Emergency Service Location Study for Kyrenia City in Cyprus

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Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the Degree of

Master of Science
in
Civil Engineering

Eastern Mediterranean University
September 2012
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

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ABSTRACT

Considering the attractiveness of one of the cities in Cyprus, known as Kyrenia, among tourists due to its historical buildings and touristic environment, it is crucial to protect the area from fire. Therefore, the aim of this study is to identify suitable locations for a fire station which has been achieved through applying the Quantum Geographic Information Systems (QGIS) software and Python Programming Language.

In this thesis, a detailed study was conducted for the city of Kyrenia to identify links and nodes, travel times, and superimpose these data on an existing digital map of the City in geographic information system was utilized to assess the current situation and develop alternatives for fire station or other emergency services locations to minimize access time.

Python programming language was used for optimization process and Quantum GIS software was used to present the findings as isochrones. The findings are expected to benefit the society by allowing shorter response times if the recommendations are implemented by the government or local agencies.

This study seeks to initiate the service coverage modeling including regions with less amount of expenses as well as roads with less records of traffic and accident. Furthermore, the study, through the application of GIS is managed to locate sections of the city where the maximal service area problems exist (MSAP). In addition, applying

Python in the GIS let the research to be able to recognize the best location due to travel time among different parts of the city.

In this research, the entire possible locations for building Emergency Service Location were recognized by GIS, followed by selecting possible nodes in all intersections. Also, wherever there was lack of intersections in a wide distance, in recognized places, randomly were selected as possible nodes. Among all possible nodes (1746 different nodes), only one was selected as the best possible place for building fire station.

Based on the procedures of the modeling selection in Python programming, it was declared that only node number 1225 carried the characteristics of the best node for fire station in Kyrenia, the other nodes were considered as alternative nodes after the first one. If there seem to have any problem in constructing the building, the others nodes can be the next choices.

Keywords: Emergency Service Location, Fire Station, Geographic Information System, Travel Time, Isochrones, Python Programming Language**.**

ÖZ

Kuzey Kıbrıs Türk Cumhuriyeti'nin gözde şehirlerinden biri olan Girne, turistik ve tarihi bir şehir olduğu için bölgede çok önem taşımaktadır, bu nedenlerle yangından korunması son derece önemlidir. Bu çalışma yangın tehlikesi oluşturan nedenleri göz altına almak amacı ile hazırlanmıştır. Çalışmanın hedefi itfaiye araçlarının yangınlara tepki verme süresinin en az zamana indirilmesi konusunda en uygun istasyon konumunu elde etmektir. Bunun için Quantum Coğrafi Bilgi Sistemi yazılımı ve Python programlama dili kullanılarak Girne şehrinde itfaiye istasyonunun alan seçimi, erişim süresini kısaltma yöntemine göre yapılmıştır.

Bu çalışmada Girne şehrinin caddelerinin bağlantıları, düğümleri ve seyahat süreleri üzerine ayrıntılı bir çalışma yapılacak, ve elde edilen bilgiler Girne şehrinin mevcut dijital haritası ile Quantum Coğrafi Bilgi Sistemi yazılımına eklenerek Acil servis yerlerinin erişim süresinin en az zamana indirilmesi sağlanacaktır.

Python programlama dili optimizasyon süreci için ve Quantum Coğrafi Bilgi Sistemi yazılımı bulguları eşzaman eğrileri oluşturmak için kullanılacaktır.

Bu çalışma, hizmet kapsamı modelleme sistemine dayanarak en az masraf ve harçlar kullanılarak çok daha iyi yollar yapmak, bu yollarda en az kaza ve trafik sonucunu elde etmeyi esas almaktadır. Amaç; maksimum yüzey alanının sorunları çözülerek en iyi itfaiye durağını şehrin en optimum noktasında kurmaktır.

Bu çalışmada acil servis durağı kurmak için GIS yazılımı ile şehrin caddelerinin belirli mesafeleri dahil caddenin bütün kavşaklarında düğüm uygulanmaktadır. Bu çalışmada toplam 1746 farklı düğüm uygulanmaktadır.

Python programlama dili ile bütün bu farklı noktaların içinden buna göre özel bir programdan yazdıktan sonra 1225 numaralı düğüm Girne şehrinde itfaiye durağını kurmak için en iyi ve optimum nokta olarak belirlenmiştir. Bulunan diğer düğümler ise 1225 numaralı düğümden sonara sırası ile başka en iyi duraklardır.

Anahtar kelimeler: Acil Hizmet Yeri, İtfaiye Durağı, Coğrafi Bilgi Sistemi, Seyahat Süresi, Eşzaman Eğrileri, Python Programlama Dili.

To my parents

ACKNOWLEDGMENT

I would like to express my greatest gratitude to the people who have helped & supported me throughout my project.

I am grateful to my supervisor, Asst. Prof. Dr. Mehmet M. Kunt for his continuous support for the project. His proficiency, sympathetic and patience added noticeably to my knowledge. Without his valuable supervision, all my efforts could have been short-sighted.

I wish to thank my family for their undivided support and interest who inspired me and encouraged me all through. Their motivation and encouragement are too countless to state.

I would also like to express my appreciation to my friends Alireza, Anna and Ryan who helped me in completing this project. Their interesting ideas, thoughts and opinions really helped me.

And finally to God, who made everything possible…..

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1

INTRODUCTION

1.1 Background

1.1.1 Preface

There are considerable numbers of documents that describes the death of many people because of fire annually. In fact, fire is regarded as one of the dangerous and pernicious reasons that cause injuries, so harness of fire to be of crucial importance.

According to what was declared by Revelle and Eiselt (2005), in a location research, the assumed solution was stated and then formulation of a group of problems was defined best through conducting services in order to solve the problems. Generally, in the moment that fire occurs, the immediate response to harness is a very vital action that makes delay that cause serious injury or death.

Due to the highly growing population in Kyrenia, this city was dispread and a huge number of buildings were constructed that all of which demand a significant level of facilities. One of the desirable facilities is referred to as the efficient and economical fire station protection.

In fact a very significant time difference would refer to as the time between fire containment and flashover which would be measured in seconds. Although the mentioned time difference is not more than just few seconds, failing of fast access to the fire harness requirement would cause unfortunate situations.

Therefore, accessibility to fire is very essential for firefighters to be able to arrive to flashover location. In fact the favorable condition for the researcher is to locate situation that can provide it in minimum travel time.

Geographic Information Systems (GIS), being extremely associated with the fire station location, is regarded as one of the features that function efficiently while predicting location problems. A huge bulk of research has been suggested the existence of the possibility of the role of GIS in structural arrangement as well as decision-making that applied a bunch of procedures. In other words, the data will be collected by GIS software and Python Programming Language and nodes will be putting at the certain points of the city which tries to determine suitable location instead of the current fire station and ultimately solve the problems.

Among the techniques and the procedures that have been explained, the functional analysis is known as the most beneficial due to its easy procedures in diagnosing location. In addition, benchmarking as an approach to predict the wishes of system users ranked as the other valuable technique. And finally, the third group of techniques has been pointed out for decision-makers. The above mentioned techniques will organize mostly through the information obtained from the data and the extracted knowledge taken from geographic information system.

This study was performed by applying Python language for network analysis to obtain best location for new fire station location.

1.2 Objectives of the Study

Since decision making and analysis of choosing fire station location is very crucial part of any location process in a research- based study, in this study, it is aimed to establish a location selection process to select the most suitable places for fire station in Kyrenia in Cyprus through applying network analysis to generate service areas based on travel time limits.

Most of the previous methods in location selection research dealt with the static and deterministic location problem. For instance, in the case of selecting various probabilistic models, it was pointed out that ambulances operate as servers in a queuing system which sometimes fails to answer a call.

This study with the help of Quantum GIS with reference to generate maximal service area problem (MSAP) attempts to produce the best location for fire station. In addition, this study performed with the help of GIS software and Python programming language which is described can specify the capacity of network analysis module with option to optimal location for only one fire station in city of Kyrenia, beside with utilizing of this process, also, defining other locations when application of the first recognized fire station is impossible, several locations, will be exploited in the next priorities.

In fact, it is assumed that this research would shed lights on creating a situation in which application of Python while performing network analysis and capability of Quantum GIS would produce service areas.

This study seeks to achieve some objectives. What follow is a list of major objectives in this research:

1. To describe the capability of network analysis module being established through Python for the purpose of recognizing the best area for fire stations in Kyrenia in Cyprus due to travel time, efficiency, and economy.

2. To choose the best location for fire station among all the possible situations in two phases:

Phase I: Obtain all the potential locations which will result in response time to any node on the network within ten minutes or less time.

Phase II: Obtain all the best locations which will result in lowest total response time to all the nodes on the network

Although, the assumption for selecting only one place for fire station was the ultimate goal of this study being achieved through the application of Python, the other possible locations, also, would be regarded as the second best choice for fire station in the city if the first selected location has unexpected problems.

1.3 Justification for the Objectives

Due to rapid increase of population of city's residents and the huge amount of crowded cities and especially during touristic seasons, it seems to be crucial that city be protected from any fire misfortune.

Considering the attractiveness of touristic cities, such as Kyrenia in Cyprus and the huge amount of visitors, selecting the best location for fire station is a rather complex task. The favorable solution requires a selection procedure that could locate the fire station with the greatest efficiency and economy. Furthermore, the present fire station failed to be effective covering all sections of the city. As a result, this research will generate valuable information not only about the best possible fire station but also the other possible locations in the Kyrenia in Cyprus.

1.4 Guides to the Research

This research includes five chapters. Chapter 1 consists of a background study which has a preface of this study in definition of the problems, a short literature review about conducting location selection process study research, the objectives of the study that demonstrated the focal points of performing this study, and finally the preferred rationale about this research.

Chapter 2 includes a rather comprehensive review over the period of time about previous study similar to the title of this study which includes the most central theoretical and historical subjects in the content of location selection process. This consists of locating the places which are at the center of attention by the visitors such as important emergency facility, and fire station location. Furthermore, the usage of GIS as well as Python in network analysis usage was applied in fire station location research and the investigation of its results is presented as well.

Chapter 3 demonstrated procedures in applying GIS related to travel time, different variables of the research, sampling data, procedures in data collection and the entire data collection procedures to locate all nodes. In addition, the methodology chapter represents the information about analyzing the recorded data. Data analysis of this study has been performed through application of Python program in order to examine the data.

Chapter 4 provides a comprehensive group of results of the study such as tables, figures, and statistical information which have been gathered through the results of the data analysis. The recorded data was put together through GIS and Global Positioning System (GPS). Chapter 4 also provides the results of the study in various diagram, figures, and tables. In fact, Python is the software that provides out the best possible locations regarding to the distance, and selects the shortest path. Attribute table is designed to present comprehensive information about name of the roads, speed limitation in the as well as the length of each Street. And finally, the characteristics of the best selected node for building fire station are provided as well.

In chapter five, conclusion is provided after reviewing all data presented in chapter four.

Chapter 2

Literature Review

2.1 Location Analysis

This study shows the application and processes of collection of facilities by modeling, formulation and providing best solutions. Researchers provide the best forms of applications and maximization methods for coverage which include minimizing costs and damages to urbanites. With location study, analyzed facilities are smaller than the area in which they are located. There may not be interaction among them (Revelle. and Easel, 2005).

To classify location studies, scientists categorize the area in which each facility is located. The location models are as follows:

1. Maximal Covering Location Problem (MCLP)
2. Location Set Covering Problem (LSCP)
3. P Center Problems (PCP)
4. P Median Problem (PMP)

2.1.1 Maximal Covering Location Problem (MCLP)

Proposed by Church and Revelle (1974), this model maximizes demand coverage for services in a definite space. Researchers attempt to locate facilities with high regard to the maximization of services provided for demands. The researchers mentioned above show that MCLP is able to define prioritized facilities and also assist managers in maximizing required services for locations and sites. They also suggest that MCLP is variant of the formulation of the p – model and location covering model.

According to Pirkul and Schilling (1991), variations of this model have been formed either to account for working capacities or to increase coverage and decrease distance to each demand node in the outskirts of maximum coverage distance.

A mathematical formulation is defined as follows:

MCLP: Maximize $z = \sum_{i \epsilon I} W_i \; X_i$

Subject to: $\sum_{j \epsilon N_i} Y_j \geq X_i \quad \forall i \; \epsilon \; I$

$\sum_{j \epsilon J} Y_j = P$

$X_i \epsilon \; \{0, 1\}, Y_j \epsilon \; \{0,1\} \quad \forall i \; \epsilon \; I, \forall j \; \epsilon \; J$

Where:

i, I the index and set of demand nodes

j, J the index and set of potential facility sites

N_i $\{ j \; \epsilon \; J \mid d_{ij} \leq S \}$ the set of all node j which is within S of node i

d_{ij} the shortest distance / time between node i and node j

S the desired service distance / time for every demand node i

W_i the population to be served at node i

P the number of facilities to be sited

$$X_i = \begin{cases} 1 & \text{if demand node i is covered by one or more facility} \\ 0 & \text{otherwise} \end{cases}$$

$$Y_j = \begin{cases} 1 & \text{if a facility is sited at the node j} \\ 0 & \text{otherwise} \end{cases}$$

In a similar research Church (1986) concluded this model was useful analysis of location studies making use of statistical systems.

2.1.2 Location Set Covering Problem (LSCP)

The LSCP model covers all demands, by at least one facility, by the arrangement of optimum facility numbers. Toragas and Revelle (1972) used LSCP to locate the optimum number of facilities assuming that all defined demands are covered by at least one facility. Different studies cover different emergency situations. In 1992, Eiselt referred to differing applications of location studies implored by Jacobsen and Madsen (1980) for points of newspaper delivery, ReVelle C, Marks D and Liebman JC.(1970) for the transfer of solid waste in urban areas, Kimes and Fitzsimmons (1990) for motel locations and Hopmans (1986) for banks.

2.1.3 P- Center Problems (PCP)

Klose& Drexl (2005) attempted to locate the greatest distance and planned strategies to minimize this distance between demand and facilities. They also used this model to decrease the longest distance as much as they could.

2.1.4 P–Median Problem (PMP)

This model is capable of minimizing distance between facilities and the differing points of demand. According to Mitchell (1972), This model was used to minimize travel distance for police in Anaheim, California, answering calls from people around the city . This model could foster a palpable decrease (up to 13% - 24%) in typical response distance.

2.2 History

Based on the provided information gathered from the results of a study performed by Arogundade. OT et al (2009), it can be inferred that recently, facility location science has evolved to decrease any damage or loss to property, especially concerning urban areas. In 1929, Alfred Weber, a pioneer of this science, published “The science theory of the location industries”. In the early 70’s, famous researchers like Toregas et al. (1971) and Church and Revelle (1974) postulated opposing viewpoints with regard to what we call ‘location science’.

Furthermore, they helped solve significant optimization problems through operational research by proposing mathematical algorithms for optimizing single or multiple functions; the main goal being the minimization of costs and the maximization of benefits. As to their methodology, many questions related to fire stations, warehouses, health services (ambulances), schools, power plants and hospitals have been raised and answered by researchers throughout the globe.

However, preliminary location studies only focused on small information sets, and were conducted through simple equations for ascertaining spatial limitations among different facilities, which help meet urban area demands**.**

2.3 Facility Location Study

In a study conducted by Mahmud and Indriasari (2009), the reserchers found that most difficulties in the selection of a location for an emergency service facility are related to the coverage of the entire city. The real objective is to model these programs so that these services for the whole city can be maximized. By using a program called "Maximal Service Area Problem" (MSAP), we can solve the optimization problem. By utilizing this method, we can affect the total service offered by these emergency service locations.

As it was declared by Mahmud and Indriasari (2009), the true purpose in the search for better facility location concerns will minimize costs and maximizing profits. One of the main factors, when it comes to selection, is quicker response time and the distance traveled without injuries and accident. Therefore, according to Mahmud and Indriasari (2009), it can be assumed that the main concern in fire station facility location or other emergency service location should be to minimize time and distance constraint. Fire stations should be located such that response times are under five minute. It is impossible to place fire stations everywhere, so to save on costs, they ought to be placed in centralized locations.

The results of the research conducted by Mahmud and Indriasari (2009), revealed the fact that aim of the PMP model is minimizing average interval between emergency service locations and the demands to them. The aim of the PCP model is to minimize the endmost distance. The goal of this is to model the most beneficial facility location and expand this model in each requested location; this development will foster optimal accessibility. This goal is to combine minimum travel time and maximum service area through road network analysis. This has been described as the Maximal Service Area Problem (MSAP).

In this case, the service area is defined as the travel time zone showing the area that can be reached by a facility in particular travel time. Typically, a circular-shaped zone is identified by the facility location model, but geographic information systems can develop and enhance the service area of the emergency response system. According to Mahmud and Indriasari (2009) study, it can be realized that the following steps must be completed in order to use the MSAP as a facility location model:

1. Defining the characteristics of the model.
2. Development of an appropriate mathematical model.
3. Devise an algorithm-driven solution.
4. Compare and contrast the findings of the algorithms with different datasets.

By using GIS, this study has enhanced the traditional facility location models, which used concentric circle analysis, and instead uses a more complex and accurate analysis – the MSAP. In addition to taking advantage of GIS capability to estimate the service area and determine accurate response times, the model also considers the road accessibility in the selection of emergency facility locations. GIS is able to simulate the actual network of roads within the service area. Therefore, the solution derived by GIS is more accurate than those derived by other means Arogundade. et al, (2009).

The problem of selecting a facility location is a variant of the set of covering problem, which is a classic problem in computer science and complexity theory. In a similar study being performed by Arogundade et al. (2009), varying approaches are applied to facility location problems. For example, a mathematical model of facility location is used, called TORA. A global positioning system (GPS) program establishes the coordinates of all urban areas under consideration. After the collection of the coordinates, GIS software was used to analyze the distance between various urban areas under consideration.

The result obtained from the distance reading is a 37 by 37 matrix which is then transformed into coverings according to a specified distance (precisely 10km from each wards). The part of the result of this process is shown in Figure 2.1

1. **{1,2,3,4,5,6,7,8,9,10,15,21,25,26,27,28,29,30,31,32,33,34,35,36,37}** from Obantoko.

2. **{1,2,3,4,5,6,7,8,9,10,15,21,25,26,27,28,29,30,31,32,33,34,35,36,37}** from Ikija

3. **{1,2,3,4,5,6,7,8,9,10,15,21,25,26,27,28,29,30,31,32,33,34,35,36,37}** from Ago Oko

. . . .

. . . .

16 {16, 24} from Alagbagba

18 {18,21,23} from Osiele

. . . .

. . . .

37 {1,2,3,4,5,6,8,9,10,15,21,25,26,27,28,29,30,31,32,33,34,35,36,37} from Panseke

Figure 2.1: Part of the result of obtained from the distance reading

2.3.1 Balas Additive Algorithm

Balas Additive Algorithm has been defined in a rather similar approach. Among the scholars who provided a description for Balas Additive Algorithm, the researcher presented the statement uttered by Arogundade. OT et al (2009), as "the additive algorithm was one of the approaches known as branch and bound and is used to solve linear programs in n0-1 variables by systematically enumerating a subset of 2n possible binary n vectors, while using the logical implication of the 0-1 property to ensure that the whole set is implicitly examined."

Consequently, this algorithm is based on the systematic values 0 and 1 to a specific subset of variables and diving deeper into the implications of these assignments through a sequence of logical tests. The simplicity of this process and its effectiveness, when data is not overly expansive, makes an easy choice for this type of study.

2.3.2 Details of Balas Additive Algorithm

In definition of Balas Additive Algorithm, one of the most beneficial features of this feature is regarded as its graphical user interface (GUI) by Arogundade. OT et al. (2009) which empowers users to express their problems familiar way, similar to mathematical notation. This feature of GUI enables the users to choose the next action with the use of a menu. This flexibility allows each user to increase or decrease the data size or to remove a particular variable.

Arogundade. et al. (2009) exclusively suggested four main groups of Balas Additive Algorithm applications which gathered under the subtitle of TORA. The following list is a representation of the TORA's usage in this program.

a. Sets composed of objects in this programming model

b. Objective function of the problem

c. Constraints of the problem

d. Entered data

2.3.3 Implementation and Results

According to Arogundade et al. (2009), the input is 38x38 0-1 matrix where column 2-38 represents each covering and row 2-38 represents each ward. Therefore, for each column and row, the element is 1 if the ward is covered and 0 if not covered; e.g. the name of the matrix is **a**, if **a [2][3]** = 1, it implies that ward 3 is covered by covering 2, otherwise it is not covered and the value will be 0. Figure 2.2 shows the file format for this work**.** The output format is presented in the form of a solution vector which contains zeros and ones, 1 if a covering is selected and 0 if not selected.

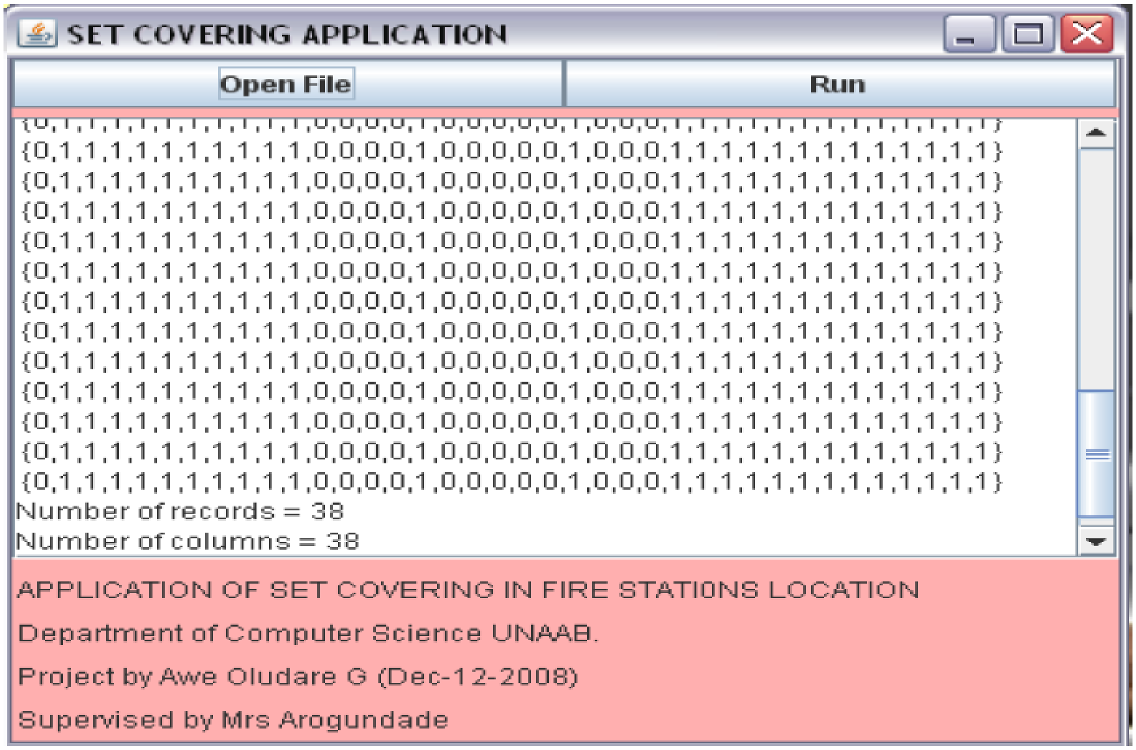

Figure 2.2: Input File Format

The focal point of the entire input files is seen in some statement of the scholars who previously made an attempt to apply these files such as the fact that reveals "once the input file has been selected, and then the program can be run to generate the output required". (Arogundade. OT et al, 2009).

2.4 Past Perspectives of Location Studies for Fire Stations

The fundamental purpose for fire control centers has been planning suitable sites for stations all over the world (Gratz, 1972). Marianov (1990) and Lewis (1986) pointed out this goal in an important location study positing that poor location planning, in turn, led to poor fire prevention, which resulted in significant loss property and life. According to Holland (1993), system effectiveness is shown in the location of fire prevention units since failure to correctly locate stations eventually results in a considerable amount of financial and human loss. Cato (1990) stated that firefighting executives' mission is to allocate proper services for protecting human life and property.

Gay and Siegel (1987) argued that there are few documents which relate to optimum planning numbers and placement of facilities in high population areas. A report by the National Fire Protection Association (NFPA) stated that existed no standard for crucial factors in fire station efficacy. These include response time and travel time. They concluded, because of lack of efficacy, each community ought to define their own appropriate response time to maximize the efficacy of its fire protection services.

2.5 Emergency Facilities

Fire stations are important sites that should be located efficiently for extinguishing sudden fires. In emergency service centers, the defining variable is response time and measuring this will offer suitable results regarding fluidity of service. Time and distance are important variables for calculating emergency coverage. According to Longley et al. (2005), a response time of 5 min or less is extremely important for cities.

Church and Revelle (1974) postulate that city planners ought to consider facility quantity. This includes a high priority for response to calculated demands. Stations encompassed in this model should be placed strategically to minimize the financial and human losses to fire. The goal of this field is related to minimizing costs by increasing the productivity of emergency systems Aly and White, (1978).

2.6 Emergency Suitability Models

"Because of suitable coverage process in MCLP and LSCP, these two models are more suitable than the PMP since they are intended to minimize the total average distance passed during the response time" (Longley et al., 2005). Location study researchers accept LSCP, MCLP and their sub-models as efficient ways to cover facility location problems. Conversely, a new version of MCLP was proposed by Revelle and Snyder (1995) for concurrent location of ambulance emergency services and firefighting facilities.

Also, LSCP was implemented by Chrissis (1980) into a dynamic algorithm so as to analyze each fire station location. Revolutionary progress was seen as a result of these methods in location study especially in the field of emergency setting.

2.7 MCLP and LSCP Efficacy

Longley et al. (2005) suggest that if response is less than five minutes in fire accidents, then emergency systems are working efficiently. These models are much better than the PMP model in their ability to define the minimization process of total average distance.

2.8 Objective of MSAP

MSAP's objective is to service the maximum total area from certain specific facilities. Total service area calculation cannot be done simply by creating a summary of area polygons, as the overlay, on top of each other. The study has solved these issues by dividing the demand region into discrete points. This use of regular points as surrogate information that assesses total service area was introduced as a different way to compute this. This method was helpful in easing mathematical modeling implementation of the MSAP. Percentage of the service area based on the amount of demand points covered reflects closely to the percentage which is based on actual coverage area in fine resolution of demand points. Hence, the method of calculation discussed previously can measure the solution quality of the problem.

2.8.1 Disadvantages of MSAP

A disadvantage of MSAP is that we cannot completely evaluate multiple facilities through mathematical operation. Areas of service regions may not be implemented and, as a result, the analyzer should dissolve the entire service area polygon into one. Then, we should refer to the area of the single polygon for defining the whole services area of facilities.

2.8.2 The Problem of Maximal Services Area (MSAP), a Modified Version of MCLP

The goal of this model is to maximize the area coverage by emergency services. This model was modified from MCLP using GIS system to find facilities and service coverage as travel distance zones. Based on this, the areas will be defined as follows:

1) The area with shorter distance, time and cost in comparison to other facility, or

2) The area that can be covered by the limited number of facilities based on specified cost, time and distance.

2.9 Best Location Study

Zilla et al. (1996) used a single objective approach to find the best location for a hospital in rural region. Their work is mainly based on statistical tables from different organization and sources. First they evaluated whether it is necessary to build a new hospital, or just expanding the current one is enough. They constructed a three steps approach to solve this problem. They did not consider all the possible locations for their calculation. Instead, they selected some candidate points, and measured the effectiveness of the selected points. They used a subjective multi criteria model called the Analytical Hierarchy Process (AHP) to address the objectives and constraints. This study was mainly a strategic research to plan for building a new facility, and they mainly used the population and neighbor cities to address the problem.

Another approach was performed by Anjali et al. (2011) to find the best location for urban distribution centers under uncertainty. Their main goal was to minimize the total cost and traffic congestion arising from goods movement in urban city. They used a multi criteria objective problem, and again they selected some potential location candidates. Their method was fuzzy logic theory to quantify the values under uncertainty. They also made sensitivity analysis to find the influence of the criteria weights on location planning for urban distribution centers. They restricted the delivery of the centers by zoning the available candidate zones (Figure 2.3).

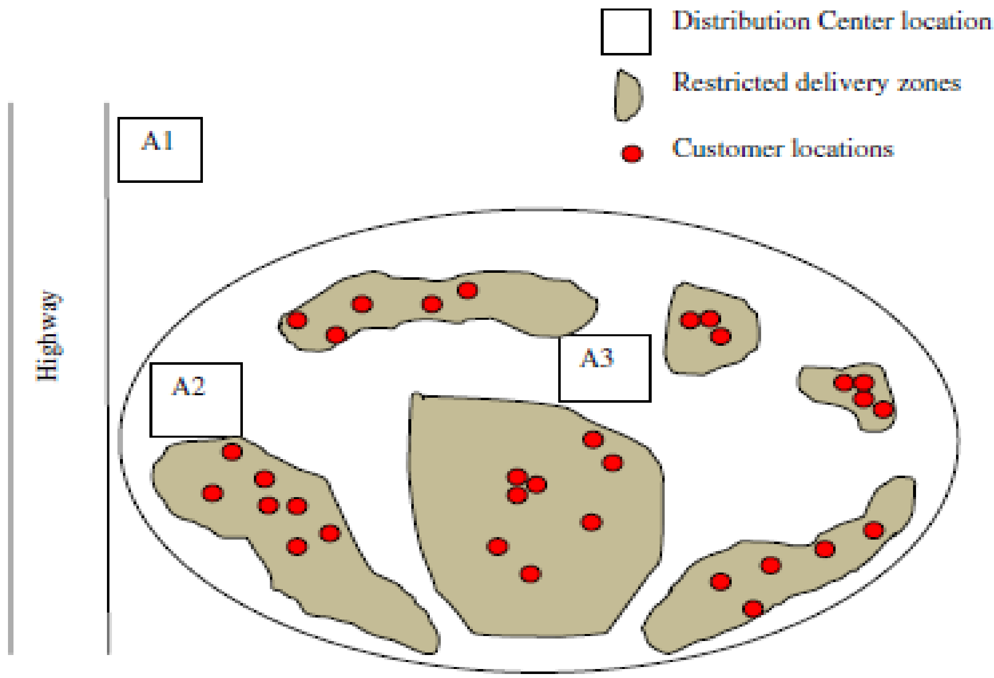

Figure 2.3: Potential locations for the urban distribution center

Another research has been done in this field by Shariff et al. (2012). Their focus was on finding the appropriate location for healthcare facility in Malaysia. The approach of the study was to find the locations that maximize the coverage of the healthcare centers. This problem called Maximal Covering Location Problem (MCLP). They changed this problem by considering the fact that each facility has its own capacity and they formulated it as Capacitated MCLP.

Zhang et al. (2011) used GIS to find the optimal location for converting forest biomass to biofuel with minimum cost involved. They used several GIS layers with their corresponding data, such as county pulpwood distribution, census population, city and villages distributions, railroads and other types of roads in their study. Their methodology included constraints such as fuel price, transportation distance and cost, pulpwood availability and etc. Panichelli and Gnansounou(2008) used a GIS-based approach for defining the bioenergy facilities location on northern Spain. In order to find the best location for settling down the Torre faction plants and gasification unit, they defined an algorithm which minimized the total transfer of bio materials from the sources to their facilities.

2.10 Previous Research at Eastern Mediterranean University

In connection with GIS usage in fire station location studies, GIS provides very nice simulation of the real transportation network. This simulation is accompanied with high level of accuracy since it uses actual travel distances, speed of vehicle and time delays. Nowadays, applying GIS is seems to be very popular for making the systems of spatial. In 2011, in a very comprehensive research that was conducted by Kazemi in Eastern Mediterranean University GIS was applied for this subject.

In their research, the location selection process related to fire stations in Famagusta city was enhanced by applying Quantum Geographic Information Systems (QGIS) and Python programming language. There is flowchart of implementing the optimum fire station location study in below:

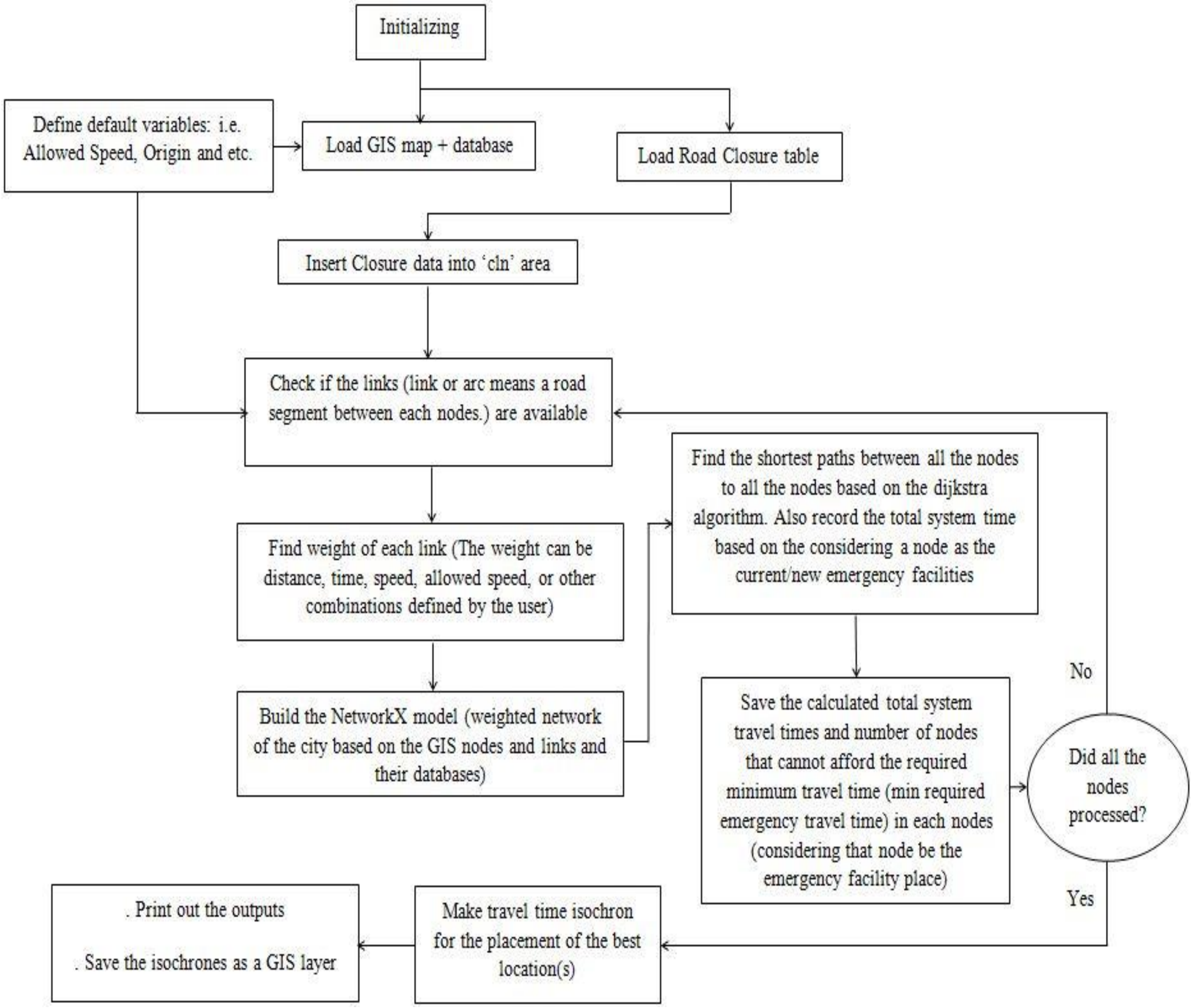

Figure 2.4: Flowchart of implementing the optimum fire station location study

Chapter 3

METHODOLOGIES

3.1 Geographic Location and Districts of Kyrenia

Kyrenia is one of the famous cities in Cyprus which is regarded as the third big city in North Cyprus being located in the northern coast of this island. Kyrenia city was founded by Cepheus from Arcadia and is well-known for its historical attractions. Its population is about 72284 people who are spread in this city with the area of 690 km^2 .

Figure 3.1: Map of Cyprus

3.2 Software Used

The study was done through the application of Windows 7; a study was done using GIS features in Python. Version of QGIS was 1.8.0 and Python Language was work with 2.6.5 version.

3.2.1Application of Geographic Information System

Geographic Information System (GIS) is a software computer program that is applied for capturing, storing, verifying, confirming, integrating, manipulating, analyzing and demonstrating, interpreting data related to positions on the Earth's surface.

GIS usage in natural exposure to real administration and improvement arrangement is limited to the information being available in nature.

In general, a Geographical Information System is employed for interpreting different kinds of maps. The representations of the maps are possible in a variety of ways including various covers. In fact, GIS is a tool that provides a chance for its users to easily understand different places on earth by presenting layers in which there is a possibility of keeping data related to a specific map.

GIS provides the opportunity for its users to observe the data in a short period of time, comprehend them easily, show the possible connection between data, and assist the researcher to respond effectively to questions and resolve problems. This can be achieved by simply looking at the graphs and maps and imagine the existed relations among all trends, charts, tables, figures, and globes.

GIS is referred to as a scientific field that integrates environmental features with tabular data for the purpose of map making, feature analyzing, and natural problem solving. The key factor about this science is Geography which is regarded as the part of the data which is special. In fact, these data are mainly the features of the various locations on different parts of the earth.

Analyzing time can be accomplished through operating levels for fire station, street, boulevard, and long avenues. For instance, the level specialized for street is mostly demonstrated in GIS as a sequence of lines that interconnect with each other in the map and make a network together which is called GIS network. Also, every line in each street can be included some roads, squares, destination, and distance or even safe allowed speeds (miles or kilometers per hour).

3.2.2 What is Python Programming?

Python is a computer programming language that provides the situation for its users to work effectively and efficiently. Python is defined as an interpreter, object-oriented, high-level programming language with dynamic semantics that high level of which has been made in data structures, combined with dynamic typing and dynamic binding.

Python has the capability of supporting sections and packages, which encourage program modularity and code reuse.

As Python amplifies the efficiency of its production, programmers most of the time are highly interested in its application. Applying Python programs does not require high effort. Python is a tool that will be applied while performing network analysis and capability of Quantum GIS in producing service areas.

3.3 Finding the Best Location for Emergency Vehicle Station

Finding the best location for emergency vehicles' station (such as fire station, polis, hospitals and etc.), is a problem that can be addressed by GIS technology. Best location means a location which covers most of the area of the city with minimum cost. Minimum cost corresponded to the travel time, distance, traffic congestion, speed limit and etc.

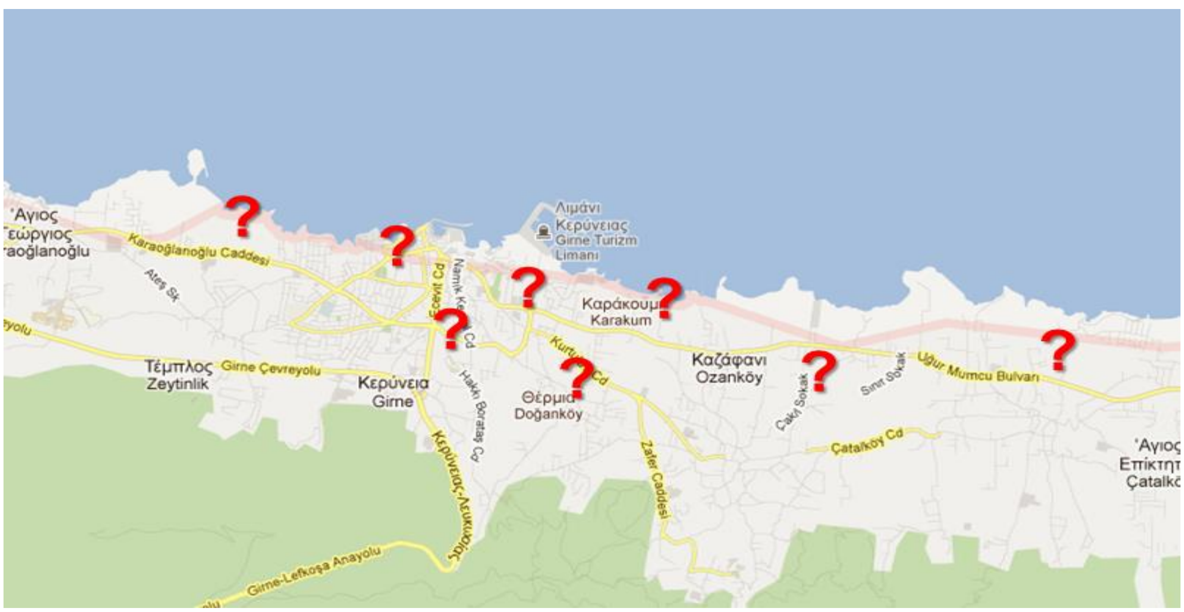

Figure 3.2: Map of the Kyrenia city in Cyprus

Discovering the optimum location manually is almost impossible. However, using new technologies came from the power of calculation of computers, make this problem easier to solve. Other possibilities related to this issue are having some previous stations and one wants to add a new station; although, someone may want to add more than one location to the city, which increase the size of the problem exponentially. The best approach in finding the most suitable areas for placing the emergency service stations is using GIS.

The best locations are usually determined by their accessibly. Accessibility is defined by accessing the most part of the city (or weighted by population, so the problem would be maximizing the coverage of the most of the people, while we could also have second objective function of minimizing the cost of transportation), with aim to have minimum cost. Cost can be defined as how someone can access another part of the city, shortly (minimum shortest path), quickly (with minimum travel time), easily (can be defined by minimizing the turning movements at intersections, number of signalized intersections, access points and other related features in the city).

In this project, the objective function is minimizing the shortest paths of accessing all intersections of Kyrenia in Cyprus, by testing (placing) the emergency station at each intersection and finding the travel time to the rest of the network. This process repeated until the emergency station was tried on all of the nodes on the network.

The line layer shows the roads of Kyrenia city that are available. We added some nodes in intersections between roads to model the network of the movements in the city. The overview of the map can be seen in following image (Figure 3.3).

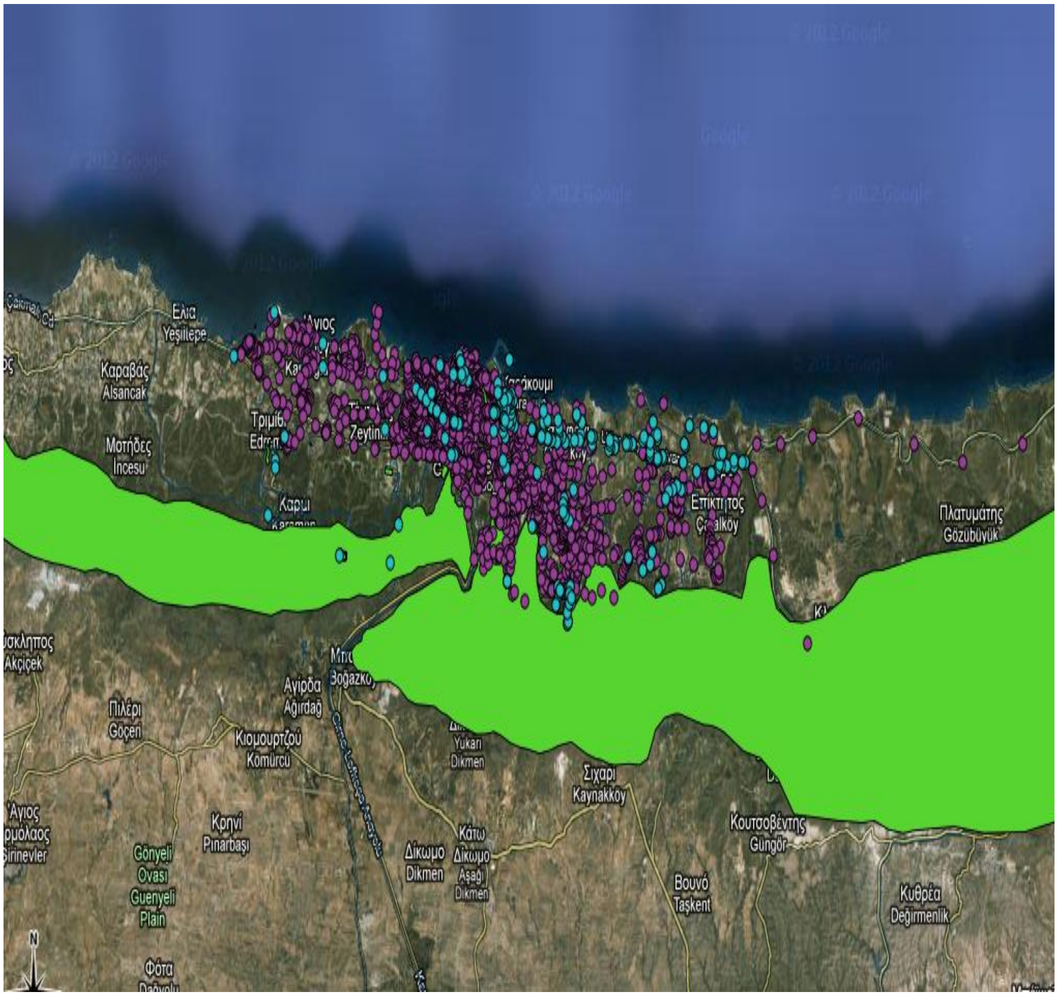

Figure 3.3: Overview of the available data in GIS (City: Kyrenia, Cyprus)

Other data that can be gathered and used in this study, is gathering the GPS data by moving in the streets of Kyrenia, with the same speed of the traffic flow, in order to have a real idea of the traffic flow speed. The speed in minor roads that maybe not collected can be estimated by several data, such as street width, neighbor street speeds, length of the street and etc. Although the time of day is an important issue which should be considered in this study, because of the fact that traffic congestion usually happened in early morning and evening after people leave their school and work. So the best approach should be gathering the data for different time of day, and categorizing them.

However, because this involves extensive work, it was excluded from the scope of the study.

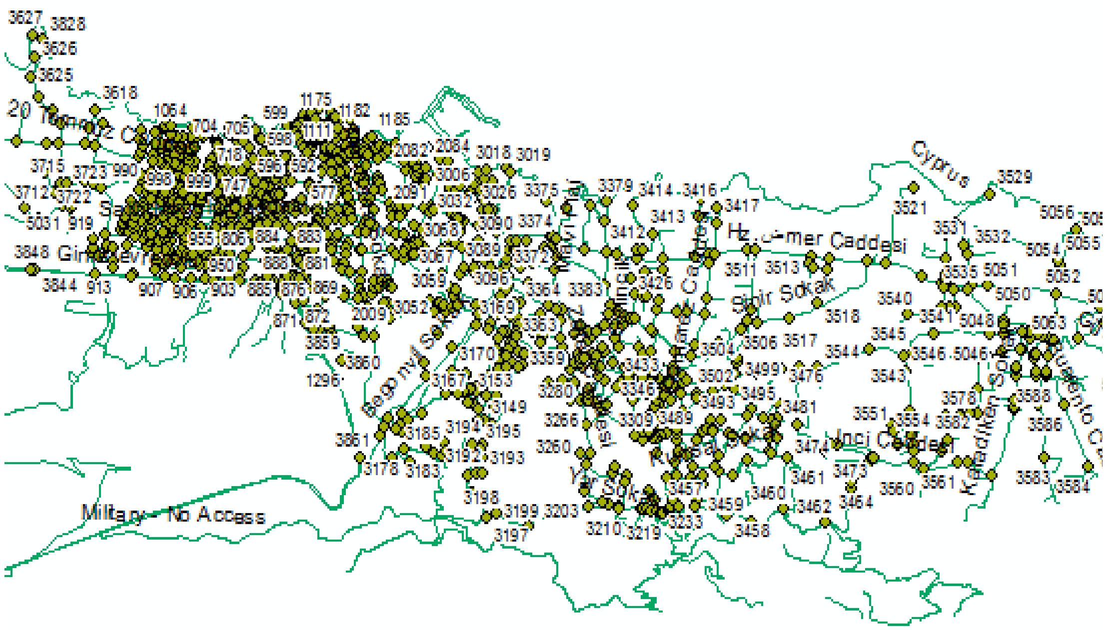

Figure 3.4: Names of Nodes and Streets

Table3.1: Attribute table in GIS

timestamp	Link1	Link2	Link3	Link4	Link5	Dist1	Dist2
501	502	504	506	707	0	140.868131	60.39157
502	501	503	605	0	0	140.868131	72.82255
503	502	600	0	0	0	72.822553	105.16635
504	501	503	505	0	0	60.391572	140.02296
505	504	506	595	0	0	91.538665	151.63629
506	501	505	507	510	712	141.148984	151.63629
507	506	508	522	0	0	76.434563	205.07052
508	507	509	518	0	0	205.070523	69.53831
509	508	510	515	0	0	69.538312	56.59560
510	509	511	506	0	0	56.595602	61.73453
511	510	512	712	0	0	61.734535	86.5078
512	511	513	724	0	0	86.50787	7.70079

Other source of data could be the Google Earth, open street map available data in GIS, Wikipedia and other online resources, police maintained data, and etc. The main data included the road networks in Kyrenia. The intersections and basic curvature of road sections were identified manually by placing 1.7k+ nodes (a new point layer) in appropriated positions. In each node, the links to the neighbor nodes were also defined. The road sections do not have the speed limit data; however, it includes the type of the road section, whether it is primary or secondary road, residential, service, unclassified and several other types.

These types can be used in future research to define the speed limit. Also riding through the traffic (while keeping the speed same as the traffic flow speed, and in different times of the day) in the road sections, and recording the speed data in a GPS device could be useful to determine the speed of the traffic flow.

3.4 Application in Quantum GIS and Python Programming Language

First we should prepare data and gather the probable necessary additional data. In order to find the best location, some programming should be done. The GIS is working with Python by default. Python is an easy programming language to learn and use in wide variety of sciences. Quantum GIS by default does not have all the functionality that one may be needed. But ones can get further benefits by coding the functions that it may need. Python by default support using GIS shape file and the dbase IV database (.dbf) and other coding environments can support that by extending their features bymodules or library add-ons: Shapefile, Numpy, Math, Random, NetworkX. Feeding NetworkX with road network and links costs, it will provide function to find the shortest paths.

It also has several additional packages, such as Numpy, Scipy and etc. which empower its capabilities to solve more complex mathematical and theoretical problems. One package that will be useful in this problem is NetworkX, which is used to address the graph theory models, and make a network between our defined nodes, and their related cost and capacity.

In this problem, preparing data and feeding the NetworkX model with it, make it possible to have some function such as shortest path between two nodes and all the nodes (what is the minimum cost between two nodes), finding the best path (series of nodes) and etc. To have a more accurate data, we can drive through the roads in different times with different congestion, and record the pass route and insert them into GIS to find average real speeds in the streets.

The distance between each node was calculated based on their links to the neighbor nodes. Because each node defined by one NodeID and one FID, and the links defined by NodeIDs, the length of the links was calculated by spatial joining the nodes by their NodeIDs. To find the suitable areas, a code was developed in Python 2.6.5. Python by itself does not have capabilities to work with GIS files, and also it lacks numerical functions; however it has a lot of libraries which can be added to improve its capabilities.

The imported libraries were shape file, math, random, recipe, numpy, matplotlib and dbfpy. For finding the shortest path between each node, the Dijkstra algorithm in the NetworkX module was used. To use this algorithm, first the whole network was inserted into the NetworkX library. The network is basically a graph, which each node in the graph corresponds to its respective node in the road network, and the cost of the links can be defined as the distance, travel time, speed limit or other appropriate costs.

The essential parts of the code can be summarized as:

- Create the NetworkX Graph:

```
> G = nx.Graph()
>G.add_weighted_edges_from([(From,int(i[1]),int(i[1+b]))])
>G.add_edges(int(i[0]),int(i[1]),weight=int(i[3]))
```

- Get the total cost (Distance, Travel Time, Speed, Speed Limit or a Combination of different factors) of placing the emergency service in one location:

```
>nx.dijkstra_path(G,From,To) #'Path S
>nx.dijkstra_path_length(G,From,To)
```

- and save it in a new point layer:

```
>w.point(r.shape.points[0][0],r.shape.points[0][1]) #'Geo. File
>w.record(From,TotalCost,NofOutRanges) 'Database File
```

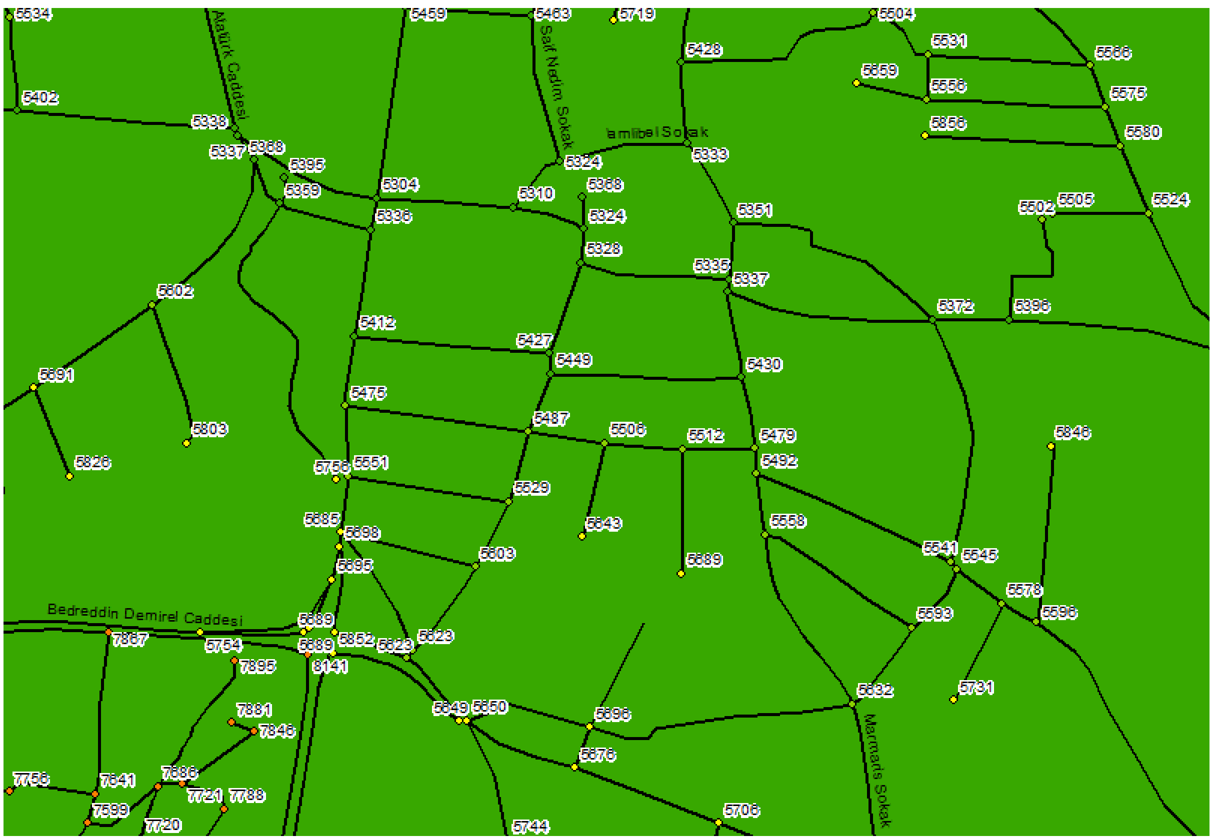

Figure 3.5: Result from python code

The result from python code does not provide an easily understandable map. It only contains a series of numbers on the node layer. Creating a contour map from the fitness of the node layer would be useful in this problem. A neighbor interpolation toolbox used to generate the contour map.

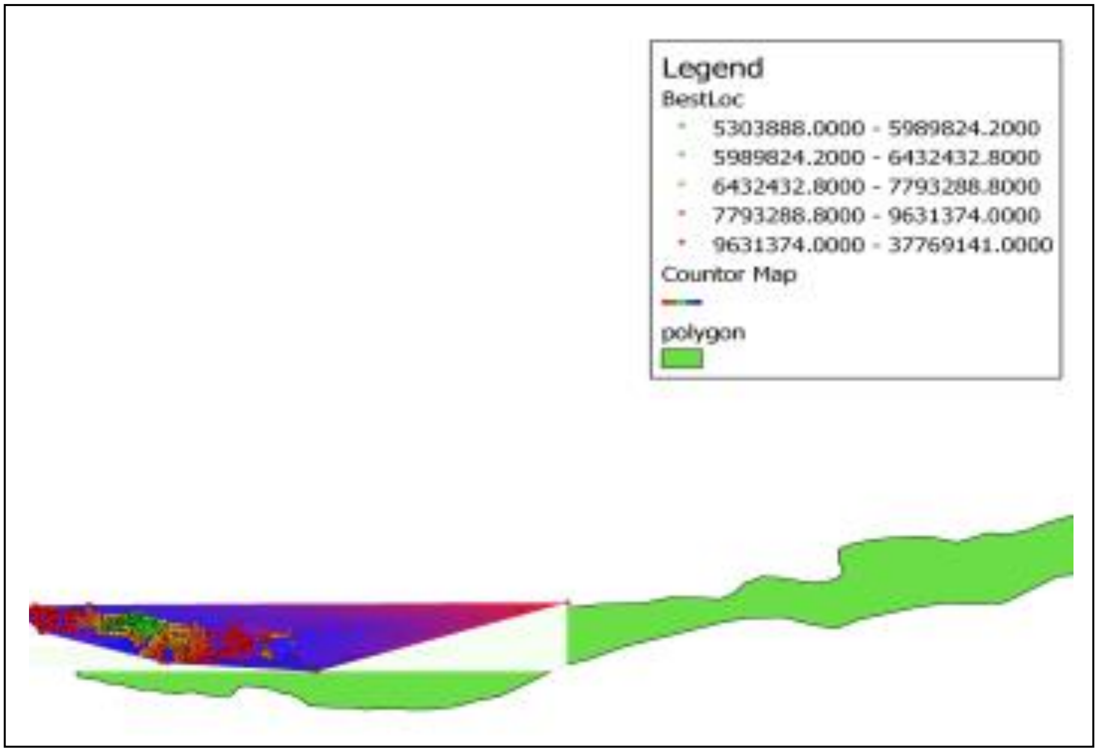

Figure 3.6: Generation of the contour map

Chapter 4

RESULTS

This study including defining the best location for only one fire station in city,

4.1 Use of Geographic Information System

The excepted feedback on time analysis based on Geographic Information System (GIS) has been performed based on the study is done through taking into consideration the different levels of fire station and street layer. GIS illustrates the levels of the street the same as a shape consisting a variety of inside layers and lines interconnecting on the map that each of which is a representation of the related information including the kinds of the road, street, avenue, highway, acceptable speed limit, and distance to source sites. The highly valuable data have the capability to assist the researcher to discover the position of a fire station, known as travel time and can be established as a connection of lines shaping a network. The network can be shaped either in a heterogeneous or homogenous position.

This study has to identify the best possible location for the new facilities to be recognized in a city which there is the network and some other data in GIS according to the situation. The GIS- based research is known as the best approach to come up with a solution about these problems.

The first step was devoted to identify all possible nodes, the result of which suggested 1746 nodes on the city road map manually that a majority of which have been connected to each other. After that, a map layer has been made in Quantum GIS software which is shown in Figure 4.1.

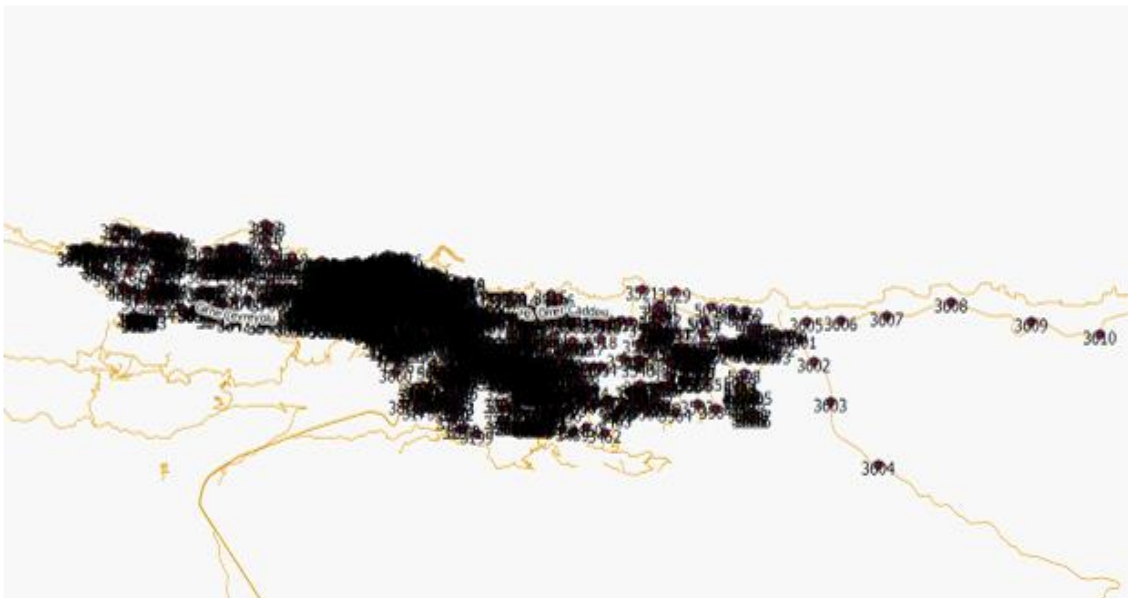

Figure 4.1: Map layer in Quantum GIS

As it can be seen from the Figure 4.2, a much specified examination of layers is presented in this figure.

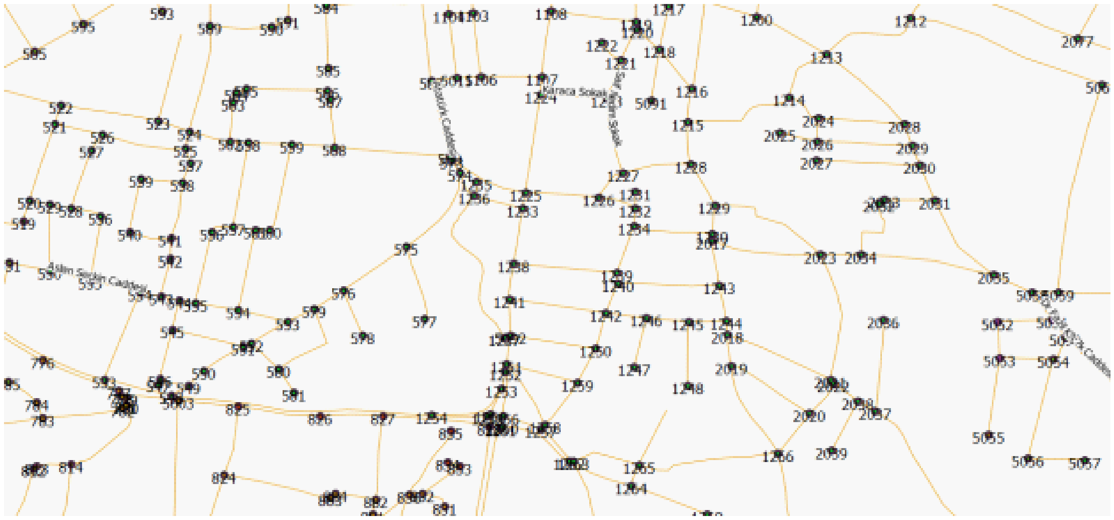

Figure 4.2: Zoomed – in view of the sheet network with the scale: 1:3858

4.2 Results from Quantum GIS

Considering the gathered outcome from this stage, it is suggested that the best locations are associated with the green color and dark green, yellow, orange and red colors are next priorities.

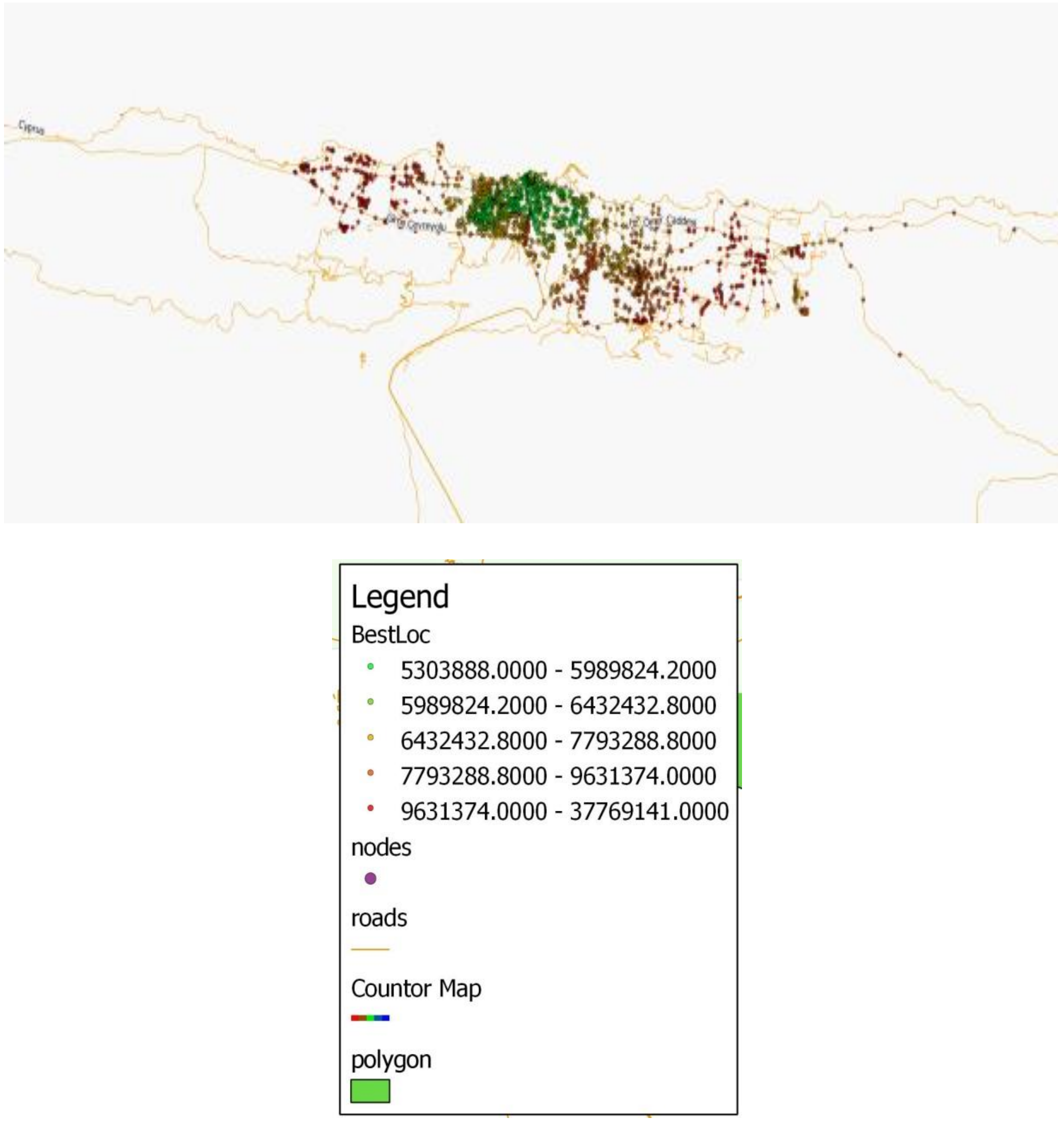

Figure 4.3: Colored view of nodes and colors represent

In the Figure 4.4, all the nodes are shown in Kyrenia roads. For instance, in the middle of the map, the green nodes are selected as the best nodes with the lowest time interval, furthermore, the poor nodes are located in the edge of map are shown in dark green, yellow, orange and red colors nodes.

Figure 4.4: Colored of nodes shown on Kyrenia road network

4.3 Routing Method for Shortest Path

Routing method, for the purpose of identifying shortest path, has been performed through the application of the Python program.

The analysis of the data being performed through application of the Python program revealed which node is the best road to travel from one node to another. Then, a number was accomplished for each node and the best two nodes were selected based on the least amount of time needed to travel between two nodes.

4.4 Attribute Table of Nodes

As it is apparent from the Table 4.1, the names of nodes, numbers of links, distance of each link (distance of two nodes of together), and the assumed node in column 1 with the name of the node being linked with that has been measured in Column 3.

Table 4.1: Attribute Table of Nodes

Attribute table - nodes :: 0 / 1747 feature(s) selected

	Link1	Link2	Link3	Link4	Link5	Dist1	Dist2	Dist3	Dist4	Dist5	JID1	JID2	JID3	JID4	JID5	d1	d2	d3	d4	d5
0	502	504	506	707	0	140.868131192	60.3915724318	141.148983752	192.257960626	0	501_502	501_504	501_506	501_707	501_0	141	60	141	192	0
1	501	503	605	0	0	140.868131192	72.8225527398	59.681000384	0	0	502_501	502_503	502_605	502_0	502_0	141	73	60	0	0
2	502	600	0	0	0	72.8225527398	105.16635167	0	0	0	503_502	503_600	503_0	503_0	503_0	73	105	0	0	0
3	501	503	505	0	0	60.3915724318	140.022963604	91.5386652956	0	0	504_501	504_503	504_505	504_0	504_0	60	140	92	0	0
4	504	506	595	0	0	91.5386652956	151.636297975	86.9886313011	0	0	505_504	505_506	505_595	505_0	505_0	92	152	87	0	0
5	501	505	507	510	712	141.148983752	151.636297975	76.4345626961	134.392309072	97.3139638841	506_501	506_505	506_507	506_510	506_712	141	152	76	134	97
6	506	508	522	0	0	76.4345626961	205.07052313	105.917694601	0	0	507_506	507_508	507_522	507_0	507_0	76	205	106	0	0
7	507	509	518	0	0	205.07052313	69.5383123422	62.1250966936	0	0	508_507	508_509	508_518	508_0	508_0	205	70	62	0	0
8	508	510	515	0	0	69.5383123422	56.5956023161	52.5865387905	0	0	509_508	509_510	509_515	509_0	509_0	70	57	53	0	0
9	509	511	506	0	0	56.5956023161	61.7345345613	134.392309072	0	0	510_509	510_511	510_506	510_0	510_0	57	62	134	0	0
10	510	512	712	0	0	61.7345345613	86.5078702973	115.786754029	0	0	511_510	511_512	511_712	511_0	511_0	62	87	116	0	0
11	511	513	724	0	0	86.5078702973	7.70079510031	181.39453943	0	0	512_511	512_513	512_724	512_0	512_0	87	8	181	0	0
12	512	514	727	0	0	7.70079510031	33.1360328686	202.282210167	0	0	513_512	513_514	513_727	513_0	513_0	8	33	202	0	0
13	513	515	532	0	0	33.1360328686	21.0786123139	200.84241463	0	0	514_513	514_515	514_532	514_0	514_0	33	21	201	0	0
14	509	514	516	0	0	52.5865387905	21.0786123139	24.6884162914	0	0	515_509	515_514	515_516	515_0	515_0	53	21	25	0	0
15	515	517	0	0	0	24.6884162914	117.563137787	0	0	0	516_515	516_517	516_0	516_0	516_0	25	118	0	0	0
16	516	518	531	0	0	117.563137787	59.0662137585	23.7293423022	0	0	517_516	517_518	517_531	517_0	517_0	118	59	24	0	0
17	508	517	519	0	0	62.1250966936	59.0662137585	29.7470685328	0	0	518_508	518_517	518_519	518_0	518_0	62	59	30	0	0
18	518	520	0	0	0	29.7470685328	34.2679582224	0	0	0	519_518	519_520	519_0	519_0	519_0	30	34	0	0	0
19	519	521	529	0	0	34.2679582224	127.004381985	31.3667330468	0	0	520_519	520_521	520_529	520_0	520_0	34	127	31	0	0
20	520	522	526	0	0	127.004381985	30.5739628352	74.7830155342	0	0	521_520	521_522	521_526	521_0	521_0	127	31	75	0	0
21	507	521	523	0	0	105.917694601	30.5739628352	152.049842363	0	0	522_507	522_521	522_523	522_0	522_0	106	31	152	0	0
22	522	524	0	0	0	152.049842363	49.7161029186	0	0	0	523_522	523_524	523_0	523_0	523_0	152	50	0	0	0
23	523	525	589	0	0	49.7161029186	28.2568824715	170.626488189	0	0	524_523	524_525	524_589	524_0	524_0	50	28	171	0	0
24	524	526	537	0	0	28.2568824715	129.432491518	23.0979801514	0	0	525_524	525_526	525_537	525_0	525_0	28	129	23	0	0
25	521	525	527	0	0	74.7830155342	129.432491518	30.0187880609	0	0	526_521	526_525	526_527	526_0	526_0	75	129	30	0	0
26	526	528	0	0	0	30.0187880609	96.9210126502	0	0	0	527_526	527_528	527_0	527_0	527_0	30	97	0	0	0
27	527	529	536	0	0	96.9210126502	34.422320359	46.197382635	0	0	528_527	528_529	528_536	528_0	528_0	97	34	46	0	0
28	520	528	530	0	0	31.3667330468	34.422320359	103.318376473	0	0	529_520	529_528	529_530	529_0	529_0	31	34	103	0	0
29	529	531	535	0	0	103.318376473	63.0924533349	64.9413078156	0	0	530_529	530_531	530_535	530_0	530_0	103	63	65	0	0
30	517	530	532	0	0	23.7293423022	63.0924533349	101.261742863	0	0	531_517	531_530	531_532	531_0	531_0	24	63	101	0	0

Look for

Show selected only Search selected only Case sensitive

4.5 Attribute Table of Best location

The Table 4.2 demonstrates the best node due to travel time in seconds. As we move from the top of the table, time interval increases, for instance, the best node in the beginning of the table is 1225 with the least possible time.

Table 4.2: The best possible nodes are shown in order

Table

BestLoc

FID	Shape *	Node	Sec	NofOutRangeN
629	Point	1225	530388	0
630	Point	1226	530976	0
631	Point	1227	532363	0
636	Point	1232	532441	0
637	Point	1234	532770	0
632	Point	1228	533285	0
634	Point	1230	533480	0
638	Point	1233	533575	0
69	Point	573	533675	0
721	Point	2017	533679	0
68	Point	569	533832	0
633	Point	1229	535062	0
640	Point	1236	535895	0
70	Point	574	536762	0
635	Point	1231	536781	0
727	Point	2023	537223	0
639	Point	1235	539540	0
738	Point	2034	539601	0
67	Point	568	540249	0
642	Point	1238	541231	0
58	Point	559	542497	0
643	Point	1239	542696	0
618	Point	1215	542812	0
647	Point	1243	542974	0

1 (1 out of 1708 Selected)

BestLoc

4.6 Contour Map and Using Python Programming Language

This section seeks to create a contour map with the best areas whereas other feature including the price of possession, the revolving actions, bearing in mind the travel times, measuring the traffic flow in road, networks distance among all nodes as well as the access managements are possible approaches to be applied in order to choose the location more precisely.

GIS does not include suitable purpose to come up with a logical solution for the urgent problem therefore, the researcher has to describe the program and identify the required purposes so that the optimization problem can be solved empirically. Optimization, being known as the minimizing the entire expenses in the system such as the travel time between nodes, and covering the maximum area, is one of the effective approaches in dealing with such difficulties.

A study was performed by applying GIS shapes in Python in which the most appropriate areas being determined was due to the least possible distance among all areas.

```
##t = [[0 for i in range(2)] for j in range(1500)]
cln=[]
try:
    datafile = open('closurenow.csv', 'r')
    for line in datafile.readlines():
        items = line.split(',')
    ##     cln1 = items[0]
    ##     cln2 = items[1]
        cln.append([int(items[0]),int(items[1])])
except:
    print 'file closurenow.csv does not exist'
    cln=[]
##cln=[]
print 'Closed links are: ' + str(cln)

b=0
From=0
AllowedSPD=40
for i in records:
```

Figure 4.4: Part of the code to read the GIS file, and generate the NetworkX model

In providing a definition for the contour map, it is necessary to write a Python code. For example, in the map, one of the nodes was applied to the Quantum GIS software which supplied layers various in colors that demonstrated the response time contours in minutes in the situation where the fire station is constructed at the node.

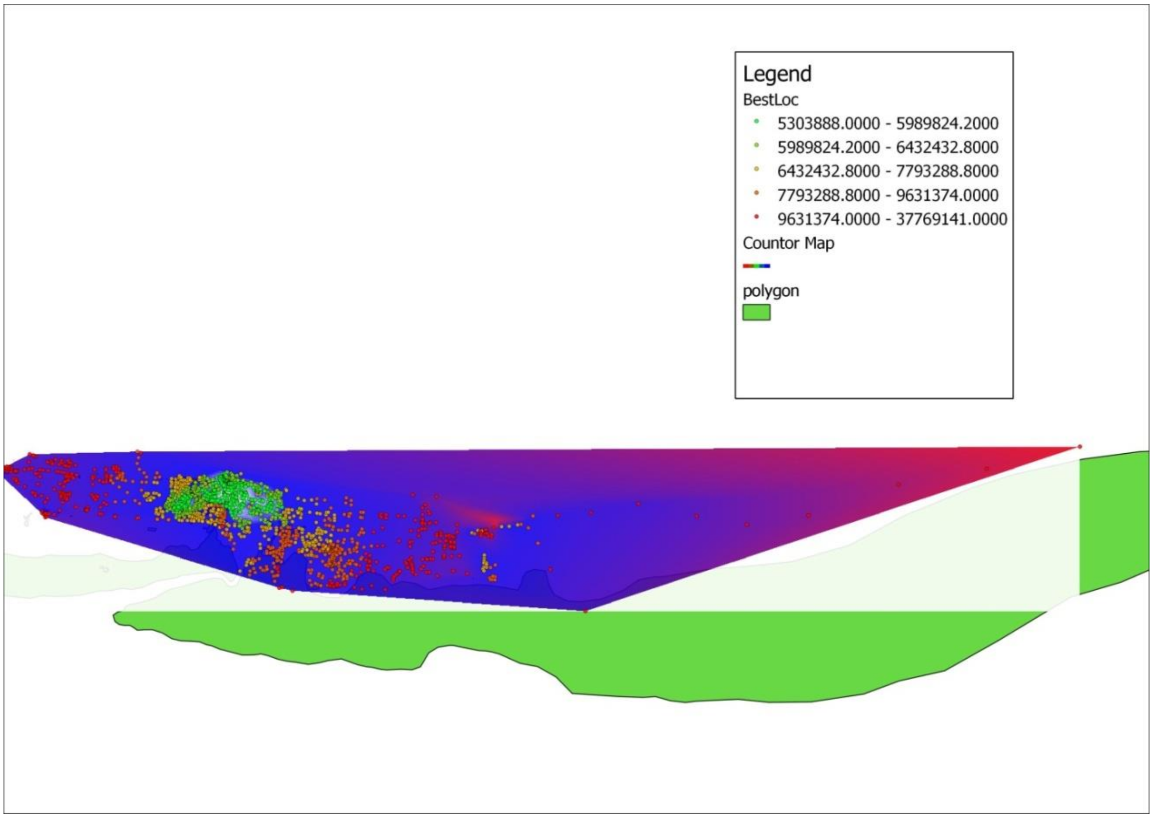

Figure 4.5: Contour map with Scale 1:122125

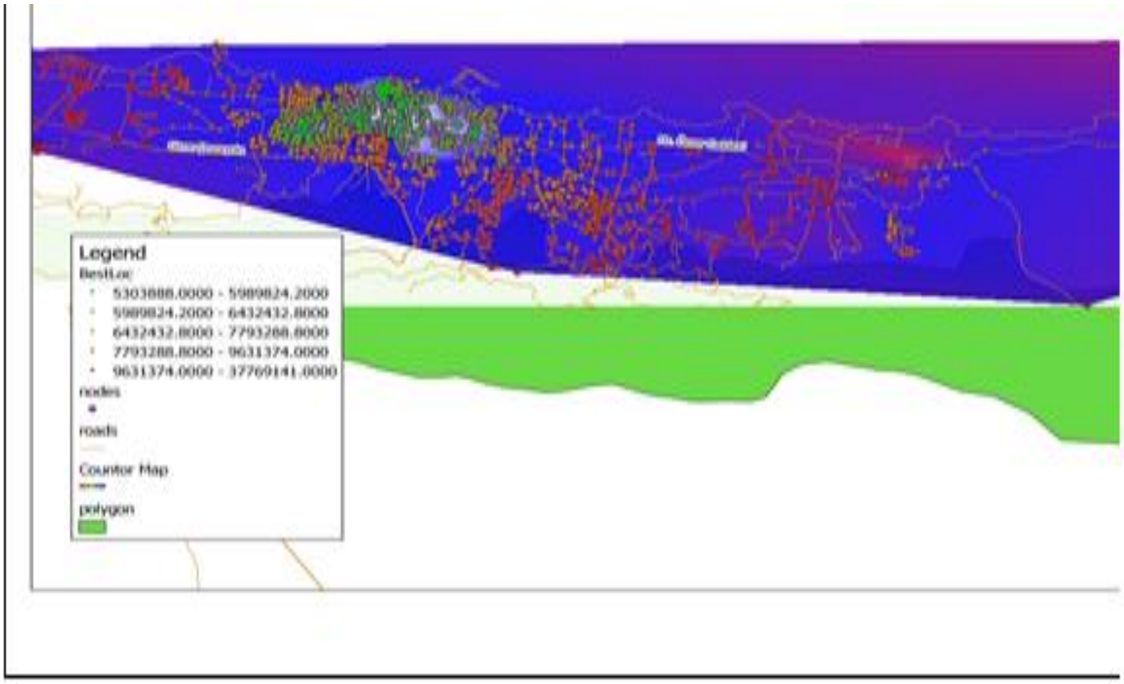

Figure 4.6: Zoomed of the contour map with Scale of response time

4.7 Defining the Best Location for Only One Fire Station in City

This stage involves writing a code in Python according to following processes:

The first step is randomly selecting one node the time period of which will be calculated by the designed program in the all nodes that remained and will be accomplished for all nodes. And at the end, the existed nodes with lowest time period and number of out ranged will be selected as the best location.

```
#read .shp file using shapefile.py
sf = shapefile.Reader('nodes.shp')
shapes = sf.shapes()
fields = sf.fields
records = sf.records()
shapeRecs = sf.shapeRecords() #contain both records
points = shapeRecs[3].shape.points[0:2]

##t = [[0 for i in range(2)] for j in range(1500)]
cln=[]
try:
    datafile = open('closurenow.csv', 'r')
    for line in datafile.readlines():
        items = line.split(',')
##      cln1 = items[0]
##      cln2 = items[1]
        cln.append([int(items[0]),int(items[1])])
except:
    print 'file closurenow.csv does not exist'
    cln=[]
##cln=[]
print 'Closed links are: ' + str(cln)

b=0
From=0
AllowedSPD=40
for i in records:
```

Figure 4.7: The major role to calculate the fitness (total travel distance from all other nodes to proposed node)

Based on the final results, the best location for constructing fire station in Kyrenia is node number 1225. This indicates that, constructing a fire station in node number 1225 will save the city in the fastest time.

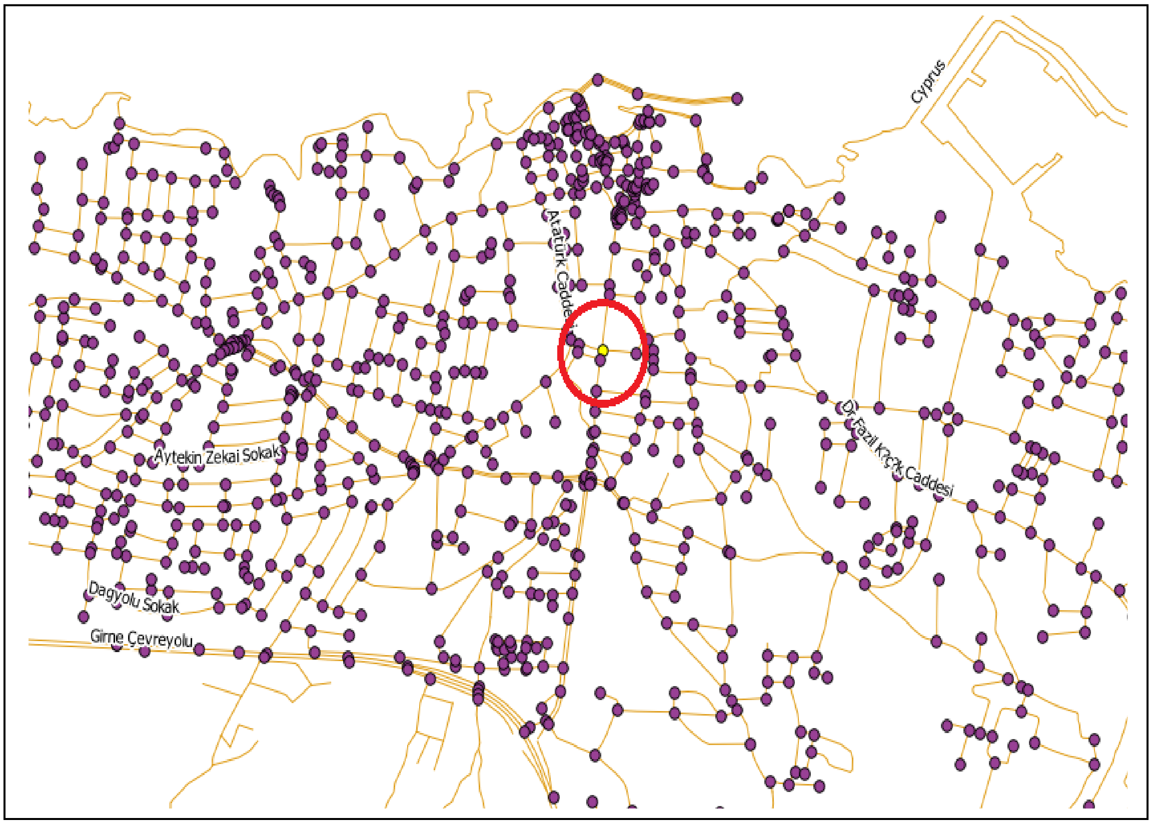

Figure 4.8: The best location for fire station in Kyrenia (node of 1225)

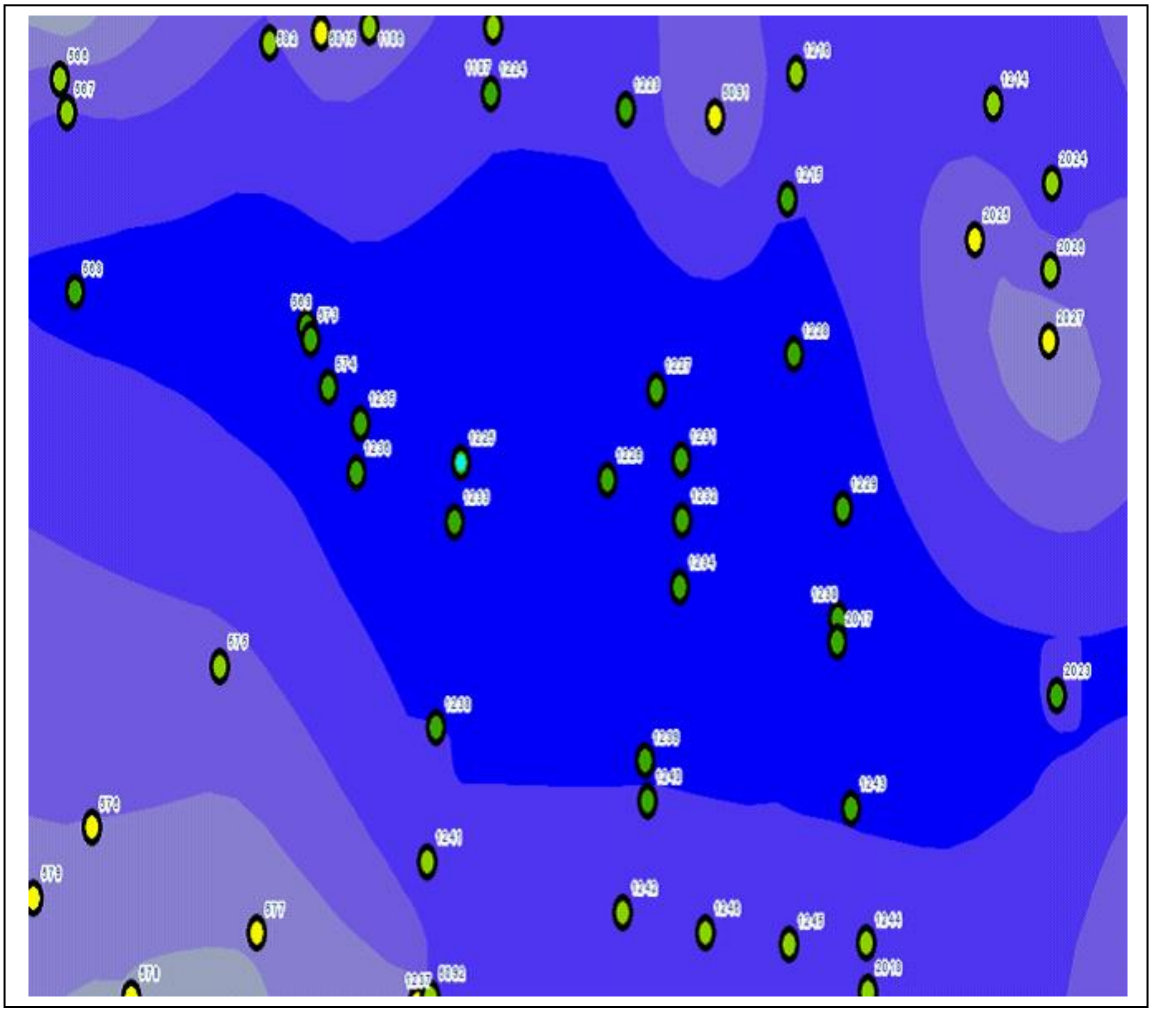

Figure 4.9: Closer view of the best location for fire station in Kyrenia

Chapter 5

CONCLUSIONS

Considering the beauty of all the cities in Cyprus such as Kyrenia among the visitors of the other countries, it is vital to save it from any harm that may be caused by fire. To accomplish such a purpose, this research attempts to identify the best place in the city to construct the fire station which had been achieved through the application of a bunch of programs, the important ones of which are the QGIS software and Python Programming Language. The best possible node has been selected based on the travel times, and the economics of the distance traveled from one place to the other.

A study was done using GIS features in Python. The most suitable areas determined, in terms of minimizing the distance accessible to all other areas. This study must address the best location for the new facilities to be established in a city which we have the network, and some other data in GIS based environment. The GIS based method is the best way to solve these kinds of problems. However, the GIS does not have an appropriate function to solve our proprietary problem. We should define and program the required function, in order to solve the optimum location problem.

Based on the final results, the best location for constructing fire station in Kyrenia is node number 1225. This indicates that, constructing a fire station in node number 1225 will save the city in the fastest time.

For future research, a more accurate study would be including: the turning movements, considering the travel times, measuring the traffic flow in road networks speeded by GPS devices, or other methods, and considering the access management as well.

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