a connection point between ArcMap and the programming language (Visual Studio 2010). This toolset consists of three tools and the goals of these tools are as follows:

The purpose of the first tool to change the name of the ArcMap project to "Iraq Railways". The second tool browses the results and records for each layer from those results and shows the difference between these layers. The third tool adds a new candidate location (by picking up the X and Y coordinates from the computer screen) **[39].**

Thus, these tools were programmed as follows:

1. Open a new project in Visual Studio 2010:

Start → Microsoft Visual Studio 2010 (C#) → new project → ArcGIS® → extending ArcObjects → class library ArcMap → OK, as shown in Figure 63.

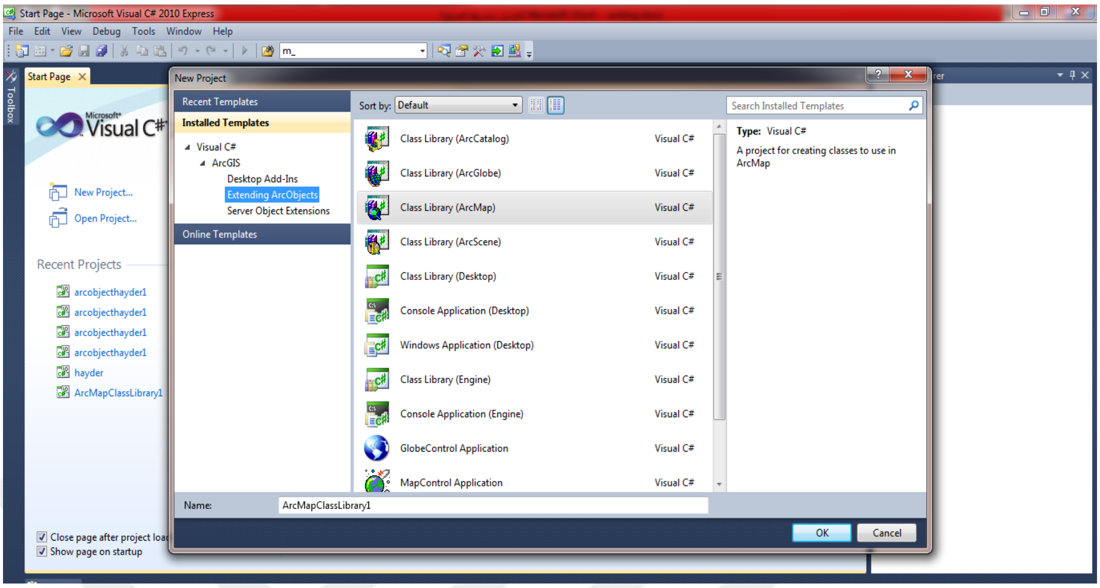


Figure 63 Opening a new project in ASP.Net (C#)

2. A new toolbar is added as a base for the new tools. Then the code for this new toolbar should be written. The code was written by using (C#). The steps below were followed in order to add the toolbar and program it:

   Solution explore → right click on the new project → add → new item → ArcGIS® → extending ArcObjects→ base toolbar, as shown in Figure 64.

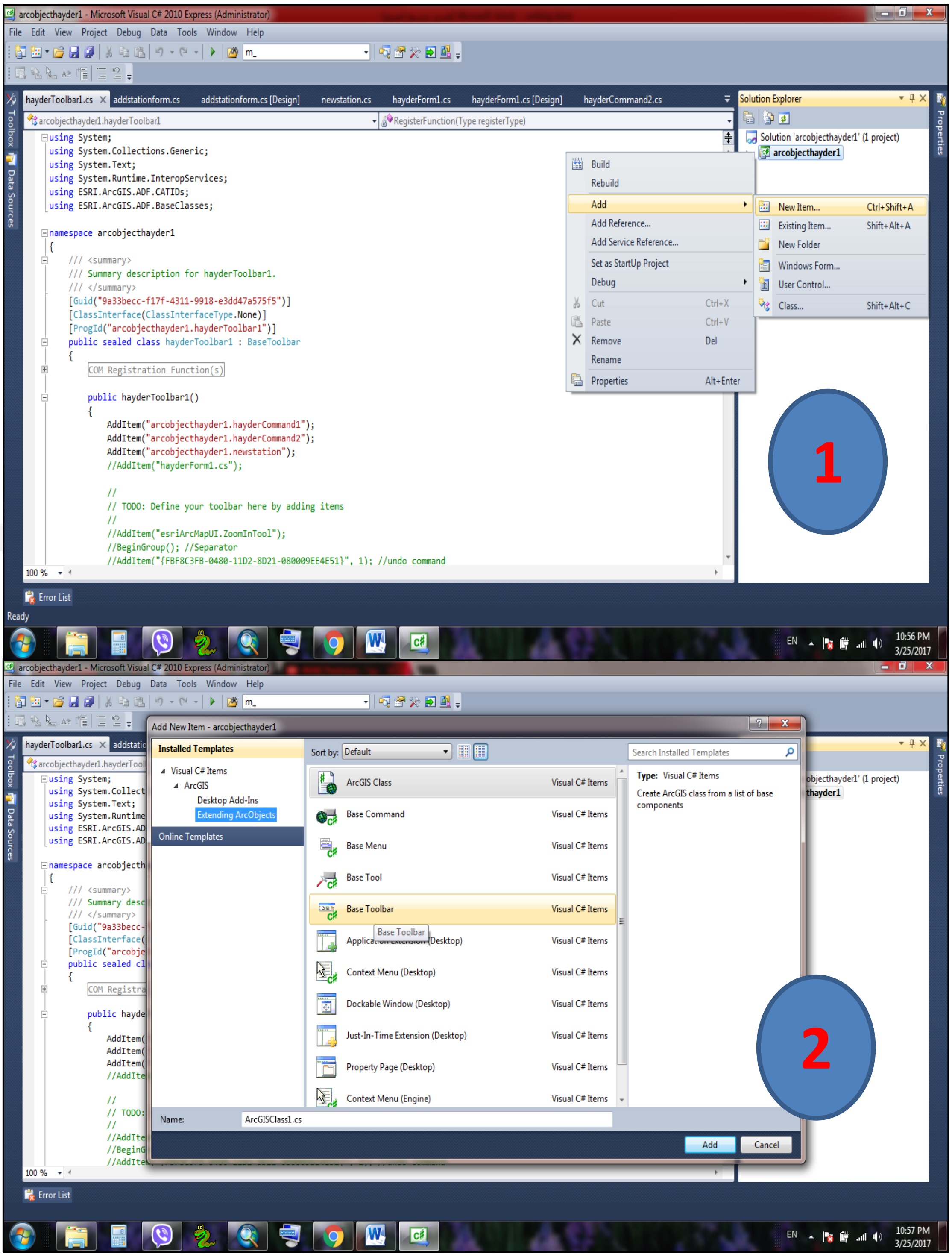


Figure 64 Addition of a new toolbar in

Then, the code for this toolbar should be written in order to define the new tools for the toolbar (Figure 65).

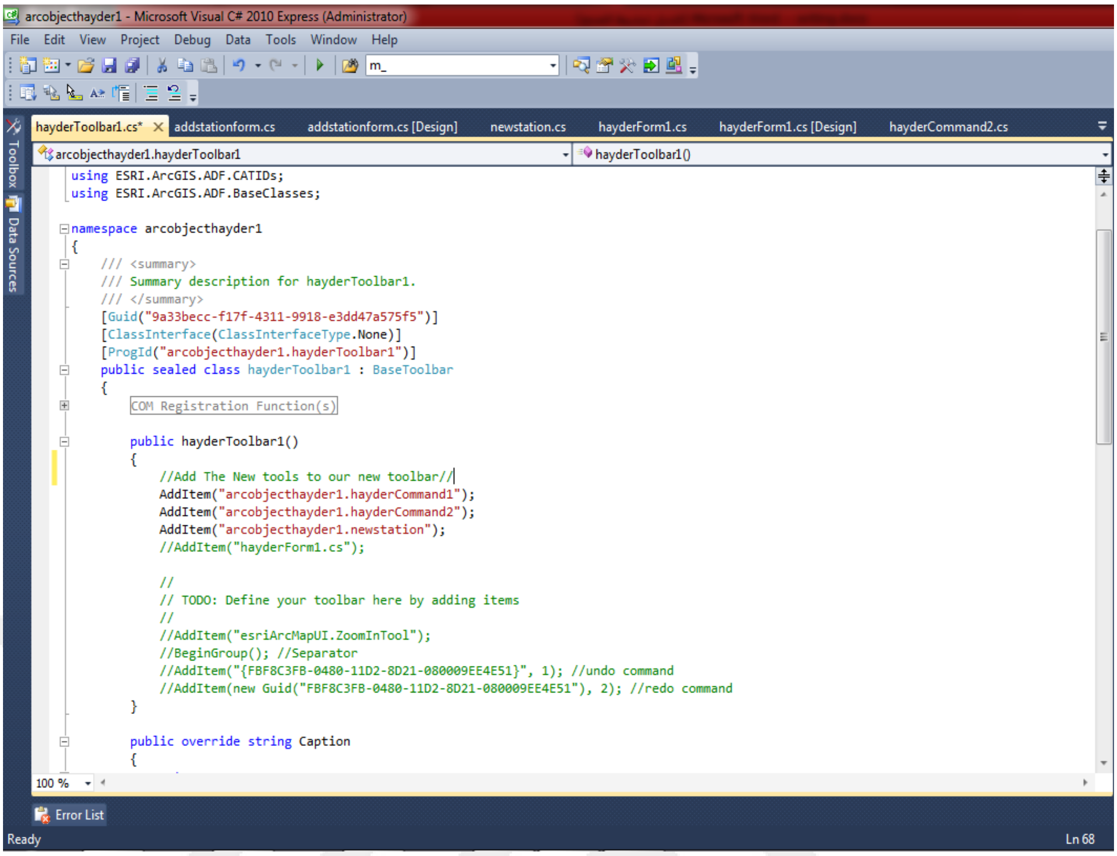


Figure 65 Programming the new toolbar

3. The first tool was added to the project in order to change the name of the ArcMap project and to show the help feature for using the other new tools. The first tool was added as a command tool to the new toolbar and then programmed by using these steps:

   Solution explore → right click on the new project → add → new item → ArcGIS® → extending ArcObjects → base command, as shown in Figure 66.

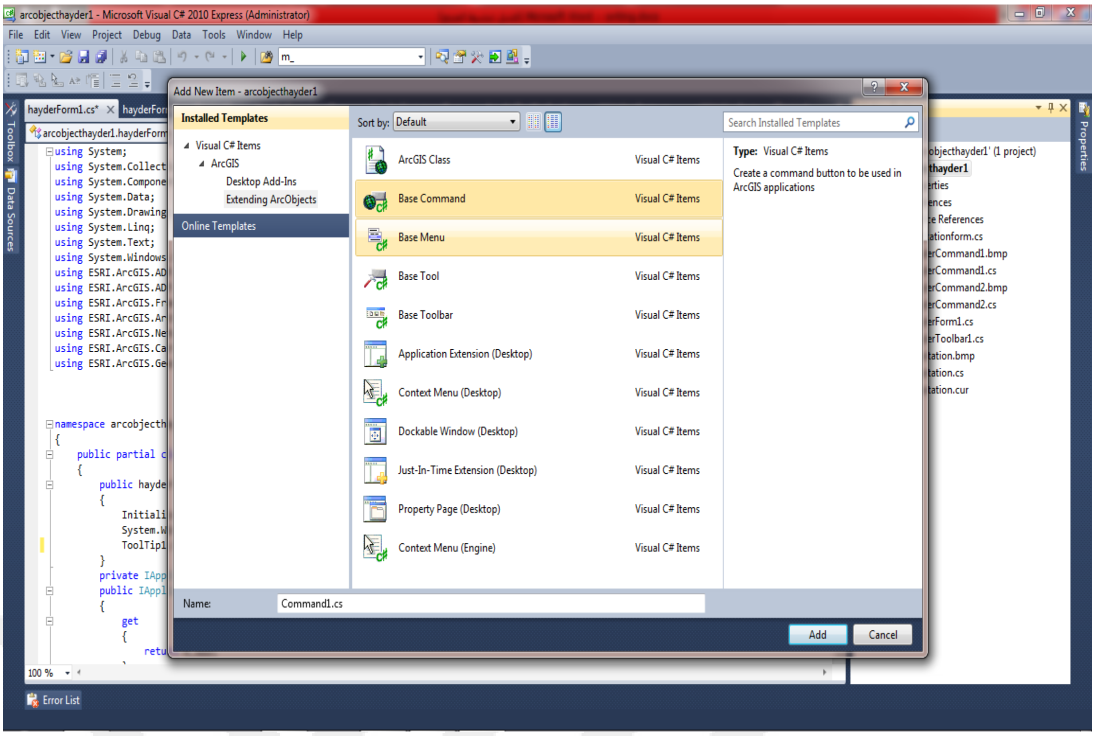


Figure 60 Addition of the new tool, which is a command

By using the same steps as described above, other tools were added. The second tool was also as a command but the third tool was a windows form.

Then, a code was written to link these tools with the toolbar in order to show them in the new toolbar. This step was done by writing some lines of code as shown in Figure 67.

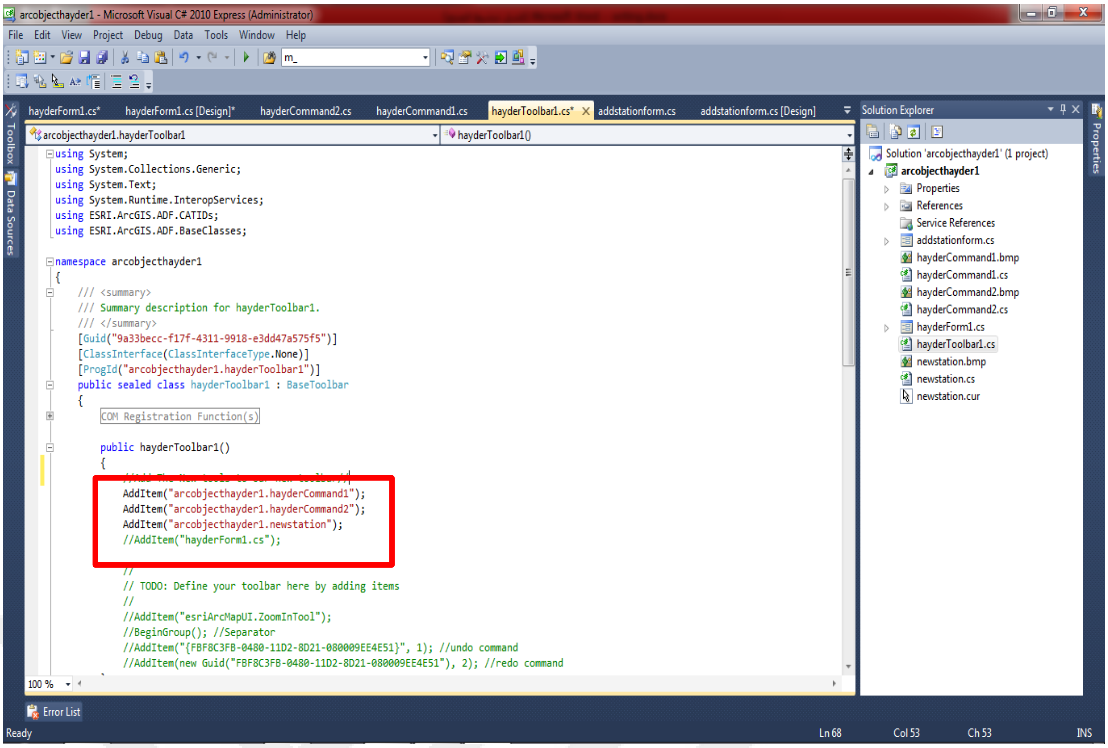


Figure 67 Addition of the tools to the toolbar

The next step was to program these tools one by one as described below:

The code of the first tool changes the project name in ArcMap and shows the help feature for all three of the new tools. Figure 68 shows a sample of the coding for the first tool.

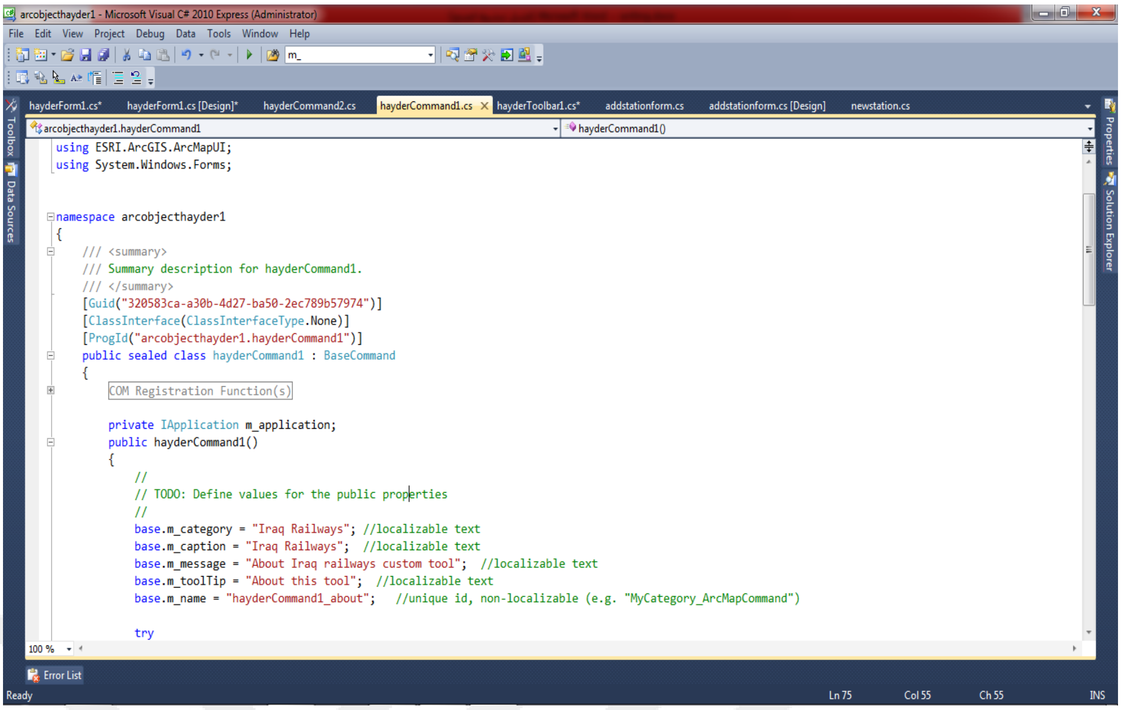


Figure 68 Sample code for the first tool

As mentioned previously, the second tool browses the results and records and hides or shows the resulting layers. Figure 69 shows the design of the user interface for this tool. Moreover, Figure 70 shows a sample of the coding for this tool.

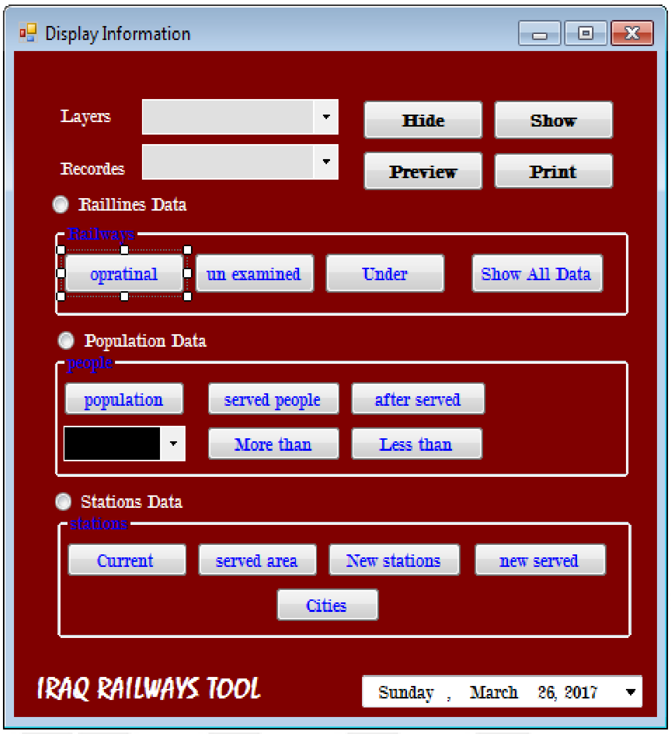


Figure 69 Design of the second tool

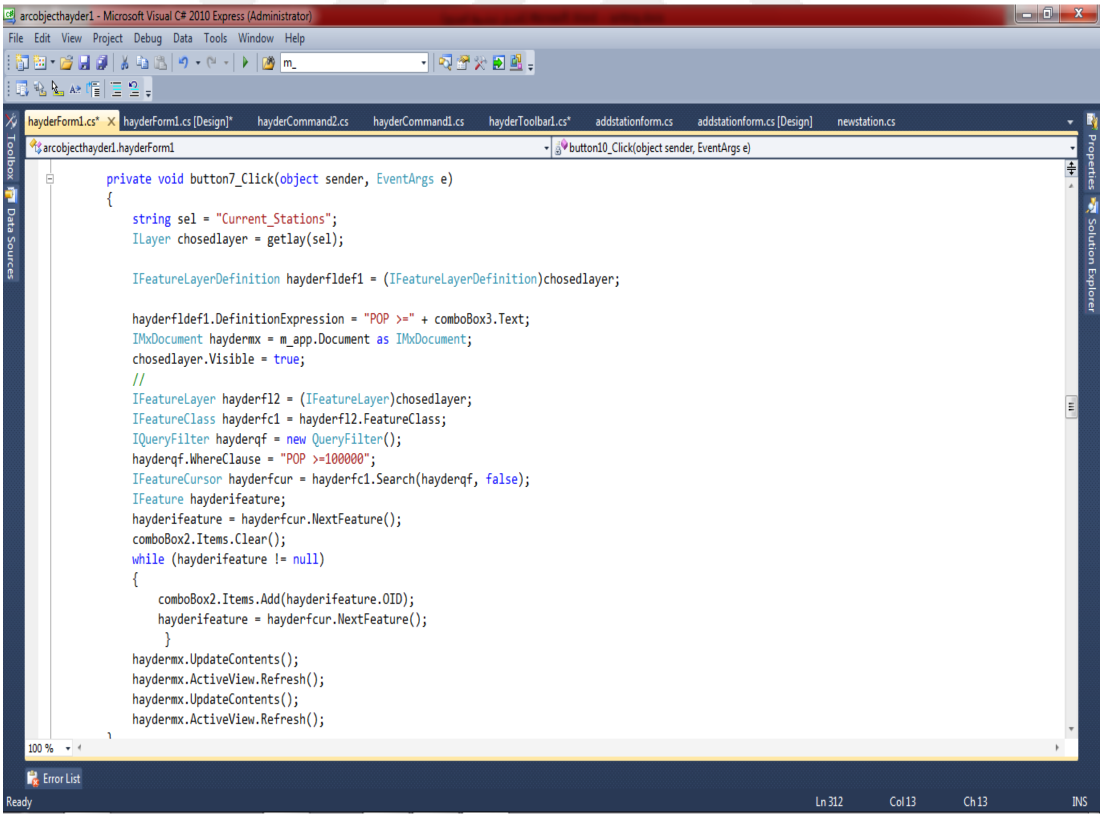


Figure 70 Sample code for the second tool

The third tool adds a new candidate location by selecting the X and Y coordinates of the cursor on the computer screen. In addition, the user can input additional information about that location by using a custom form developed for this purpose in this work. Figure 71 shows the input window of this tool. Figure 72 shows a sample of the programming used for this tool **[40].**

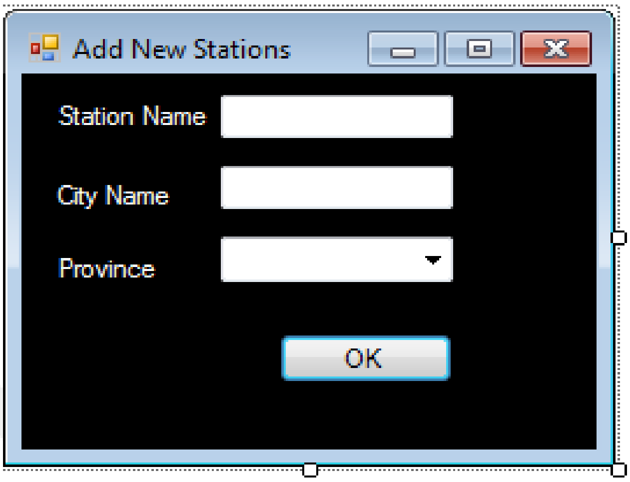


Figure 71 Input form

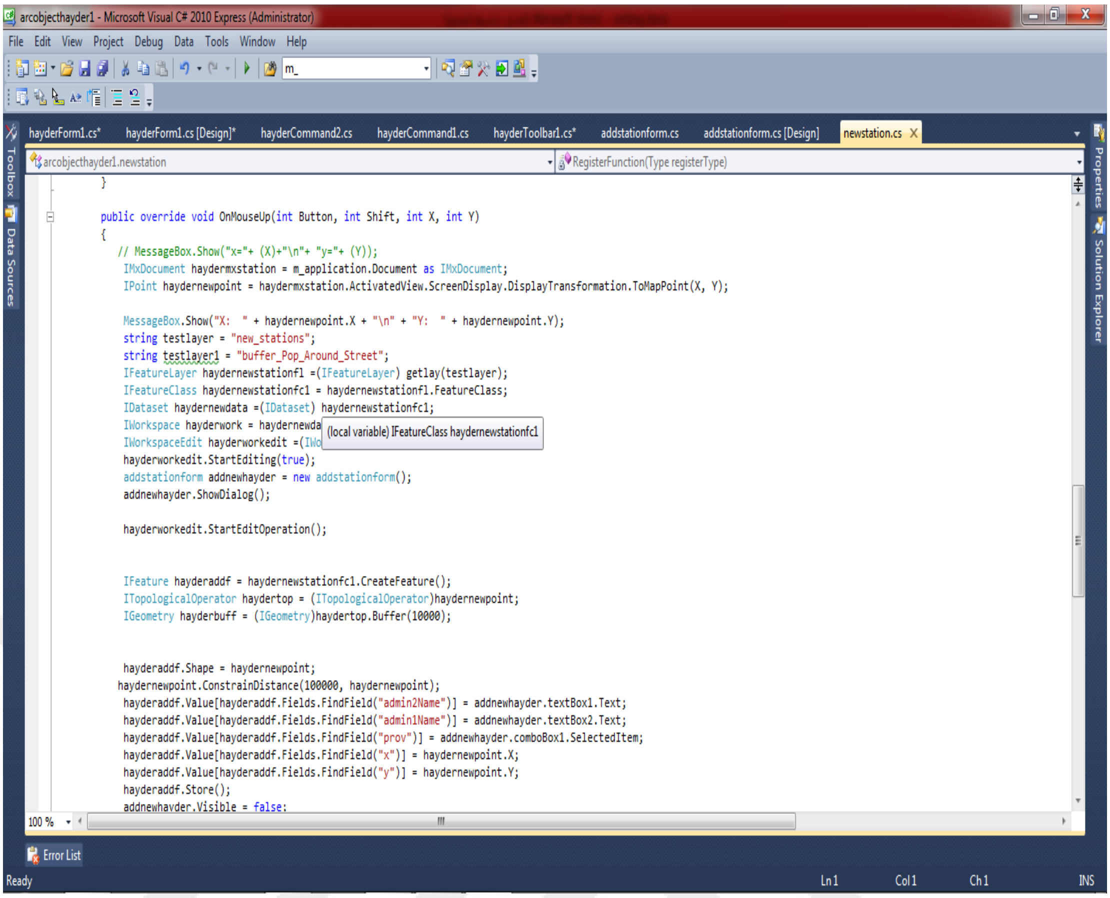


Figure 72 Sample code for the third tool

4. The program was run by using the steps below:

   Visual studio → debug menu → start debugging (with the this symbol )

5. The new toolbar was added to ArcMap in order to use its new tools inside the ArcMap programme. This step was done by applying the steps below: ArcMap → customize → toolbar → Iraq railways toolbar → add, as shown in Figure 73.

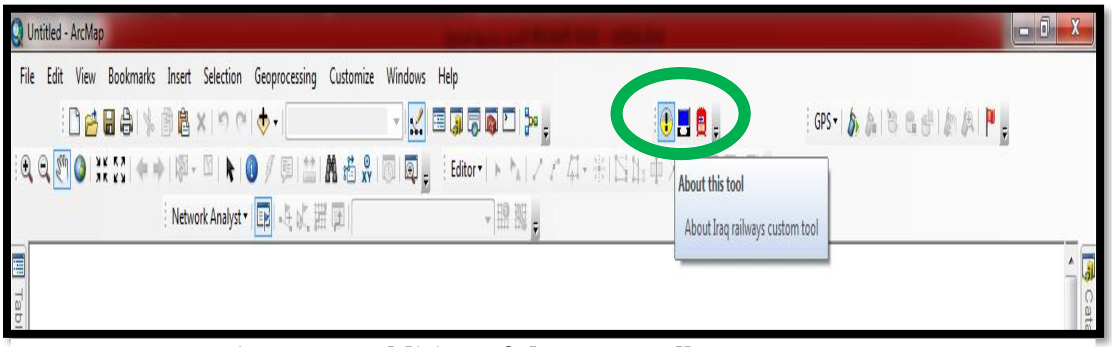


Figure 73 Addition of the new toolbar to ArcMap

All of the programming code for this toolbar and its three tools are attached to the thesis in Appendix A.

Note: This application was examined on the researcher's PC, which possesses the following specifications: Windows 7 OS (64 bit), with an Intel Core I5 processor and 2.6 GHz CPU.

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CHAPTER 4

Conclusion

As mentioned in the previous chapters, there are some problems associated with train stations in Iraq. Moreover, additional problems appeared at some stages of this research. All of these problems were addressed by using ArcGIS®, PYTHON™, and ASP.Net in this thesis. This chapter will present the results obtained in the previous chapter. Furthermore, future studies related to this thesis will be considered. In the final part of this chapter, the conclusion of this thesis will be presented.

4.1 Results

All the results obtained from the previous chapter are layers. These layers contain both spatial and tabular data, which represent the results. As mentioned in the first chapter, the aims of this thesis are separated into two parts**:** analysis of the current stations and finding the best locations for new stations. In this section, all the results are presented as layers and records in the form of maps with attribute tables. These results are as follows:

1. The roads layer which resulted from Steps 3.1.1 and 3.1.2, which contains all of the required information for roads in order to become a Suitable for use in network analysis. This layer contains **28,279** roads and their tabular data.
2. The network dataset (ND). This dataset contains three layers, which resulted from Section 3.2. Those three layers were used later in the

network analysis (road network, road-network edges, road-network junctions).

3. 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 Figure 74.

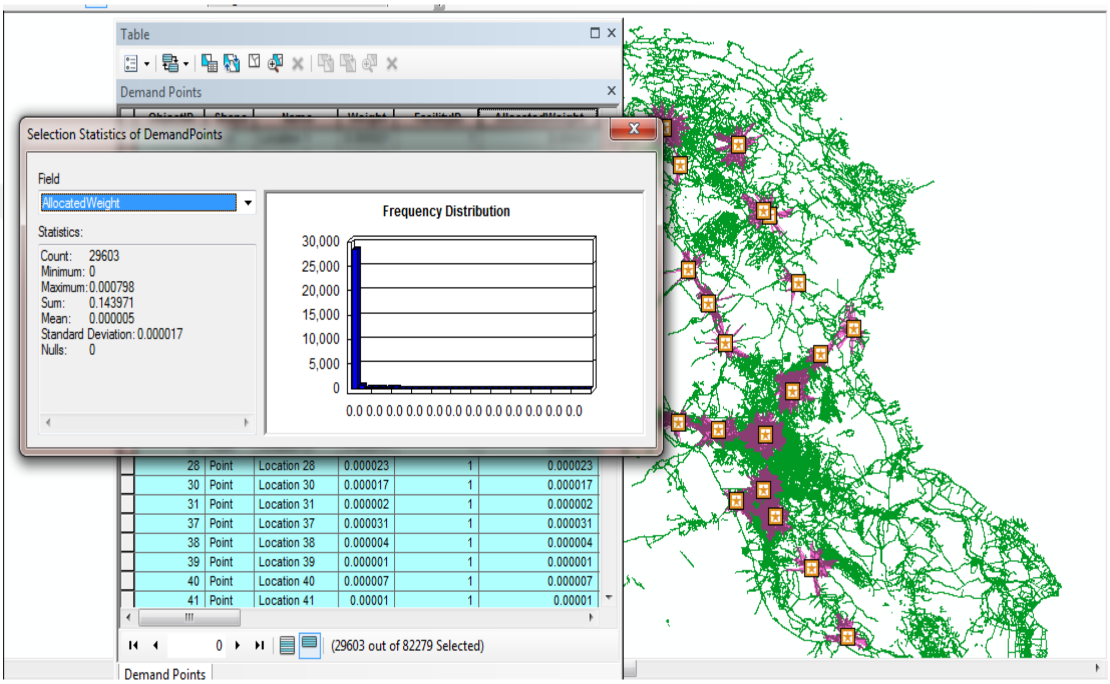

Figure 74 Layer resulting from the analysis of current stations

4. 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** km^2, as shown in Figure 75.

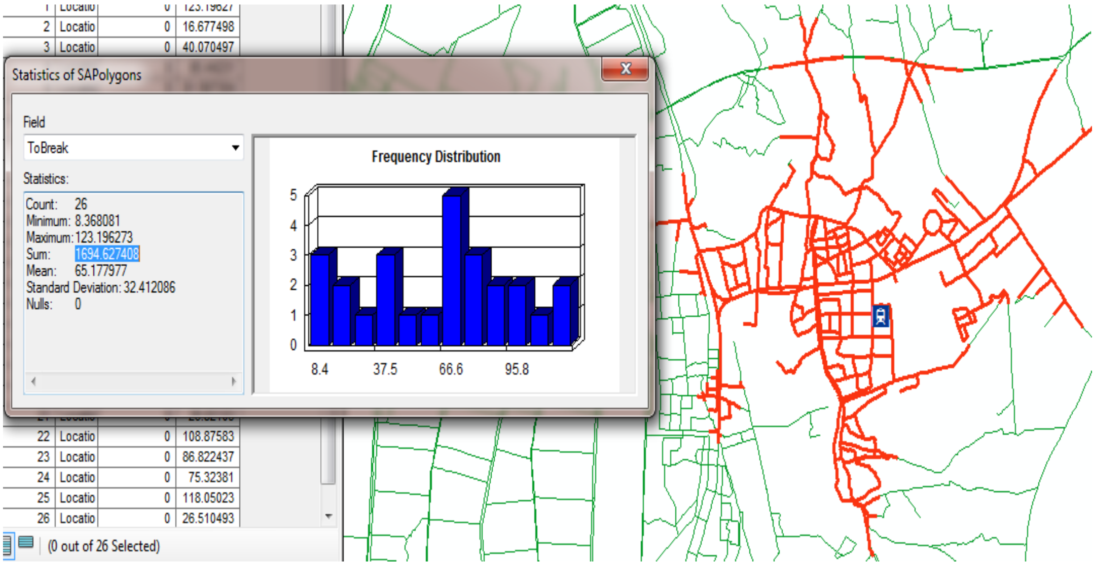

Figure 75 Total area covered by surrounding stations

5. The new candidate locations for new train stations, comprising a layer containing **150** locations. This layer resulted from the use of the new custom PYTHON™ tool, as mentioned in Step 3.4.
6. The resulting layer of new candidate locations analyzed, which is the result of Step 3.4. It contains **58,681** records, which represent the population points from which those stations can be reached within a walking time of 20 minutes.

   Here we can see the difference between the number of beneficiaries of the current stations and of the new stations.
7. The total area served within 2 km of the new train stations, which is **12,403** km^2.

   Here we can see the difference between the areas covered by the current stations and the new stations.
8. Three new tools developed on top of ArcMap, as mentioned in Step 3.5. By using those custom tools, we can easily deal with and browse the results and its records and see the differences between those results in order to improve the decision making.
9. The layer resulting from the use of the third tool, as mentioned in the previous chapter. This layer contains candidate locations for new train stations with their X and Y coordinates, names, and cities.

4.2 Recommendations

1. The same criteria as are used around the world for the development of the railways and the train stations should be used.
2. In addition, standards should be defined according to the needs of the places where these stations are located in order to know the order of priority of new train stations to be constructed in each place.
3. The GIS techniques should be used for everything related to the development of rail transport in order to serve more people and meet their requirements.
4. Joint advisory committees should be formed between the Ministry of Transportation and GIS specialists with the aim of expressing opinions on proposed projects in the railway sector.
5. People should be encouraged to use trains for transportation. What are their effects on the environment and the economic aspect?
6. A GIS unit equipped with all the required hardware and software should be established in all sections of the Iraqi Railway Company.
7. Data for the earth's surface type should be calculated by using satellite images in order to calculate the construction cost of the new train stations in Iraq.
8. Accurate data for population density (buildings, houses, flats, etc.) should be calculated in order to become a reference for developing the railway network.
9. The directions should be calculated for the road network layer in order to calculate the driving accessibility values of the stations.
10. This system should be uploaded to a server with a specific domain so that it can be widely used.
11. Decision-makers of the Iraqi Railway Company should be trained to use this system to improve decision making with regard to the locations of new stations and also trained to use GIS techniques..

4.3 Future Works

1. The same application should be developed by using the ArcGIS server in order to deal with a central application with a single dataset. If the application is developed by using the ArcGIS server and installed on a server, then it will be possible for users to use it via wired or wireless networks **[41].**
2. It will be possible to use or develop the same application for other purposes such as determining 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.
5. This application could be upgraded to make it a comprehensive system for management, planning, maintenance, finance, and train movements, giving a specific authorization type to allow each of those sections to access and work on the system.
6. The same idea as for this thesis could be developed by using different GIS programs such as QGIS, JavaScript, and Visual Studio (VB).
7. A new tool should be developed for determining the train station located nearest to where the user is looking. This tool should be developed so that it is available on the Web browsers and can be accessed by multiple devices such as phones, tablets, and so on.

4.4 Conclusion

As a conclusion, by using GIS techniques for dealing with and solving transportation problems, the results will be more accurate. Thus, in this thesis, the GIS techniques offered by ArcGIS (10.2) were used. In addition, new tools for ArcMap were built by using PYTHON and Visual Studio(C#) programming languages as mentioned in the third chapter. This study aimed to determine the best locations for new train stations in Iraq. The methodology in this thesis is based on network analysis of train stations in GIS. This analysis is based on applying some criteria that are mentioned in previous chapters in order to measure the accessibility values of those train stations by using the existing road network. Also, the areas serviced around each train station were measured by using the service area analysis technique in GIS. Therefore, this study aimed to support the decision making. The results show the differences between the number of people who can use the current train stations and the number of people who would be able to use the new train stations. Also, the results show the difference between the areas covered (2 km around each station) by the current and new train stations where people can take advantage of the train services within those areas.

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APPENDIX A

The Code of the new tools, which were programmed on top of ArcMap by using ASP.Net (C#) programming language

Define the New Toolbar with its Tools

```
using System;
using System.Collections.Generic;
using System.Text;
using System.Runtime.InteropServices;
using ESRI.ArcGIS.ADF.CATIDs;
using ESRI.ArcGIS.ADF.BaseClasses;

namespace arcobjecthayder1
{
    [Guid("9a33becc-f17f-4311-9918-e3dd47a575f5")]
  [ClassInterface(ClassInterfaceType.None)]
  [ProgId("arcobjecthayder1.hayderToolbar1")]
  public sealed class hayderToolbar1 : BaseToolbar
  {
    #region COM Registration Function(s)
    [ComRegisterFunction()]
    [ComVisible(false)]
    static void RegisterFunction(Type registerType)
    {

    }

    [ComUnregisterFunction()]
    [ComVisible(false)]
    static void UnregisterFunction(Type registerType)
    {

    }

    private static void ArcGISCategoryRegistration(Type registerType)
    {
```

```
            string regKey =
string.Format("HKEY_CLASSES_ROOT\\CLSID\\{{{0}}}",
registerType.GUID);
            MxCommandBars.Register(regKey);
        }

        private static void ArcGISCategoryUnregistration(Type
registerType)
        {
            string regKey =
string.Format("HKEY_CLASSES_ROOT\\CLSID\\{{{0}}}",
registerType.GUID);
            MxCommandBars.Unregister(regKey);
        }
        public hayderToolbar1()
        {
            // Add three the tools to the toolbar
            AddItem("arcobjecthayder1.hayderCommand1");
            AddItem("arcobjecthayder1.hayderCommand2");
            AddItem("arcobjecthayder1.newstation");
            //AddItem("hayderForm1.cs");


        }

        public override string Caption
        {
            get
            {
                //TODO: Replace bar caption
                return "IRAQ Railways Tool";
            }
        }
        public override string Name
        {
            get
            {
                //TODO: Replace bar ID
                return "hayderToolbar1";
            }
        }
    }
```

}

The First Tool to Change the Application Name and Show the Help for the New Tools

```
using System;
using System.Drawing;
using System.Runtime.InteropServices;
using ESRI.ArcGIS.ADF.BaseClasses;
using ESRI.ArcGIS.ADF.CATIDs;
using ESRI.ArcGIS.Framework;
using ESRI.ArcGIS.ArcMapUI;
using System.Windows.Forms;


namespace arcobjecthayder1
{

   [Guid("320583ca-a30b-4d27-ba50-2ec789b57974")]
   [ClassInterface(ClassInterfaceType.None)]
   [ProgId("arcobjecthayder1.hayderCommand1")]
   public sealed class hayderCommand1 : BaseCommand
   {
      #region COM Registration Function(s)
      [ComRegisterFunction()]
      [ComVisible(false)]
      static void RegisterFunction(Type registerType)
      {
      }

      [ComUnregisterFunction()]
      [ComVisible(false)]
      static void UnregisterFunction(Type registerType)
      {

      }

      private static void ArcGISCategoryRegistration(Type registerType)
      {
         string regKey =
string.Format("HKEY_CLASSES_ROOT\\CLSID\\{{{0}}}",
registerType.GUID);
         MxCommands.Register(regKey);
```

```
        }

        private static void ArcGISCategoryUnregistration(Type
registerType)
        {
            string regKey =
string.Format("HKEY_CLASSES_ROOT\\CLSID\\{{{0}}}",
registerType.GUID);
            MxCommands.Unregister(regKey);

        }

        #endregion
        #endregion

        private IApplication m_application;
        public hayderCommand1()
        {
            //
            base.m_category = "Iraq Railways"; //localizable text
            base.m_caption = "Iraq Railways";  //localizable text
            base.m_message = "About Iraq railways custom tool";
//localizable text
            base.m_toolTip = "About this tool";  //localizable text
            base.m_name = "hayderCommand1_about";   //unique id, non-
localizable (e.g. "MyCategory_ArcMapCommand")

            try
            {
                //
                string bitmapResourceName = GetType().Name + ".bmp";
                base.m_bitmap = new Bitmap(GetType(),
bitmapResourceName);
            }
            catch (Exception ex)
            {
                System.Diagnostics.Trace.WriteLine(ex.Message, "Invalid
Bitmap");
            }
        }
        public override void OnCreate(object hook)
```

```
        {
            if (hook == null)
                return;

            m_application = hook as IApplication;

            //Disable if it is not ArcMap
            if (hook is IMxApplication)
                base.m_enabled = true;
            else
                base.m_enabled = false;

            // TODO:  Add other initialization code
        }
        public override void OnClick()
        {
            // TODO: Add hayderCommand1.OnClick implementation

            MessageBox.Show("This toolset produced by Hayder Naji. Any user can use it to find new candinates stations.In addition, it has made by using ASP.NET (C#) ");
            m_application.Caption = "IRAQ RAILWAYS";



        }

        #endregion
    }
}
```

Windows Form for the Second Tool to Browse between the Results

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Windows.Forms;
```

```
using ESRI.ArcGIS.ADF.BaseClasses;
using ESRI.ArcGIS.ADF.CATIDs;
using ESRI.ArcGIS.Framework;
using ESRI.ArcGIS.ArcMapUI;
using ESRI.ArcGIS.NetworkAnalysis;
using ESRI.ArcGIS.Carto;
using ESRI.ArcGIS.Geodatabase;

namespace arcobjecthayder1
{
    public partial class hayderForm1 : Form
    {
        public hayderForm1()
        {
            InitializeComponent();
            System.Windows.Forms.ToolTip ToolTip1 = new
System.Windows.Forms.ToolTip();
            ToolTip1.SetToolTip(this.button11, "Show the results");
        }
        private IApplication m_app;
        public IApplication arc_applcation
        {
            get
            {
                return m_app;
            }
            set

            { m_app = value; }
        }
        private void button1_Click(object sender, EventArgs e)
        {
            string sel = comboBox1.SelectedItem.ToString();
            ILayer chosedlayer = getlay(sel);
            chosedlayer.Visible = true;
            IMxDocument haydermx = m_app.Document as IMxDocument;

            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
        }
```

```
        private void comboBox1_SelectedIndexChanged(object sender,
EventArgs e)
        {
            string sel = comboBox1.SelectedItem.ToString();
            ILayer chosedlayer = getlay(sel);
            IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IFeatureCursor hayderfcur = hayderfc1.Search(null,false);
            IFeature hayderifeature;
            hayderifeature = hayderfcur.NextFeature();
            comboBox2.Items.Clear();
            while (hayderifeature != null)
            {
                comboBox2.Items.Add(hayderifeature.OID);
                hayderifeature = hayderfcur.NextFeature();

            }
        }
        private void hayderForm1_Load(object sender, EventArgs e)
        {

        }
        private void button2_Click(object sender, EventArgs e)
        {
            string sel =comboBox1.SelectedItem.ToString();
            ILayer chosedlayer = getlay(sel);
            chosedlayer.Visible = false;
            IMxDocument haydermx = m_app.Document as IMxDocument;
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
        }
        public ILayer getlay(string h)
        {
            IMxDocument haydermx = m_app.Document as IMxDocument;
            IMap hayderpmap = haydermx.FocusMap;
            for (int i = 0; i <= hayderpmap.LayerCount - 1; i++)
            {
                ILayer hayderplayer = hayderpmap.get_Layer(i);
                if (hayderplayer.Name == h)
                    return hayderplayer;
            }
            return null;
```

```
        }

        private void button3_Click(object sender, EventArgs e)

        {

            string sel = "railways";
            ILayer chosedlayer = getlay(sel);
           IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;

            hayderfldef1.DefinitionExpression = "EXS_DESCRI=
'Operational'";
            IMxDocument haydermx = m_app.Document as IMxDocument;

            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
            IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IQueryFilter hayderqf = new QueryFilter();
            hayderqf.WhereClause="EXS_DESCRI= 'Operational'";
            IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
            IFeature hayderifeature;
            hayderifeature = hayderfcur.NextFeature();
            comboBox2.Items.Clear();
            while (hayderifeature != null)
            {
                int filed1 = hayderifeature.Fields.FindField("admin2Name");
                //string name1 = hayderifeature.Value(filed1.ToString());
              comboBox2.Items.Add(hayderifeature.Value[filed1].ToString());

                hayderifeature = hayderfcur.NextFeature();

            }
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
            //comboBox2.Items.Clear();
        }
        private void button4_Click(object sender, EventArgs e)
        {
            string sel = "railways";
            ILayer chosedlayer = getlay(sel);
```

```
            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
        hayderfldef1.DefinitionExpression = "EXS_DESCRI= 'Under
Construction'";
            IMxDocument haydermx = m_app.Document as IMxDocument;
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
            IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IQueryFilter hayderqf = new QueryFilter();
            hayderqf.WhereClause = "EXS_DESCRI= 'Under Construction'";
            IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
            IFeature hayderifeature;
            hayderifeature = hayderfcur.NextFeature();
            comboBox2.Items.Clear();
            while (hayderifeature != null)
            {
                int filed1 = hayderifeature.Fields.FindField("admin2Name");


comboBox2.Items.Add(hayderifeature.Value[filed1].ToString());
               // comboBox2.Items.Add(hayderifeature.OID);
                hayderifeature = hayderfcur.NextFeature();
            }

            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
          }

        private void button5_Click(object sender, EventArgs e)
        {
            string sel = "railways";
            ILayer chosedlayer = getlay(sel);
            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;

            hayderfldef1.DefinitionExpression = "EXS_DESCRI=
'Unexamined/Unsurveyed'";
            IMxDocument haydermx = m_app.Document as IMxDocument;
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
            IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
```

```
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IQueryFilter hayderqf = new QueryFilter();
            hayderqf.WhereClause = "EXS_DESCRI=
'Unexamined/Unsurveyed'";
            IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
            IFeature hayderifeature;
            hayderifeature = hayderfcur.NextFeature();
            comboBox2.Items.Clear();
            while (hayderifeature != null)
            {
                int filed1 = hayderifeature.Fields.FindField("admin2Name");


comboBox2.Items.Add(hayderifeature.Value[filed1].ToString());
                //comboBox2.Items.Add(hayderifeature.OID);
                hayderifeature = hayderfcur.NextFeature();
            }
            //comboBox2.Items.Clear();
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
            }
        private void button6_Click(object sender, EventArgs e)
        {
            string sel = "railways";
            ILayer chosedlayer = getlay(sel);
            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
             hayderfldef1.DefinitionExpression = "";
            IMxDocument haydermx = m_app.Document as IMxDocument;
            chosedlayer.Visible = true;
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
        }
        private void button7_Click(object sender, EventArgs e)
        {
            string sel = "Current_Stations";
            ILayer chosedlayer = getlay(sel);

            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
            hayderfldef1.DefinitionExpression = "POP >=" +
comboBox3.Text;
```

```
            IMxDocument haydermx = m_app.Document as IMxDocument;
            chosedlayer.Visible = true;
             IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IQueryFilter hayderqf = new QueryFilter();
            hayderqf.WhereClause = "POP >=100000";
            IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
            IFeature hayderifeature;
            hayderifeature = hayderfcur.NextFeature();
            comboBox2.Items.Clear();
            while (hayderifeature != null)
            {
                comboBox2.Items.Add(hayderifeature.OID);
                hayderifeature = hayderfcur.NextFeature();
                 }
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
        }
                private void button8_Click(object sender, EventArgs e)
        {
            string sel = "Current_Stations";
            ILayer chosedlayer = getlay(sel);
            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
            hayderfldef1.DefinitionExpression = "POP <" +comboBox3.Text;
            IMxDocument haydermx = m_app.Document as IMxDocument;
            chosedlayer.Visible = true;
            IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IQueryFilter hayderqf = new QueryFilter();
            hayderqf.WhereClause = "POP < 100000";
            IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
            IFeature hayderifeature;
            hayderifeature = hayderfcur.NextFeature();
            comboBox2.Items.Clear();
            while (hayderifeature != null)
            {
                comboBox2.Items.Add(hayderifeature.OID);
                hayderifeature = hayderfcur.NextFeature();
            }
```

```
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
        }

        private void button9_Click(object sender, EventArgs e)
        {
            string sel = "Current_Stations";
            ILayer chosedlayer = getlay(sel);
            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
            hayderfldef1.DefinitionExpression = "";
            IMxDocument haydermx = m_app.Document as IMxDocument;
            chosedlayer.Visible = true;
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
        }

        private void button10_Click(object sender, EventArgs e)
        {
            string sel = "befor_served";
            ILayer chosedlayer = getlay(sel);
            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
            hayderfldef1.DefinitionExpression = "";
            IMxDocument haydermx = m_app.Document as IMxDocument;
            chosedlayer.Visible = true;
            IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IQueryFilter hayderqf = new QueryFilter();
            hayderqf.WhereClause = "";
            IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
            IFeature hayderifeature;
            hayderifeature = hayderfcur.NextFeature();
            comboBox2.Items.Clear();
            while (hayderifeature != null)
            {
                comboBox2.Items.Add(hayderifeature.OID);
                hayderifeature = hayderfcur.NextFeature();
            }
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
        }
```

```
        private void button11_Click(object sender, EventArgs e)
        {
             string sel = "after_served";
            ILayer chosedlayer = getlay(sel);
            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
            hayderfldef1.DefinitionExpression = "";
            IMxDocument haydermx = m_app.Document as IMxDocument;
            chosedlayer.Visible = true;
            IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IQueryFilter hayderqf = new QueryFilter();
            hayderqf.WhereClause = "";
            IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
            IFeature hayderifeature;
            hayderifeature = hayderfcur.NextFeature();
            comboBox2.Items.Clear();
            while (hayderifeature != null)
            {
                comboBox2.Items.Add(hayderifeature.OID);
                hayderifeature = hayderfcur.NextFeature();
            }
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
        }

        private void button12_Click(object sender, EventArgs e)
        {
            string sel = "cand_stations";
            ILayer chosedlayer = getlay(sel);

            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
            hayderfldef1.DefinitionExpression = "";
            IMxDocument haydermx = m_app.Document as IMxDocument;
            chosedlayer.Visible = true;
            IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IQueryFilter hayderqf = new QueryFilter();
            hayderqf.WhereClause = "";
            IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
```

```
    IFeature hayderifeature;
    hayderifeature = hayderfcur.NextFeature();
    comboBox2.Items.Clear();
    while (hayderifeature != null)
    {
        comboBox2.Items.Add(hayderifeature.OID);
        hayderifeature = hayderfcur.NextFeature();
    }
    haydermx.UpdateContents();
    haydermx.ActiveView.Refresh();
}
private void button13_Click(object sender, EventArgs e)
{
    //populationPer_Roads.shp
        string sel = "populationPer_Roads";
    ILayer chosedlayer = getlay(sel);

    IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
    hayderfldef1.DefinitionExpression = "";
    IMxDocument haydermx = m_app.Document as IMxDocument;
    chosedlayer.Visible = true;
    IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
    IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
    IQueryFilter hayderqf = new QueryFilter();
    hayderqf.WhereClause = "";
    IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
    IFeature hayderifeature;
    hayderifeature = hayderfcur.NextFeature();
    comboBox2.Items.Clear();
    while (hayderifeature != null)
    {
        comboBox2.Items.Add(hayderifeature.OID);
        hayderifeature = hayderfcur.NextFeature();
    }
    haydermx.UpdateContents();
    haydermx.ActiveView.Refresh();
}
private void button14_Click(object sender, EventArgs e)
{
    //service_area
         string sel = "service_area";
```

```
            ILayer chosedlayer = getlay(sel);
            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
            hayderfldef1.DefinitionExpression = "";
            IMxDocument haydermx = m_app.Document as IMxDocument;
            chosedlayer.Visible = true;
            IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IQueryFilter hayderqf = new QueryFilter();
            hayderqf.WhereClause = "";
            IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
            IFeature hayderifeature;
            hayderifeature = hayderfcur.NextFeature();
            comboBox2.Items.Clear();
            while (hayderifeature != null)
            {
               comboBox2.Items.Add(hayderifeature.OID);
               hayderifeature = hayderfcur.NextFeature();
            }
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
         }

         private void button15_Click(object sender, EventArgs e)
         {
            //\cand_served_area.shp
                string sel = "cand_served_area";
            ILayer chosedlayer = getlay(sel);
            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
            hayderfldef1.DefinitionExpression = "";
            IMxDocument haydermx = m_app.Document as IMxDocument;
            chosedlayer.Visible = true;
            IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IQueryFilter hayderqf = new QueryFilter();
            hayderqf.WhereClause = "";
            IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
            IFeature hayderifeature;
            hayderifeature = hayderfcur.NextFeature();
            comboBox2.Items.Clear();
            while (hayderifeature != null)
```

```
            {
                comboBox2.Items.Add(hayderifeature.OID);
                hayderifeature = hayderfcur.NextFeature();
            }
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
        }
        private void button16_Click(object sender, EventArgs e)
        {
            string sel = "cities_Pop";
            ILayer chosedlayer = getlay(sel);
            IFeatureLayerDefinition hayderfldef1 =
(IFeatureLayerDefinition)chosedlayer;
            hayderfldef1.DefinitionExpression = "";
            IMxDocument haydermx = m_app.Document as IMxDocument;
            chosedlayer.Visible = true;
            IFeatureLayer hayderfl2 = (IFeatureLayer)chosedlayer;
            IFeatureClass hayderfc1 = hayderfl2.FeatureClass;
            IQueryFilter hayderqf = new QueryFilter();
            hayderqf.WhereClause = "";
            IFeatureCursor hayderfcur = hayderfc1.Search(hayderqf, false);
            IFeature hayderifeature;
            hayderifeature = hayderfcur.NextFeature();
            comboBox2.Items.Clear();
            while (hayderifeature != null)
            {
                comboBox2.Items.Add(hayderifeature.OID);
                hayderifeature = hayderfcur.NextFeature();
            }
            haydermx.UpdateContents();
            haydermx.ActiveView.Refresh();
        }
        private void button17_Click(object sender, EventArgs e)
        {
                    m_app.PrintDocument();
        }
        private void button18_Click(object sender, EventArgs e)
        {
            m_app.PrintPreview();
        }
        private void radioButton1_CheckedChanged(object sender,
EventArgs e)
```

```
        {
            radioButton2.Checked = false;
            radioButton3.Checked = false;
            if (radioButton1.Checked == true)
            {
                button3.Visible = true;
                button4.Visible = true;
                button5.Visible = true;
                button6.Visible = true;
                button7.Visible = false;
                button8.Visible = false;
                button10.Visible = false;
                button11.Visible = false;
                button13.Visible = false;
            }
        }
        private void radioButton2_CheckedChanged(object sender,
EventArgs e)
        {
            radioButton1.Checked = false;
            radioButton3.Checked = false;
            if (radioButton2.Checked == true)
            {
                button7.Visible = true;
                button8.Visible = true;
                button10.Visible = true;
                button11.Visible = true;
                button13.Visible = true;
                button3.Visible = false;
                button4.Visible = false;
                button5.Visible = false;
                button6.Visible = false;
                button9.Visible = false;
                button12.Visible = false;
                button14.Visible = false;
                button15.Visible = false;
                button16.Visible = false;
            }
        }

        private void radioButton3_CheckedChanged(object sender,
EventArgs e)
```

```
        {
            radioButton1.Checked = false;
            radioButton2.Checked = false;
            if (radioButton3.Checked == true)
            {
                button9.Visible = true;
                button12.Visible = true;
                button14.Visible = true;
                button15.Visible = true;
                button16.Visible = true;
                button3.Visible = false;
                button4.Visible = false;
                button5.Visible = false;
                button6.Visible = false;
                button7.Visible = false;
                button8.Visible = false;
                button10.Visible = false;
                button11.Visible = false;
                button13.Visible = false;
            }

        }
    }
}
```

Second Tool to hide, show, browse, present records for Results

```
using System;
using System.Drawing;
using System.Runtime.InteropServices;
using ESRI.ArcGIS.ADF.BaseClasses;
using ESRI.ArcGIS.ADF.CATIDs;
using ESRI.ArcGIS.Framework;
using ESRI.ArcGIS.ArcMapUI;
using ESRI.ArcGIS.NetworkAnalysis;
using ESRI.ArcGIS.Carto;
using System.Windows.Forms;

namespace arcobjecthayder1
{

    [Guid("5d304122-2f9e-4b02-a346-2d0b271f2703")]
    [ClassInterface(ClassInterfaceType.None)]
```

```
    [ProgId("arcobjecthayder1.hayderCommand2")]
    public sealed class hayderCommand2 : BaseCommand
    {
        #region COM Registration Function(s)
        [ComRegisterFunction()]
        [ComVisible(false)]
        static void RegisterFunction(Type registerType)
        {

        }

        [ComUnregisterFunction()]
        [ComVisible(false)]
        static void UnregisterFunction(Type registerType)
        {

        }


        private static void ArcGISCategoryRegistration(Type registerType)
        {
            string regKey = 
string.Format("HKEY_CLASSES_ROOT\\CLSID\\{{{0}}}", 
registerType.GUID);
            MxCommands.Register(regKey);

        }

        private static void ArcGISCategoryUnregistration(Type 
registerType)
        {
            string regKey = 
string.Format("HKEY_CLASSES_ROOT\\CLSID\\{{{0}}}", 
registerType.GUID);
            MxCommands.Unregister(regKey);

        }

        #endregion
        #endregion

        private IApplication m_application;
```

```
        public hayderCommand2()
        {

            base.m_category = "IRAQ Railways"; //localizable text
            base.m_caption = "Iraq Railways ";  //localizable text
            base.m_message = "You can show layers with some queries in
this tool";  //localizable text
            base.m_toolTip = "Show data";  //localizable text
            base.m_name = "hayderCommand1_showdata";   //unique id, non-
localizable (e.g. "MyCategory_ArcMapCommand")

            try
            {

                string bitmapResourceName = GetType().Name + ".bmp";
                base.m_bitmap = new Bitmap(GetType(),
bitmapResourceName);
            }
            catch (Exception ex)
            {
                System.Diagnostics.Trace.WriteLine(ex.Message, "Invalid
Bitmap");
            }
        }

        #region Overridden Class Methods


        public override void OnCreate(object hook)
        {
            if (hook == null)
                return;

            m_application = hook as IApplication;

            //Disable if it is not ArcMap
            if (hook is IMxApplication)
                base.m_enabled = true;
            else
                base.m_enabled = false;

        }
```

```
        public override void OnClick()
        {
            hayderForm1 hayderviewer = new hayderForm1();
            hayderviewer.arc_applcation = m_application;
            hayderviewer.Show();
            IMxDocument haydermx = m_application.Document as
IMxDocument;

            IMap hayderpmap = haydermx.FocusMap;
            //ILayer hayderplayer = hayderpmap.get_Layer(0);
            //hayderviewer.comboBox1.Items.Add(hayderplayer.Name);

            for (int i = 0; i <= hayderpmap.LayerCount - 1;i++ )
            {
                ILayer hayderplayer = hayderpmap.get_Layer(i);
                hayderviewer.comboBox1.Items.Add(hayderplayer.Name);
            }
            // TODO: Add hayderCommand2.OnClick implementation
        }
        #endregion
    }
}
```

Windows Form for the Third Tool to Add New Station

```
using System;
using System.Drawing;
using System.Runtime.InteropServices;
using ESRI.ArcGIS.ADF.BaseClasses;
using ESRI.ArcGIS.ADF.CATIDs;
using ESRI.ArcGIS.Framework;
using ESRI.ArcGIS.ArcMapUI;
using System.Windows.Forms;
using ESRI.ArcGIS.Carto;
using ESRI.ArcGIS.Geometry;
using ESRI.ArcGIS.Geodatabase;
using ESRI.ArcGIS.NetworkAnalysis;

namespace arcobjecthayder1
{
        [Guid("c7b79cd7-0130-4462-9daf-e38cd0181b7e")]
    [ClassInterface(ClassInterfaceType.None)]
```

```
    [ProgId("arcobjecthayder1.newstation")]
    public sealed class newstation : BaseTool
    {
        #region COM Registration Function(s)
        [ComRegisterFunction()]
        [ComVisible(false)]
        static void RegisterFunction(Type registerType)
        {
        }

        [ComUnregisterFunction()]
        [ComVisible(false)]
        static void UnregisterFunction(Type registerType)
        {
        }
        private static void ArcGISCategoryRegistration(Type registerType)
        {
            string regKey =
string.Format("HKEY_CLASSES_ROOT\\CLSID\\{{{0}}}",
registerType.GUID);
            MxCommands.Register(regKey);

        }

        private static void ArcGISCategoryUnregistration(Type
registerType)
        {
            string regKey =
string.Format("HKEY_CLASSES_ROOT\\CLSID\\{{{0}}}",
registerType.GUID);
            MxCommands.Unregister(regKey);

        }

        private IApplication m_application;
        public newstation()
        {
           base.m_category = "IRAQ RAILWAYS new_station";
//localizable text
            base.m_caption = "create new stations";  //localizable text
```

```
            base.m_message = "you can chose a good place and click to add a
new postion for a new station with buffer (10 KM) around it to see the
area that will be served with the new station  ";  //localizable text
            base.m_toolTip = "use this tool to add a new station";
//localizable text
            base.m_name = "newstation";   //unique id, non-localizable (e.g.
"MyCategory_ArcMapTool")
            try
            {
                string bitmapResourceName = GetType().Name + ".bmp";
                base.m_bitmap = new Bitmap(GetType(),
bitmapResourceName);
                base.m_cursor = new
System.Windows.Forms.Cursor(GetType(), GetType().Name + ".cur");
            }
            catch (Exception ex)
            {
                System.Diagnostics.Trace.WriteLine(ex.Message, "Invalid
Bitmap");
            }
        }
         public override void OnCreate(object hook)
        {
            m_application = hook as IApplication;

            //Disable if it is not ArcMap
            if (hook is IMxApplication)
                base.m_enabled = true;
            else
                base.m_enabled = false;

        }

        public override void OnClick()
        {
         }

        public override void OnMouseUp(int Button, int Shift, int X, int Y)
        {
           // MessageBox.Show("x="+ (X)+"\n"+ "y="+ (Y));
            IMxDocument haydermxstation = m_application.Document as
IMxDocument;
```

```
            IPoint haydernewpoint =
haydermxstation.ActivatedView.ScreenDisplay.DisplayTransformation.T
oMapPoint(X, Y);

            MessageBox.Show("X:  " + haydernewpoint.X + "\n" + "Y:  " +
haydernewpoint.Y);
            string testlayer = "new_stations";
            string testlayer1 = "buffer_Pop_Around_Street";
            IFeatureLayer haydernewstationfl =(IFeatureLayer)
getlay(testlayer);
            IFeatureClass haydernewstationfc1 =
haydernewstationfl.FeatureClass;
            IDataset haydernewdata =(IDataset) haydernewstationfc1;
            IWorkspace hayderwork = haydernewdata.Workspace;
            IWorkspaceEdit hayderworkedit =(IWorkspaceEdit) hayderwork;
            hayderworkedit.StartEditing(true);
            addstationform addnewhayder = new addstationform();
            addnewhayder.ShowDialog();
            hayderworkedit.StartEditOperation();
            IFeature hayderaddf = haydernewstationfc1.CreateFeature();
            ITopologicalOperator haydertop =
(ITopologicalOperator)haydernewpoint;
            IGeometry hayderbuff = (IGeometry)haydertop.Buffer(10000);
            hayderaddf.Shape = haydernewpoint;
           haydernewpoint.ConstrainDistance(100000, haydernewpoint);
            hayderaddf.Value[hayderaddf.Fields.FindField("admin2Name")]
= addnewhayder.textBox1.Text;
            hayderaddf.Value[hayderaddf.Fields.FindField("admin1Name")]
= addnewhayder.textBox2.Text;
            hayderaddf.Value[hayderaddf.Fields.FindField("prov")] =
addnewhayder.comboBox1.SelectedItem;
            hayderaddf.Value[hayderaddf.Fields.FindField("x")] =
haydernewpoint.X;
            hayderaddf.Value[hayderaddf.Fields.FindField("y")] =
haydernewpoint.Y;
            hayderaddf.Store();
            addnewhayder.Visible = false;
            hayderworkedit.StopEditOperation();
                //Graphics hh=      addnewhayder.CreateGraphics();
                // hh.DrawPolygon("red",
            hayderworkedit.StopEditing(true);
            haydermxstation.ActiveView.Refresh();
```

```
        }
        #endregion
        public ILayer getlay(string h)
        {
            IMxDocument haydermx = m_application.Document as
IMxDocument;
            IMap hayderpmap = haydermx.FocusMap;
            for (int i = 0; i <= hayderpmap.LayerCount - 1; i++)
            {
                ILayer hayderplayer = hayderpmap.get_Layer(i);
                if (hayderplayer.Name == h)
                    return hayderplayer;
            }
            return null;
        }
    }
 }
```

Add New Station by Clicking on the Screen

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Windows.Forms;
using ESRI.ArcGIS.Geometry;
using ESRI.ArcGIS.Geodatabase;
using ESRI.ArcGIS.Carto;
using System.Runtime.InteropServices;
using ESRI.ArcGIS.ADF.BaseClasses;
using ESRI.ArcGIS.ADF.CATIDs;
using ESRI.ArcGIS.Framework;
using ESRI.ArcGIS.ArcMapUI;
using ESRI.ArcGIS.NetworkAnalysis;
```

```
namespace arcobjecthayder1
{
    public partial class addstationform : Form
    {
        public addstationform()
        {
            InitializeComponent();
        }
        public IPoint stationlocation
        {
            get
            {return stationlocation;}
            set { stationlocation = value; }

            }
        private void addstationform_Load(object sender, EventArgs e)
        {
        }
        private IApplication m_application;
        public ILayer getlay(string h)
        {
            IMxDocument haydermx = m_application.Document as
IMxDocument;
            IMap hayderpmap = haydermx.FocusMap;
            for (int i = 0; i <= hayderpmap.LayerCount - 1; i++)
            {
                ILayer hayderplayer = hayderpmap.get_Layer(i);
                if (hayderplayer.Name == h)
                    return hayderplayer;
            }
            return null;
        }
        private void button1_Click_1(object sender, EventArgs e)
        {
            addstationform.ActiveForm.Close();

        }
    }
}
```

CURRICULUM VITAE (C.V.)

Personal Information

Surname, Name: NAJI Hayder Faris
Nationality: Iraqi (IQ)
Date and Place of Birth: December 26, 1989, Iraq
Marital Status: Married
Tel.: +90 96221639
+9647805171400
Email: Haydernaji4@gmail.com
Ha_za5@yahoo.com

Education

1. B.Sc. in Computer Science, University of Babylon
2. Al-Hilla High School
3. Al-Hudabia Primary School

Certifications

1. IEEE Conference of Texas A&M University 2007
2. Computer Science Department, Babylon University, Annual Software Exhibition 2007
3. Solidarity NGO, Al-Sulaymaniyah Workshop 2006
4. IC3, 2008
5. Al-Thakra Company, Electronic Library Workshop, Beirut, 2013.
6. TOFLE, 2014

Work Experience

1. Al-Emmar Institute for Information Technology (EIIT), 2010–2011
2. Al-Mustaqbil University, 2011–2012
3. University of Babylon, College of IT, 2012–

Languages: Arabic, English, Turkish

Hobbies: Computer hardware, software, cars, music, sport