Emergency Service Location Study for City of Famagusta in Geographic Information System

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ABSTRACT

In this study the location selection process related to fire stations in Famagusta city has been enhanced by applying Quantum Geographic Information Systems (QGIS) and Python programming language. This procedure led to obtaining the optimum emergency service location based on the minimization of response time.

This study aims to commence service coverage modeling in a consistent demand region, with road availability considerations. On the other hand, this study concentrated on the capability of GIS to create service areas by means of the travel time regions in a facility location model named the maximal service area problem (MSAP). This model is referred to emergency facilities for the situation where accessibility is the main requirement.

The purpose of this model (MSAP) is to maximize the overall service area of a determined number of facilities. Moreover, this study aims to state the capability of GIS to establish the suitable service areas of fire stations in Famagusta city and for achieving a maximal overall service area from a specific fire station facilities based on three alternatives.

In this study three alternatives are assigned in this study including (a) Defining the best location for only one fire station in city, (b) Defining the best location for 1 fire station when several other fire stations are also located in the city and (c) Defining the best location when two fire stations are active concurrently. According to this study, when only one fire station in city is assumed, nodes 230 and 231that placed around the signalized intersection joining Mustafa Kemal Boulevard and Topçular Boulevard in Gazimağusa are the most important.

Keywords: Emergency Service Location, Famagusta, Geographic Information System, network analysis, dijkstra algorithm, travel time, isochrones.

ÖZ

Bu çalışma itfaiye istasyonlarının yangınlara tepki süresinin en aza indirilmesi konusunda en uygun istasyon konumunu elde etmek için Quantum Coğrafi Bilgi Sistemi yazılımı ve Python programlama dili kullanılarak Gazimağusa kentinde itfaiye istasyonlarının yerleşke seçimi, erişim süresini kısaltma yöntemine göre yapılmıştır. erişilebilirlik düşünceler kurmak için. Diğer bir deyişle, bu

Bu çalışmanın amacı, sürekli bir talep bölgede hizmet kapsama modelleme, yol çalışmada bir tesis konumu modele seyahat süresi bölgeleri maksimum servis alanı sorunu (MSAP) denilen hizmet alanları oluşturmak için CBS yeteneği üzerinde odaklanır.

Bu model, erişilebilirlik önemli bir gereksinimdir olduğu acil tesislerine ele alınmaktadır. MSAP modelinin amacı, belirli bir sayıda tesislerin toplam hizmet alanını maksimize etmektir. Çalışmanın amacı, Gazimağusa kentinde erişim zaman aralıkları kullanarak itfaiye istasyonları hizmet alanları oluşturmak ve bunu üç alternatif istasyon çözümüne dayanan maksimum toplam hizmet alanı elde etmek.

Bu çalışmada üç senaryo da dahil olmak üzere bu çalışmada (bir) şehirde sadece bir yangın istasyonu için en uygun yerin belirlenmesi, (b) birden fazla itfaiye istasyonlarının aktif olması durumunda yeni bir istasyon için en uygun yerin belirlenmesi ve (c) iki yeni itfaiye istasyonu aynı anda aktif olan en iyi konum tanımlama.

Anahtar Kelimeler: Acil Servis Yerleşkesi, Gazi Mağusa, Coğrafi Bilgi Sistemi, şebeke analizi, dijkstra algoritması, seyahat süresi, eşit zaman eğrisi.

To my parents

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

MSAP: Maximal service area problem

PMP: P-median problem

PCP: P-center problem

LSCP: Location set covering problem

MCLP: Maximal covering location poriblem

NFPA: The National Fire Protection Association

GPS: Global Positioning System

QGIS: Quantum Geographic Information System

Chapter 1

INTRODUCTION

1.1 Background

1.1.1 Preface

A location research states the solution, modeling and formulation of a group of problems that can be the best defined as positioning and creating services in some given sites (Revelle and Eiselt, 2005). Researches about Location Science that protection the problems of facility location was published in the commencement of the 1970s by researchers such as Church and ReVelle (1974)and many other researchers before them such as, Toregas and Revelle (1972) and Hogg (1968).

With the growth of populations and building increasing, the role of the fire facility develops more demanding. Fire departments are being named upon to carry facilities with more efficiency and economy.

Once a fire happens, every delay of responding fire firms can cause to important injury to people and houses and can threaten their lives. The critical time between fire control and flashover may be measured in minutes. Though fast access to critical information is necessary, but appropriate site of fire stations is very important in this area. Important things that assistance firefighters identify the emergency call site measure the potential consequences and describe the most effective plan will decrease property injury and better keep the security of occupants and fire facility personnel.

Geographic information systems (GIS) have been measured for a lot of applications in service location problems today specifically for researches related to fire stations sites and facilities. Several researchers such as Huxhold & Levinsohn, (1995) and Demers (1997) stated that current methods to assessing the potential role of GIS in organizational planning and decision-making utilize techniques such as functional need analysis and benchmarking to assess the wishes of system users and decision-makers and potential beneficiaries. These techniques are planned and implemented based on some knowledge of the data, geographical information and the decision-making process relating to health care planning and emergency service providers in different parts of the world.

There are numerous different GIS abilities and we essential more study into how they can be efficiently applied to improve results for service site problems in emergency locations. Most of the models which are used for emergency studies are designated to be analyzed by the GIS program. But on the other hand, not all location models are suitable to be adopted for emergency facilities. In fact, certain models are only suitable for certain kinds of facilities. To select a suitable model, the scientist should realize the nature of the model and the purpose of facility services. For example, there are location models about reducing distance named the P-median problem (PMP) and P-center problem (PCP). Regarding to Klose and Drexl (2005), the PMP is designed for reducing the total or average distance between services and demands assigned to them, whereas the PCP has the objective to minimize the farthest distance.

There are also further models about optimizing facility analysis, like the location set covering problem (LSCP) and maximal covering location problem (MCLP). In the LSCP, the optimum number of facilities is one aspect of the solution to the problem and the constraint requires for all demands must be covered by at least one service (Toregas and Revelle 1972).The number of services In the MCLP, is the priority and the objective becomes to maximize facilities for demands (Church and Revelle 1974). Emergency services have a unique typical in the way they measure benefits. Normally, the objective of service location problem is either to reduce costs or increase benefits.

This research will be conducted through utilizing the capability of Python software to generate service areas as the travel time zones in a facility location model called the maximal service area problem (MSAP). MSAP in this research will consider fire stations in city of Famagusta and this model addressed to emergency services for which accessibility is a main requirement.

1.1.2 Literature Review

It must be stated that most conservative methods only define an ability service area only as a limited area in terms of a specified range. Like a definition should be suitable for facilities which are not influenced by topographical barriers, like sirens or telecommunication transmitters. But for particular facilities such as fire stations, ambulances and transfer services, accessibility is a main requirement. The service area can be calculated by taking into account the way access, fences and road system characteristics. This benefit from GIS must be incorporated into the system area calculation to gain a new accurate method according to Aly and White (1978), regarding to emergency services, the objective is often defined as the minimization of injuries to the people and their properties which may be equivalent to the maximization of profits. Fire stations are planned in this study. Fire stations should be placed in order to reduce injuries resulting from fire, like property loss, loss of lives and physical damages. Toregas et al. (1971) mentioned, in any case, the response time or distance traveled is an essential factor to measure the value of emergency facilities. They considered that longer response will result in more injuries, indicating the poor facilities. In other words, quicker response will save more people and their properties from losses and damages. As a result, emergency facility location problems are particularly modeled in terms of time or distance constraint. This nature of emergency services affects the kinds of models that must be adopted for locating emergency services. For instance, it can produce more sense for a city fire department to placed fire stations so a suitable response to each property in less than 5 min, than to care about reducing the average response time (Longley et al. 2005). Assuming this consideration, coverage location problems like the MCLP and LSCP are more suitable than the PMP which try to minimize the overall/average distance. Actually, both the LSCP and MCLP and their variants appear as dominant methods useful to solve emergency facility location problems. Studies led by Murray and Tong (2007), Liu et al. (2006) have used GIS for location modeling. Revelle and Snyder (1995) developed an increasing of the MCLP for integrated fire and ambulance siting and Chrissis (1980) improved the LSCP into a dynamic method for locating fire stations. GIS is a specific software designed for performing surface modeling, capable the location study to increase its activity into three-dimensional modeling.

1.2 Objectives of the Study

This research tries to improve the location selection process related to fire stations in Famagusta city by utilizing network analysis generate service areas as travel time zones, within an emergency service context. The objective of this research is to create facility coverage modeling in a demand area, with path accessibility considerations. In other words, this study focuses on the capability of Python in doing of network analysis and capability of Quantum GIS to generate service areas as the travel time zones in a service location model named the maximal service area problem (MSAP). This model is referred to emergency facilities for which accessibility is main requirement. The objective of the MSAP is to increase the overall service area of a definite number of services. Objectives of the research are mention as follows:

1-To define the capability of network analysis module of Python to generate service areas of fire stations as the travel time zones in Famagusta city.

2-To achieve a maximal overall facility area from a specified number of fire station facilities based on three alternatives:

a. Defining the best location for only one fire station in city;
b. Defining the best location for one fire station when other fire stations are also located in the city;
c. Defining the best location when two fire stations are active concurrently.

3- Comparison of the new defined best locations with the current site of the fire station.

1.3 Justification for the Objectives

Because of the rapid development of the city, the current fire station is not able to cover all the regions of the city in acceptable response time and this important weakness of the emergency facility in the city may lead to undesirable disasters during the accidental fire events. This study provides a significant suitable data related to the fire station services and their privileges in Famagusta city and the results may guide the city authorities to solve the problems.

1.4 Scope of the Thesis

This study comprises five chapters. Chapter one is devoted to providing a background information, problem definition and presenting the objectives and reason for the objectives.

In chapter two a detailed literature review has been provided related to the most important theoretical and historical issues in the field of location science, historical perspectives of location study in the field of fire stations, important emergency facilities, standards of fire protections, variables of importance in emergency facility study in fire events. Additionally, important scientific issues related to Geographic Information Systems (GIS) and Python in network analysis usage in fire station location studies and its analysis procedures have been provided.

Methodology is provided in chapter three of this study including the procedures related to the travel time monitoring, variables of the study, sampling method and using the Python module processing the geographic data for the study.

In chapter four, a detailed set of results including tables and figures related to data analysis of the study is presented along with the description of results. First of all, gathered data downloaded from the Global Positioning System (GPS) device and are converted to KML files (KML is format of a file used to show geographic data inside an earth browser, like Google Earth or Google Maps and Google Maps that use for mobile by GPS visualizer software (Source: www.gpsvisualizer.com/). The resulted layers have been prepared and latitude and longitude of demand nodes for fire facilities in Famagusta are shown in two separated figures. Then results regarding to travel time monitoring procedure are shown in different steps and results are presented in figures and tables.

By Python software the result of routing method for the shortest path or the best way from one node to another node is obtained. Attribute table is prepared including name of the roads, speed limit for each street and length of street. Contour map is prepared using data out from Quantum GIS software with different colored layers of importance based on their shortest to longest. Finally, results related to three alternatives are shown as different GIS multi-layer maps with different colors related to the travel times.

In chapter five, conclusion is provided after reviewing all data presented in chapter four and a discussion is provided about the results.

Chapter 2

LITERATURE REVIEW

This chapter includes related scientific issues about the location study and GIS system and its capability.

2.1 Facility Location Study

Facility location models are designed and implemented in order to provide enough suitable response to spatially dispersed demands, mainly in different parts of urban areas. These types of demands are found through scientific analysis procedures. Many researchers believe that these demands are defined in dispersed areas, and also found in centralized locations.

2.2 History of Finding Best location

During the recent century, the facility location science has been evolved as an innovative way for decreasing any damage and loss for human being mainly in urban area. Alfred Weber was one of the most important pioneers of this science who published his book in 1929 titled 'The science theory of the location industries'. From the beginning of 1970 s, some important scientists such as Toregas et al. (1971) and Church and Revelle (1974) proposed different viewpoints related to the location studies called location science. They provided significant optimization problems in a scientific framework of operational research and then proposed mathematical algorithms for optimizing single or multiple objective functions with the main objective of minimizing costs or maximizing the benefits. Referring to their methodology, many location problems related to warehouses, fire stations, health emergency services (ambulances), power plants, schools and hospitals have been proposed and solved by different scientists all over the world. But preliminary location studies were only focused on small data set conducted through simple equations for measuring spatial interactions among different facilities and centers, providing services for demands in urban areas.

2.3 Historical Perspectives of Location Study in the Field of Fire Stations

Planning a suitable site for fire stations all over the world has been considered as the basic goal for fire control centers (Gratz, 1972). Marianov (1990) and Lewis (1986) also pointed this goal as an important location study stressing that poor location planning of fire station will lead to poor fire prevention, resulting in significant loss of lives and properties. Holland (1993) stated that, since failure to locate a fire station correctly will eventually result in a considerable amount of financial and human loss, the effectiveness of a fire services system is shown in the location of fire prevention units. Cato (1990) also stated that the basic mission of firefighting executives and officers is to allocate a suitable level of services for protecting the public properties and human life.

According to Gay and Siegel (1987), there are few numbers of standard documents related to planning optimum number and placement of firefighting facilities in any urban area. According to a report published by the National Fire Protection Association (NFPA), there are no distinct standard for important factor in fire station efficacy including response time or travel time. In this view, they finally concluded that because of the lack of any definite efficacy in this field, each community should define an appropriate response time for maximizing the efficacy of its fire protection services.

2.4 Important Emergency Facilities

Some of the most important emergency facilities in urban areas are fire stations; police guard cars, emergency hospital wards, ambulances, warning sirens and defense station in cities. Fire stations are the most important sites that should be located in efficient sites for extinguishing sudden fires in building complexes, residential and/or administrative areas.

In these emergency service centers, the most critical variable is the response time or the traveled distance and measuring this variable will provide suitable result regarding to the efficacy of services. As a result, it may be concluded that time and distance are important variables for calculating emergency coverage. Longley et al. (2005) suggested that a less than 5 min response time is very important for emergency service centers in cities.

According to researchers such as Revelle and Church (1974), planners should consider the quantity of facilities which include maximal priority for responding to the calculated demands. Hence, fire stations in this model of analysis should be strategically located for minimizing financial and human damages resulted from fire.

2.5 Goal of Emergency Facilities

In the field of emergency facilities, the most important goal is to minimize damages and losses to the public properties. This goal is also related to minimizing costs and increasing the productivity of the emergency system (Aly and White, 1978).

2.6 Definition of Location Analysis

Location analysis is the study of different applications and procedures of a specific group of facilities through modeling, formulating and finally providing best solution in this field. In other word, researchers try to provide the best forms of applications and methods for maximizing the service coverage and minimizing costs and damages for people. In the field of location study, facilities that are analyzed are smaller than the space they are located in, and there may not be any interaction between them (Revelle. C.S. Easel, 2005).

2.7 The Objective of Facility Location Problem

The main objective of facility location problem is either to minimize costs or maximize benefits. Aly and White (1978) suggested that in the field of emergency services, the most critical objective of location studies is the minimization of the losses to the public. Some authors assume this objective is equivalent to the "maximization of benefits".

2.8 National Standards of Fire Protections

There have been many different standards of fire protection among which national fire protection association (NFPA) is the most important. These standards refer to the firefighting system and emergency health services.

NFPA 1221

NFPA 1221 includes important instructions regarding to the installation, maintenance and using communication systems of emergency service.

NFPA 1710

This source includes an organizational standard for providing suitable fire suppression practices.

NFPA 1720

In addition to the above standard (NFPA 1710), it also includes volunteer fire department.

2.9 Different Components of Location Problems

ReVelle and Eiselt (2005) referred to four components of location studies as follows:

Customers or Clients

Customers in this study are located at different points and routes.

Facilities

Facilities are located in different distances to each other.

Geographic distance

This distance is a space between customers and facilities.

Metric scale

This scale defines the length of distance or elapsing time in the study.

2.10 Coverage of Facility Location Studies

Location studies cover different common and emergency situations. Eiselt (1992) referred to much different applications of location studies implemented by (1) Jacobsen and Madsen (1980) for newspaper delivery points, (2) Marks and Liebman (1971) for transferring solid waste in a city, (3) Kims and Fitzsimmons (1990) regarding to motel locations and (4) Hopmans (1986) about bank branches.

2.11 Importance Variables in Emergency Facility Study for Fire Events

The key element in the field of protection against fire events is the location of fire station in which the main preventive measures are planned and ordered to be implemented. According to Puccia (2005), no magic formula has been provided for defining the best location, for fire station and for each city, a definite location model should be conducted.

2.11.1 Total Response Time

Toregas et al. (1971) pointed to the critical importance of response time as an important variable for evaluating emergency services; the longer response time causes more losses. As a result, during calculation and analysis of service quality in emergency services, location problems are modeled based on time and distance traveled during response time. The acceptable maximum total response time is pinpointed as the major element in the process of location study for fire stations. This means that the response time should be reduced to a minimal and acceptable time in such a way that the total average time does not exceed more than six – to – nine minutes flashover time. Some resources define “flashover” as the sudden accidental eruption into flames that produce significant quantity of heat, smoke and pressure accompanied with enough force to distribute these elements from their original site through the rooms and windows located at nearby space. This huge and sudden pushing force will lead to combustion event, concurrently burning greater amount of unburned objects (Puccia, 2005).

2.11.1.1 The Importance of Response Time for Emergency Facilities

Toregas et al. (1971) suggested that for increasing the efficacy of emergency services such as firefighting services, the response time is regarded as a critical factor, since longer response time will lead to slower action, more damages and human loss, defining poor and inefficient services. On the other hand, quick time response will result in lower damages and injuries in a susceptible area. For this reason, the foundation of quicker service coverage of emergence facilities is based on two important variables: time and distance.

2.11.2 Avoiding Brain Death in Emergency Setting

In order to minimize any body injuries to people, rescue workers and firefighters, specially the people who work at state department fire station, the response time should be between four and six minutes, for preventing brain death in cardiac arrest events. On the other hand, national fire protection association (NFPA), referred to its (standard 1710), pointing to five minutes limit as the suitable response time goal.

2.12 Models used for Location Analysis

In order to classify their location studies, scientists in location studies categorized the space where facilities are located. There are many location models such as the following list.

- Maximal covering location problem (MCLP)
- Location set covering problem (LSCP)
- P center problems (PCP)
- P median problem (PMP)

2.12.1 Maximal Covering Location Problem (MCLP)

This model was proposed by church and Revelle (1974) in order to maximize the demand coverage regarding services in a defined acceptable distance. In MCLP model, the researchers tried to find facilities with higher priority for maximizing services provided for demands (Church and ReVelle, 1974). Church and Revelle (1974) suggested that MCLP is capable of defining the prioritized facilities and help managers to maximize services for the needed locations and sites. Church and Revelle (1976) also suggested that MCLP is a variant for the formulation of p – model and the location covering model. Pirkul and Schilling (1991) stated that variations of MCLP were formulated to cover either work load capacities or to increase the coverage and decrease the distance to demand nodes in the outer side of maximum covering distance.

Church and Revelle (1976) were the first researchers who developed the MCLP in 1974. This model evaluates the maximum number of people that can be helped by a limited number of facilities within a defined distance or time. A mathematical formulation is defined as follows:

$$z = \sum_{i \in I} w_i x_i \quad (1)$$

$$\sum_{j \in N_i} y_i > x_i \quad \forall i \in I \quad (2)$$

$$\sum_{j \in J} y_i = P \quad (3)$$

$$x_i \in \{0, 1\}, y_i \in \{0, 1\} \; \forall i \in I, \forall j \in J \quad (4)$$

Where:

i, I demand nodes indexes

j, J potential facility site indexes

Ni {j ϵ J | dij < S} = all j nodes set located within a of node i

dij the demanded services distance/time between i and j nodes

S Demanded services distance/time for each i node

Wi number of people served at i node

P number of facilities to be located

$$xi = \begin{cases} 1 \text{ if demand node i is covered by one or more facilities} \\ 0 \quad otherwise \end{cases}$$

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

2.12.1.1 Advantage of MCLP

Church (1986) in his study mentioned the applicability of MCLP and concluded that this model was useful for clear analysis of location studies using suitable statistical systems.

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

The main goal of this model of location study is to maximize the total area coverage by emergency services, based on a constant number of facilities. This model was modified from MCLP using GIS system to find facilities and services coverage as travel time zones. Based on this modified model, the services area will be define as follows:

- The area with shorter distance, time and cost in comparison to other facility, or
- The area that can be covered by the limited number of facilities based on specified cost, time and distance. It should be stated that this model of analysis can be designed by the analyzer in planer region within a network systems. In this model, in a more detailed view, the analyzer tries to cover demands node in a situation in which the shortest distance and time is needed to cover the closest facility. In this model, for each demand node, different values of S may be selected by the analyzer.

In order to calculate distance between demanded nodes and facilities, a straight – line systems will be assumed through measuring coordinates of locations between two entities, with or without using GIS. Different service areas used in MSAP model are as follows:

- **View Shed Modeling**

In this type of facility coverage, the view shed of an observer point can be defined as the service area of the observer point. View shed identifies regions of visibility from one or more observer points. It typically works with raster digital elevation model. Each cell in the output raster receives a value that indicates how many observer points can be seen from each location. All cells that cannot see the observer point are given a value of zero. According to V. Indriasaria et al. (2010), this model is used for locating towers, electric transmission facilities and forest fire controlling towers.

- **Travel Time Zones**

This polygon layer system is overlaid on the network focusing on band of travel time. This model is especially used for emergency facilities which are basically modeled based on variables of time and distance. Analyzer in this model generates services in a polygon shape referring to network, implementing a network analysis in a route GIS environment. Variables such as width of the road, speed of the facility, limit of speed in the area, physical and transportation barriers and finally one way and U-turn limitations of the road in the area will be defined and analyzed. All of the GIS packages can create travel time zones. They are including TransCAD, Arc GIS, GIS Analyzer and SANET.

Like the MCLP model, the MSAP model is planned as a discrete model where a specific amount of facility locations that achieve the best objective function value of the model are selected out of a limited set of applications. The following figure shows different service area:

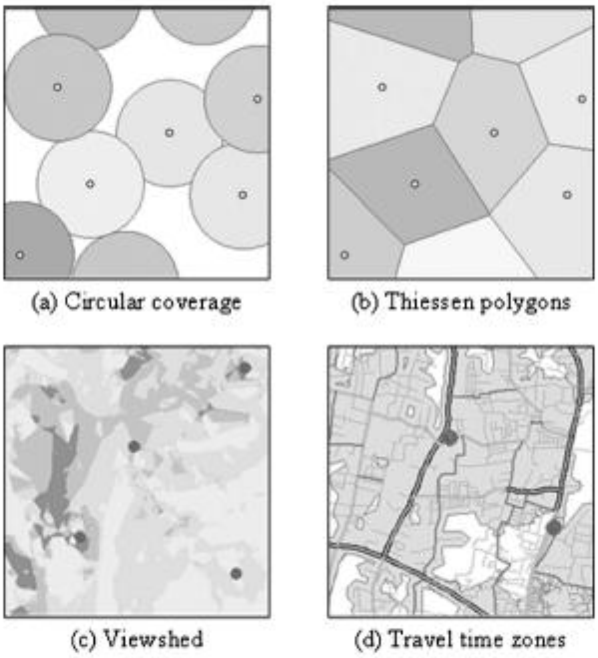

Figure 1: Different service area used in MSAP model
[Indriasaria. (2010)]

- **Disadvantages of MSAP**

One of the disadvantages of MSAP is that we cannot perform a total evaluation from multiple facilities through mathematical operation. In other word, summing areas of services region may not be implemented and as a result, analyzer should dissolve the entire services area polygon into a single polygon. At the next step, we should refer to the area of the single polygon for defining the whole services area of facilities.

2.12.2 Location Set Covering Problem (LSCP)

Researchers use LSCP model to cover all demands, by at least one facility through arranging optimum number of facilities (Toregas and Revelle, 1972).

In other word, Toragas and Revelle (1972) used LSCP to find the optimum number of facilities assuming that all defined demands are covered at least by one facility.

2.12.3 P- Center Problems (PCP)

In PCP model, Klose & Drexel (2005) tried to find the farthest distance and planned new ways for minimizing this long distance between facilities and demand needs. Also they used PCP model for decreasing the farthest distance as much as possible.

2.12.4 P–Median Problem (PMP)

P – median problem (PMP) is capable to minimize the overall or average distance between facilities and demand nodes related to them. In PMP model, the researcher focuses on the average distance between facilities and demands related to them. This model was used for minimizing total travel distance for police groups in Anaheim, California to answer the calls from people around the city (Mitchell, 1972). This model could result in a significant rate of decrease (13% - 24%) in average response distance.

2.13 Efficacy of MCLP and LSCP Models in Emergency Location Studies

According to Longley et al. (2005), if the response time in fire accidents is less than five minutes, it can be concluded that the emergency systems is working efficiently in this way, many researchers implement their analytic procedures using MCLP and LSCP models since they can define the minimization process of total average distance much better than PMP model.

2.14 Suitability Models in Emergency Settings

Longley et al. (2005) suggested that 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. In other word, both LSCP and MCLP and their subclass models are accepted by location study researcher as efficient methods for covering facility location problems. On the other hand, Revelle and Snyder (1995) proposed a new version of MCLP for concurrent location of firefighting facilities and ambulance emergency services.

Chrissis (1980) also implemented LSCP into a dynamic algorithm for analysis of the fire station locations. These innovative methods led to revolutionary progress in location study especially in the field of emergency setting.

2.15 Geographic Information Systems (GIS)

During the recent decade an innovative systems called "Geographic Information Systems" abbreviated as GIS has been used for standard location of facilities in location studies. This system that uses many satellites around the earth is based on sophisticated computer technology as well as site selection procedures which provide clear spatial measurement and spatial modeling and analysis. Miller (1996) stated that GIS is able to represent spatial objects as geometric indexes figured as points, line or polygons and this property of GIS is very flexible in comparison to other traditional methods. GIS is also capable of performing surface modeling in the form of three dimensional systems. In addition, Aerts and Heuvelink (2002) as well as other scientists such as Murray and Tong (2007), Liu et al. (2006) and Liand Yeh (2005) were able to integrate GIS into location studies in their research projects. On the other hand, many other scientists believe that GIS capabilities will be explored through future studies.

2.15.1 GIS Usage in Fire Station Location Studies

GIS provides very nice simulation of the real transportation network that we intend to analyze. This simulation is accompanied with high level of accuracy since it uses actual travel distances, speed of vehicle and time delays.

The most important mission of fire stations is to save life, properties and natural resources against the sudden damage of fire emergencies. For these reasons, fire stations should be equipped with the most innovative technologies and training methods to meet the people’s need in condensed areas.

GIS is helping managers in different process of protection against fire events including preparedness, planning, mitigation and risk management procedures. GIS extracts valuable data considered in maps providing a feasible access to related information analysis and data. When a fire event threatens public life, any delay of fire stations may lead to terrible injuries to people. In this situation, GIS helps managers of fire stations to decrease the critical response time and increase the benefits and efficiencies. GIS technology links maps to database helping users to see, analyze and interpret data of the following resources:

1 = streets, 2 = parcels, 3 = fire hydrants, 4 = network of utilities, 5 = topography, 6 = rivers and lakes, 7 = governmental buildings and 8 = fire station location. All of these data are presented as map layers (figure 2).

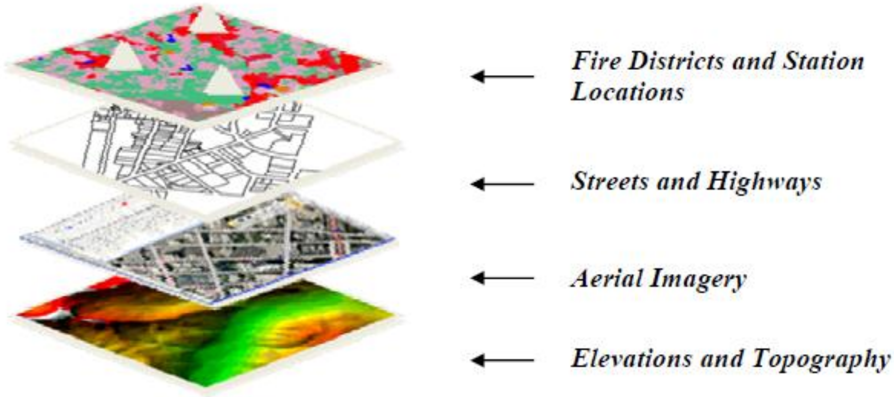

Figure 2: GSA data as map layers
[ESRI. (2007)]

2.15.2 Incident Analysis in GIS

GIS can conduct different sequential analysis procedures to show trends, as well as identifying areas associated with high call volume. Some important data are represented as points or icons showing their occurrence rate. GIS is also able to classify these events based on their types, causes, data, and arrival times and responding units (figure 3).

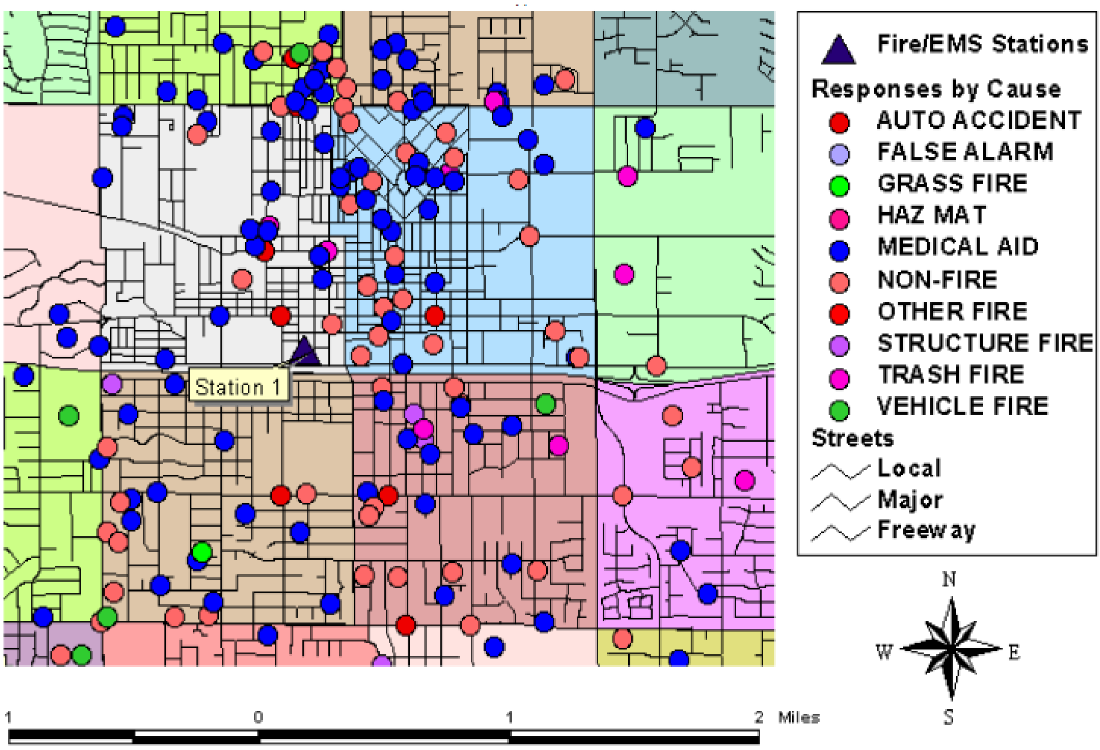

Figure 3: GIS capability to show time, location, cause
[ESRI. (2007)]

2.15.3 Travel Time Monitoring

Response time analysis based on GIS study is done through considering fire station layer and street layer. GIS shows the street layer as a figure including different liners intersecting on the map. Each line represents related information such as type of the road or street, speed of travel and distance to source sites. These important data help the researcher to find out the location of a fire station, define travel time and perform a network analysis in a single station or in other stations to find any delay in coverage. The following figure shows the travel times as well as response time (figure 4).

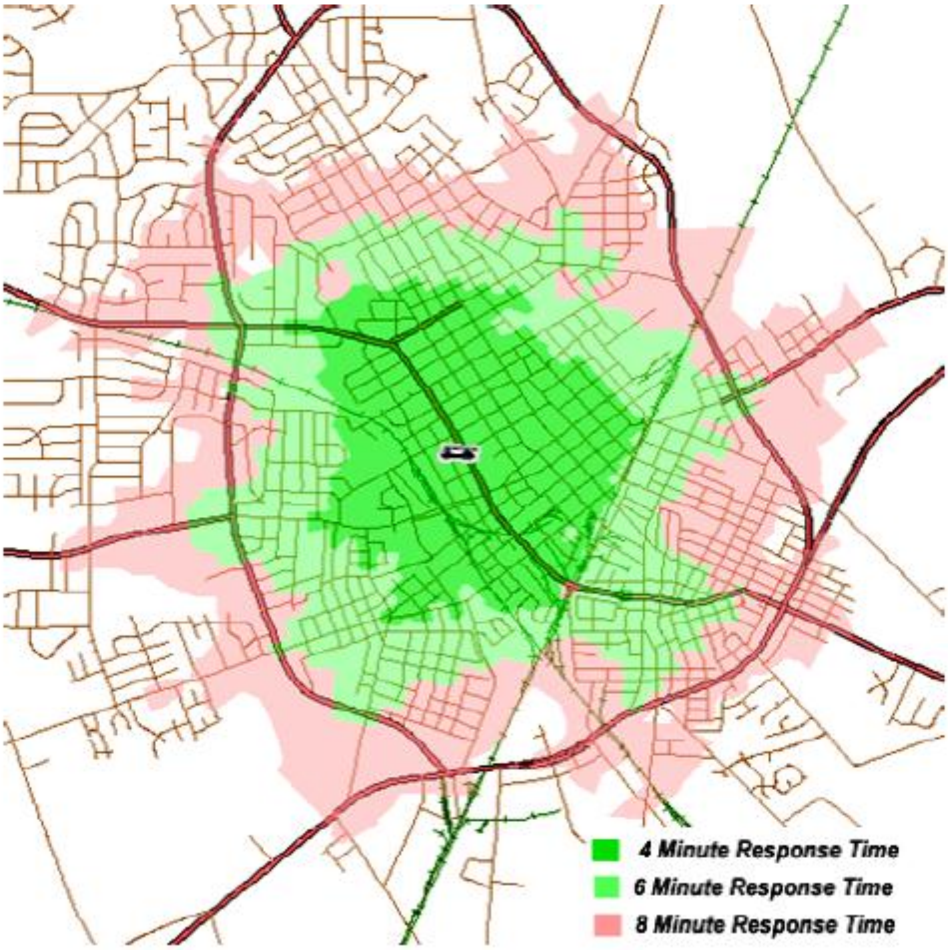

Figure 4: GIS capability in defining the travel time
[ESRI. (2007)]

2.15.4 Importance of Time in Location Study Based on GIS System

The critical responsibility of a firefighting department is to provide efficient rescue service as soon as possible. Since the growth of fire intensity occurs very suddenly, this process requires that the crews of fire station should be ready to act very quickly. There is a direct relationship between the fire loss and the time period. On the other hand, emergency medical services should be delivered on time and rapidly, therefore, survival rates for much resuscitation activation directly depends on the time interaction of experienced medical emergency personnel.

2.15.5 Flashover Time

Flashover is calculated based on time and temperature signifying the fact that fire is doubled in every minute. The following figure shows this mechanism (Figure 5).

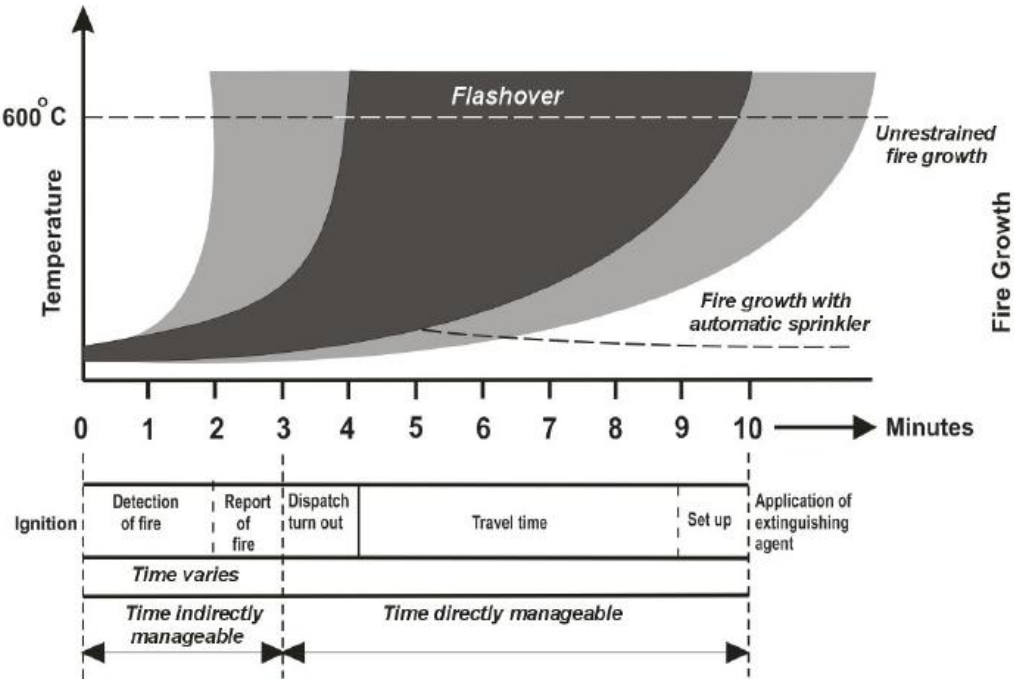

Figure 5: Flashover time and its effect in fire loss

[ESRI. (2007)]

Factors such as fuel type, size of the rooms and materials such as wood, plastic and steel cause indirect effects on flashover. Referring to figure 5, it shows that the time from ignition to report of fire is titled as “indirectly manageable time”. This length of time is managed by using machine detectors, human reporting etc.

2.15.6 Important Factors in Total Reflex Time

There are five steps after reporting fire to fire station:

Dispatch Time

This time period is also composed of the following processes**:**

A) Call receive

B) Emergency definition

C) Location defining

D) Connecting with other related centers for more help.

Turn out Time

The time between the notification of the emergency services and the moment they start responding.

Response Time

Response time is the time between the notification of the emergency services and their arrival at the emergency site.

Access Time

Access Time is the time between leaving the fire station and arriving at the emergency site. This may involve passing through first stories and opening different gates and locks.

Set up Time

The time period for preparing equipment such as rolling out the hose lines and connecting them.

It is important to say that if a victim of a fire accident has an heart attack, needing cardiopulmonary resuscitation, he / she has may benefit from this CPR if undertaken in period lower than four minutes. The following figures (Figs. 6 and 7) show significant improvement begins in 4 minutes or less.

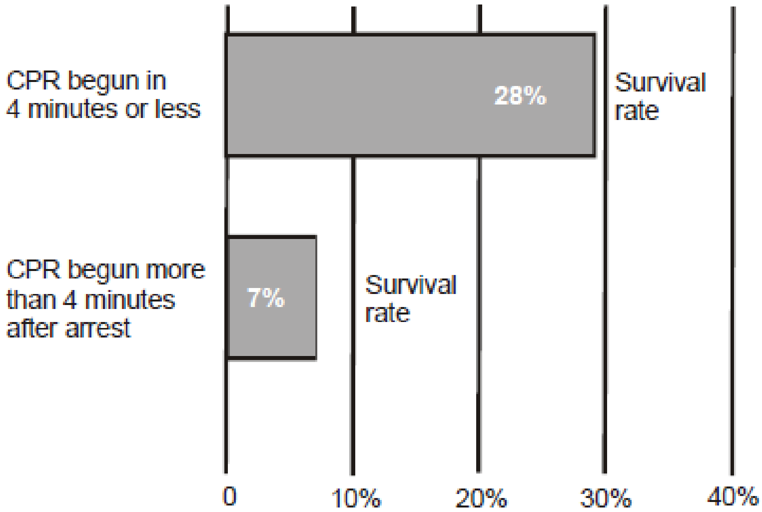

Figure 6: Survival of the victim when CPR (cardio pulmonary resuscitation) is performed in a fire event
[ESRI. (2007)]

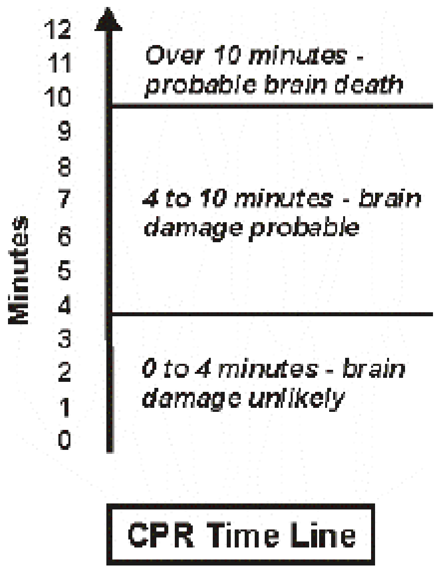

Figure 7: Outcome of on time CPR
[ESRI. (2007)]

These results show the importance of response time. In this reason, by measuring the response time, researchers are able to pay attention to different factors effective in this indicator.

2.15.7 Steps in Location Study for Fire Station

The main step for locating the fire station is done through considering the response time and the related standards.

After defining the standard of the response time in the related location study, the analyzer divides it into definite time travels for each of its subclasses such as reflex time, dispatch time, turnout, access and set up times. The dispatch time and also the turn out time will be calculated through referring to historical information. On the other hand, the set up time will be evaluated based on the nature and complexity of the fire event. Finally, the response time minus the total times of different components mentioned above will lead to calculation of the travel time. After selecting the needed travel time the process of locating the fire stations will be implemented. In the following figures, a four minute travel time is assigned for location study.

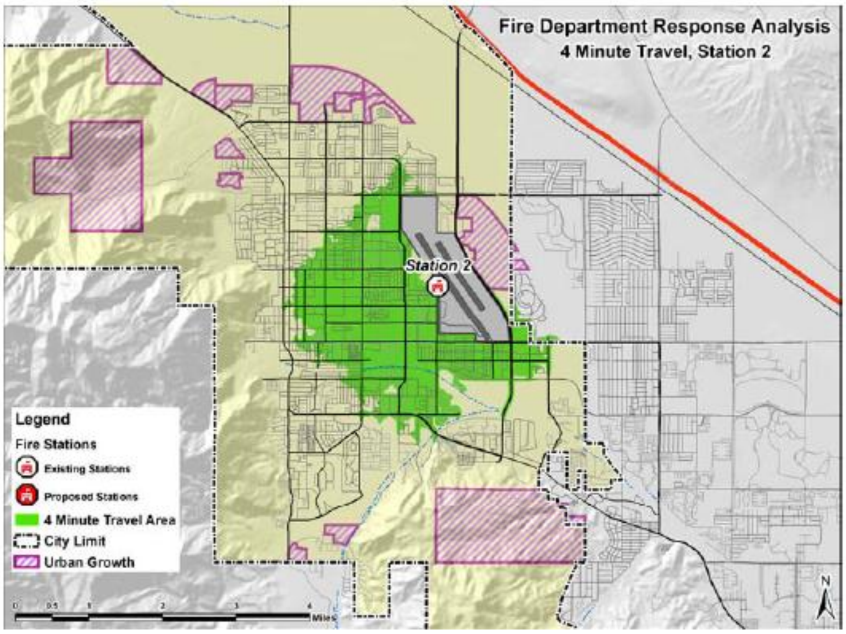

Figure 8: Response time analysis of fire department based on travel time
[ESRI. (2007)]

Chapter 3

METHODOLOGY

This study is conducted to implement a MSAP test through developing new algorithm for calculation process for defining an optimal locating system for fire stations in Famagusta. In other word, this unique study is based on new innovative procedure that utilizes Python networkX module for defining the best locations for different assumed situations. First of all, geographic information about the city is presented.

3.1 Geographic Location and Districts of Famagusta

Famagusta (Gazimagusa) is defined as the second largest city of Northern Cyprus. This city is currently sited on the eastern coast of the Cyprus, mainly in east of Nicosia. Its total population is about 69273 people based on the data derived from census of 2011[Census 2011].

In a more detailed view, it should be stated that before 1974, the population of the Famagusta was about 39,000 of which 26,500 were of Greek people, and also about 8,500 Turkish people as well as 4,000 people from other ethnic groups were also living in this city. According to some other data sources, the population of this city was about 39,000. The geographic location of the city on the island is presented in figure 9.

Figure 9: The location of Famagusta on Cyprus Map

Real aerial photograph of the city is shown in Figure 11:

Figure 10: Aerial photograph of the city

The foundation and establishment of Famagusta is related to the first century AD and during the long historical life period, this city has been developed during seven periods.

Famagusta is one of the most attractive cites for tourists because of its long historical perspectives and this unique condition has led the cultural center to list the as one of the 100 Most Endangered Sites in the world on the World Monuments Fund's 2008 Watch List.

According to some urban planning researchers, this city has been changed under the progressive influence of the Eastern Mediterranean University (EMU) that has more than 14,000 students from 67 different countries (Oktay and Rustemli, 2010). During the recent two decades, because of the rapid increase of new students entering the university, properties demand for housing has also increased to a significant level and urban transportation system has also been progressively complicated to a noticeable level in comparison to other cities of the island. According to Pasaogullari and Doratli (2004), development of multi-story housing facilities shaped as residential buildings or villas, as well as that of commercial sectors with little reference to coordinated master plan led to progressive cautious need for accessibility of more security facilities such as police and fire stations (Pasaogullari and Doratli, 2004).

3.2 Steps of the Methodology

In this study, the best location of the new fire station defined for covering the whole city in the shortest time period. This process was mainly conducted through using GPS and also through developing new software’s in the following steps:

1) Different nodes were selected randomly on the road map of the city and these nodes were defined in GPS system for further evaluations. Totally 1473 nodes were selected in this study.

2) Traveling through the main roads of the city as well as using GPS software, geographic data were gathered by GPS system including the latitude and longitude, traveled distance and travel times for different assigned nodes in the city roads.

3) These gathered data were downloaded from the device and converted to KML files by GPS visualizer and different vector layers have been prepared.

- Travel time monitoring was performed using the following steps:

First step:

In this step, 1473 nodes were marked on the city road map manually, and all of them have been linked and finally a map with layers has been prepared in Quantum GIS.

Second step:

All layers of travel time were adapted on the city map in the software and relationship between all nodes were defined and shown in the related tables.

4) A routing program was developed to find the best route from one node to another one. This program tries to find the shortest path or fastest way.

5) Another program was developed to find the travel time between a node and all other nodes and finally to find the best location for the new fire station that covers all demand nodes in shortest travel time in comparison with other nodes. On the other words, anticipated demand for emergency services at nodes.

6) Finally a comparison was made between the current fire station location and the new defined location.

In figure of 11 the procedures of Python programming are shown. This process started from initializing until the outputs.

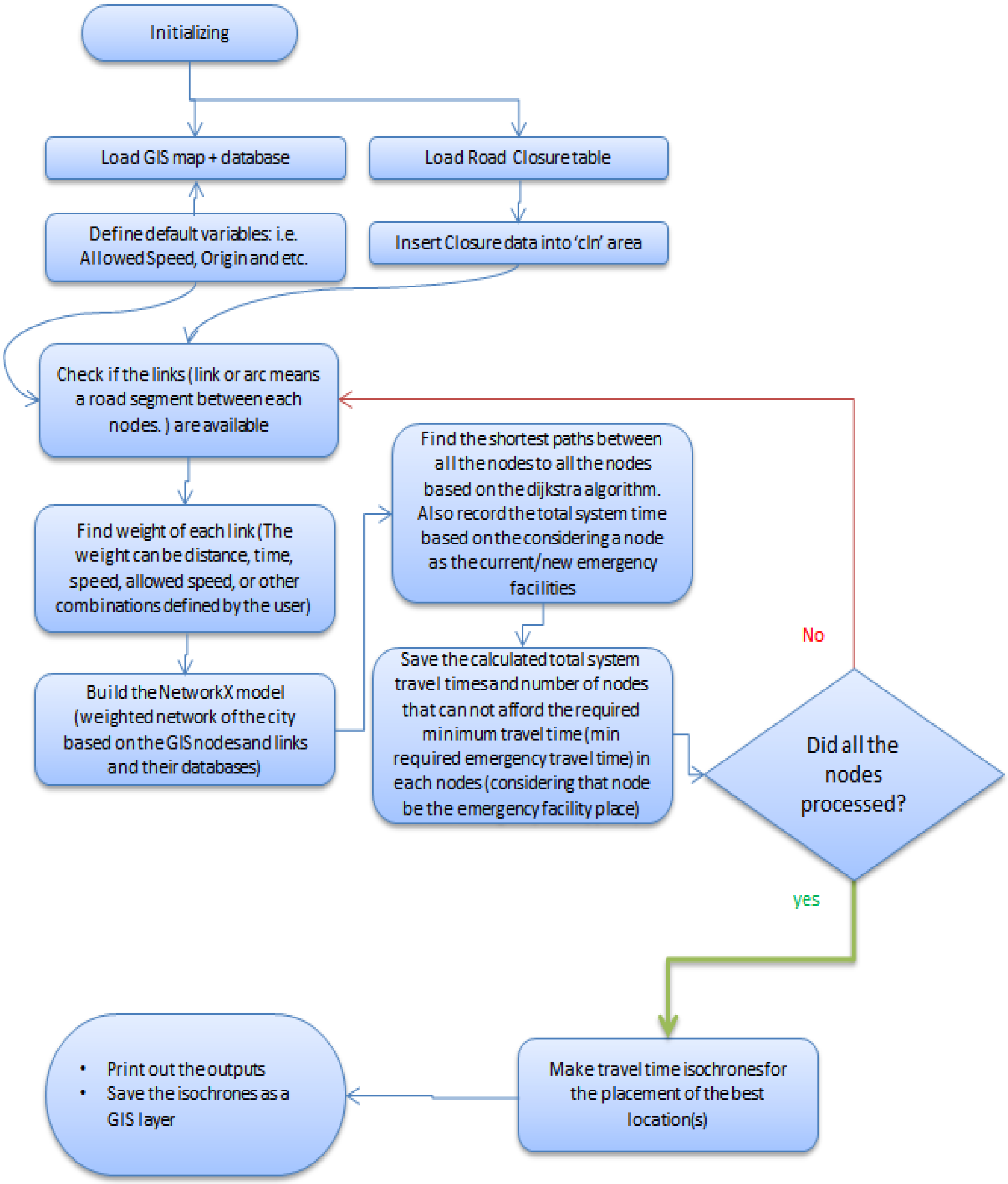

Figure 11: Flowchart for finding the best location

3.3 Variables of the Study

Variables of this study are travel time (in seconds), distance, travel speed and node demand.

The schematic aerial plan of the city is shown in figure 12.

Figure 12: The aerial view of road network of the Famagusta city

In this study, a GPS device was used for gathering the needed data for analysis.

Chapter 4

RESULTS

These gathered data were downloaded from the GPS device and converted to KML files by GPS visualizer and the following layers have been prepared.

In the following figures, geographic data including the latitude and longitude of demand nodes have been plotted in a graph.

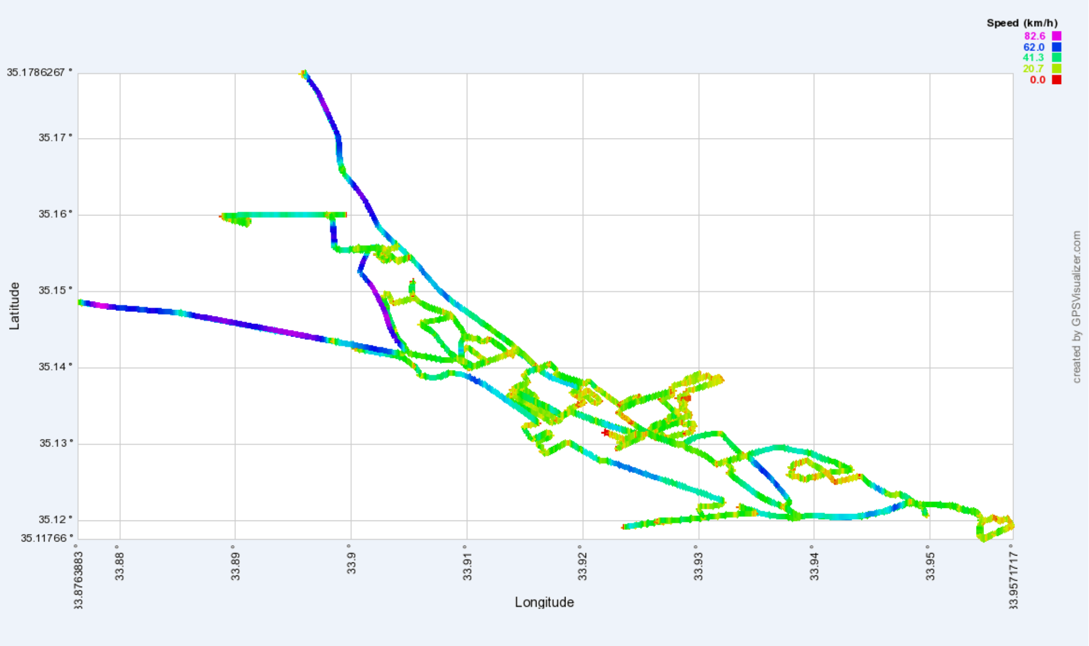

Figure 13: Latitude and longitude of demand nodes for fire facilities in Famagusta

4.1 Travel Time Monitoring

Response time analysis based on GIS study is done through considering fire station layer and street layer. GIS shows the street layer as a figure including different liners intersecting on the map. Each line represents related information such as type of the road or street, speed of traveling objects, and distance to source sites. These important data help the researcher to find out the location of a fire station, define travel time and perform a network analysis in a single or homogenous station and other stations to find any delay in coverage etc. The following figures show the travel times as well as response time. For Travel time monitoring, the following steps are implemented.

4.1.1 First Step: Defining Nodes

In this step, 1473 nodes have been assumed on the city road map manually, and all of them have been linked. Finally the following map layers have been prepared in Quantum GIS software.

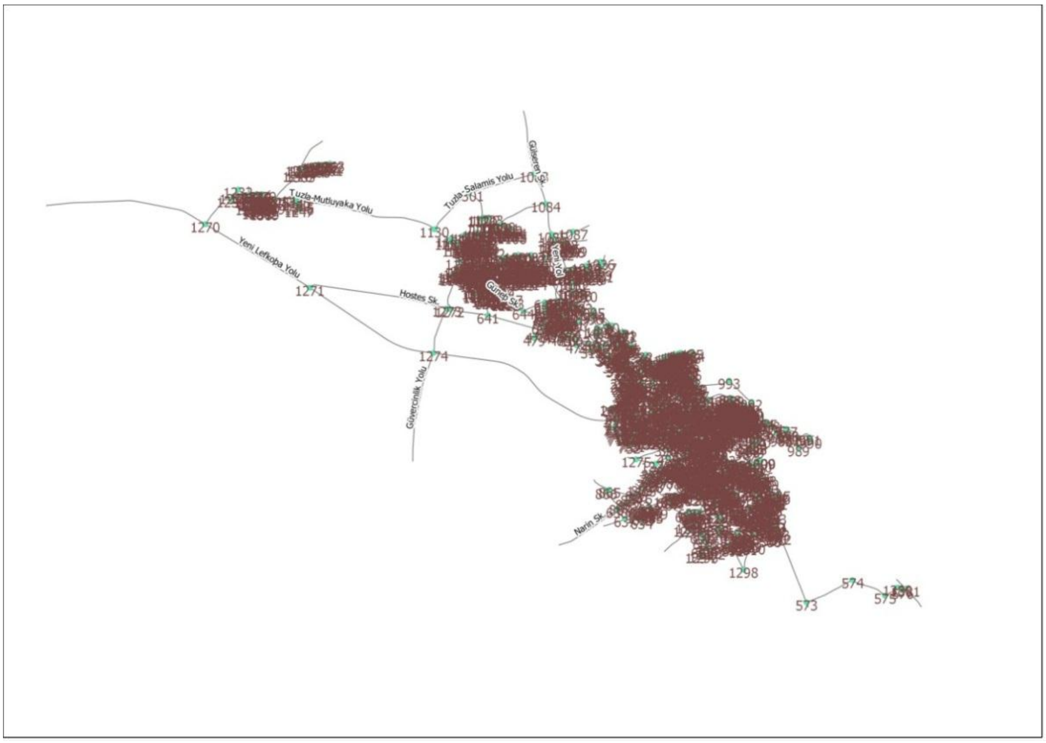

Figure 14: Map layer in Quantum GIS

In the following map, a detailed view of layers designed.

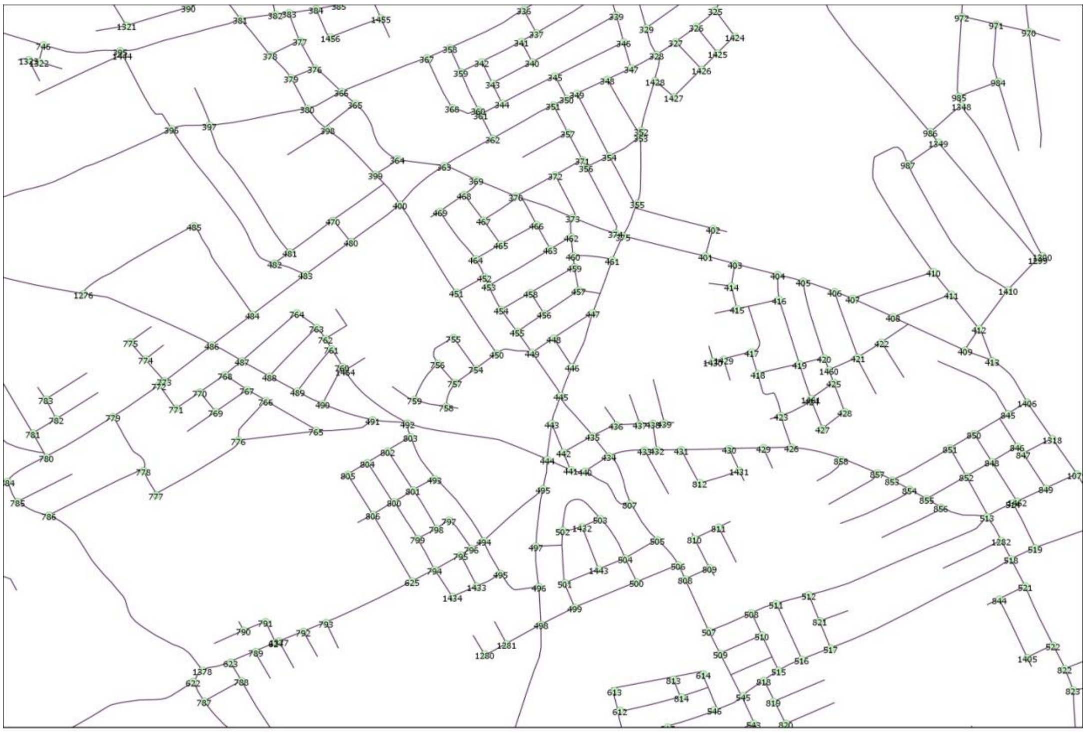

Figure 15: Zoomed – in view of the sheet network with the scale: 1:5544

4.1.2 Second Step: Overlay the Data

All layers of travel time have been overlapped on the city map in Quantum GIS and figure 16 is shown.

Figure 16: Travel times between nodes

Referring to the geometric data of each node, the distance between each node has been calculated through the following equation

$$(L_{12}) = ((X_2\text{-}X_1)^2 + (Y_2\text{-}Y_1)^2)^{1/2} \tag{5}$$

The table 1 shows the relationship between nodes (x and y dimensions). In the first row node 5 is linked to nodes 1, 3, 6 and 16. Also there are X coordinate and Y coordinate related to each node, so, by using the equation the length between each node is obtained. For instance, the length between node 5 and nodes 1, 3, 6 and 16 is calculated in terms of meter and the result is obtained 85.16, 92.09, 215.86 and 259.41 meters, respectively.

Table 1: Relationship between nodes (x and y dimensions)

1	nodes	Link1	Link2	Link3	Link4	Link5	XCOORD	YCOORD	From	To1	L1	To2	L2	To3	L3	To4	L4
2	5	1	3	6	16	0	583135.5	3891102	5	1	85.16	3	92.09	6	215.86	16	259.41
3	6	7	5	301	0	0	582960	3890976	6	7	51.87	5	215.86	301	253.42	0	#N/A
4	7	6	303	1401	0	0	582917.8	3890946	7	6	51.87	303	147.76	1401	133.26	0	#N/A
5	1	9	12	5	0	0	583207	3891148	1	9	42.66	12	206.88	5	85.16	0	#N/A
6	2	9	3	995	0	0	583154.4	3891216	2	9	44.45	3	56.57	995	481.66	0	#N/A
7	3	2	5	995	1402	0	583105.2	3891189	3	2	56.57	5	92.09	995	476.54	1402	135.26
8	9	1	2	10	0	0	583185.9	3891185	9	1	42.66	2	44.45	10	60.22	0	#N/A
9	10	9	11	0	0	0	583234.1	3891221	10	9	60.22	11	256.77	0	#N/A	0	#N/A
10	1402	3	8	1401	0	0	582989.2	3891119	1402	3	135.26	8	70.19	1401	77.74	0	#N/A
11	1401	7	8	1402	0	0	582922.5	3891079	1401	7	133.26	8	77.76	1402	77.74	0	#N/A
12	8	4	6	0	0	0	582929.8	3891157	8	4	2924.87	6	182.93	0	#N/A	0	#N/A
13	11	10	12	13	0	0	583388.2	3891016	11	10	256.77	12	68.42	13	58.28	0	#N/A
14	12	1	11	14	0	0	583329.3	3890981	12	1	206.88	11	68.42	14	46.34	0	#N/A
15	13	11	471	473	0	0	583437.4	3891047	13	11	58.28	471	58.29	473	72.74	0	#N/A
16	14	12	15	0	0	0	583348.3	3890939	14	12	46.34	15	63.84	0	#N/A	0	#N/A
17	15	14	16	17	0	0	583298.6	3890899	15	14	63.84	16	18.08	17	169.59	0	#N/A
18	16	15	5	0	0	0	583283.6	3890889	16	15	18.08	5	259.41	0	#N/A	0	#N/A

nodesxy20062011

4.1.3 Third Step: Defining Exact Travel Time

Using GPS hardware, data related to travel time like seconds, speed of vehicle and locations gathered by traveling in the city, were applied to the node layer of GPS data. For every second, GPS device recorded the distance of travel time between nodes. Then, after applying all time periods for each pair of adjacent nodes in the general road map of the city, an exact detailed result was presented showing the exact travel time between them. The following figures show the whole numbers of the assigned nodes and travel time between them in seconds.

Finally, figure 18 has been reanalyzed by GPS and this figure has been provided based on two variables of nodes locations (in red) and travel time (in green numbers).

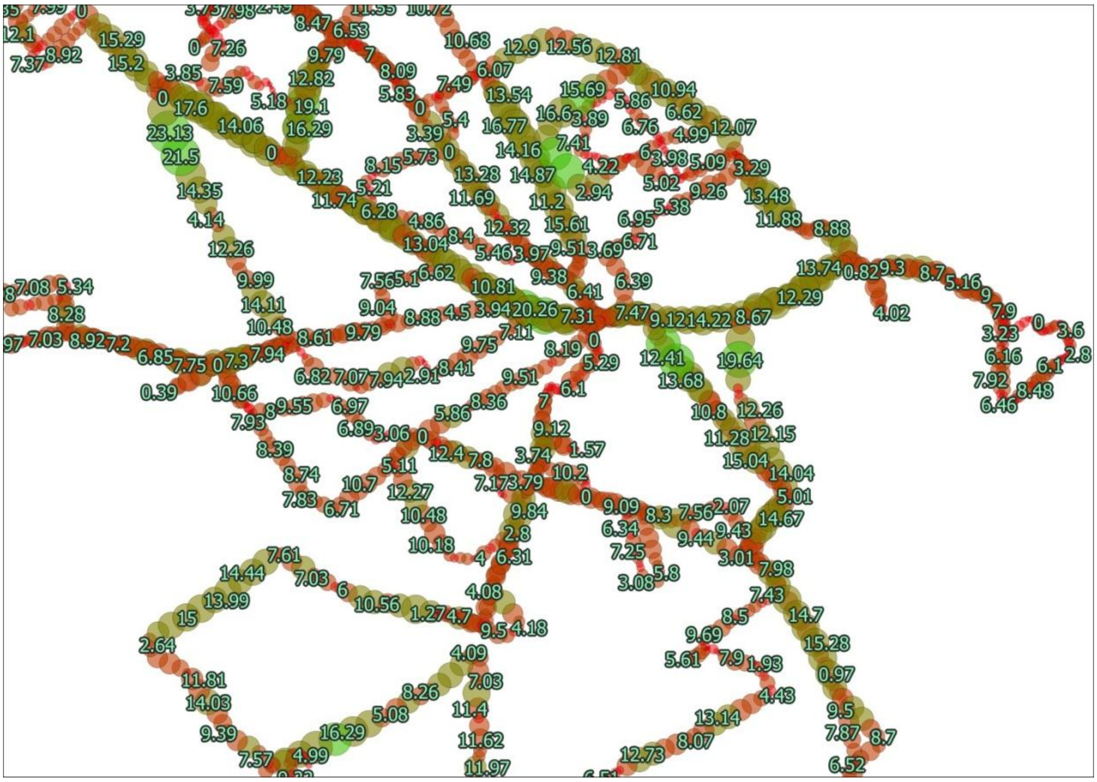

Figure 17: Assigned nodes and travel time between them (scale: 1: 44361)

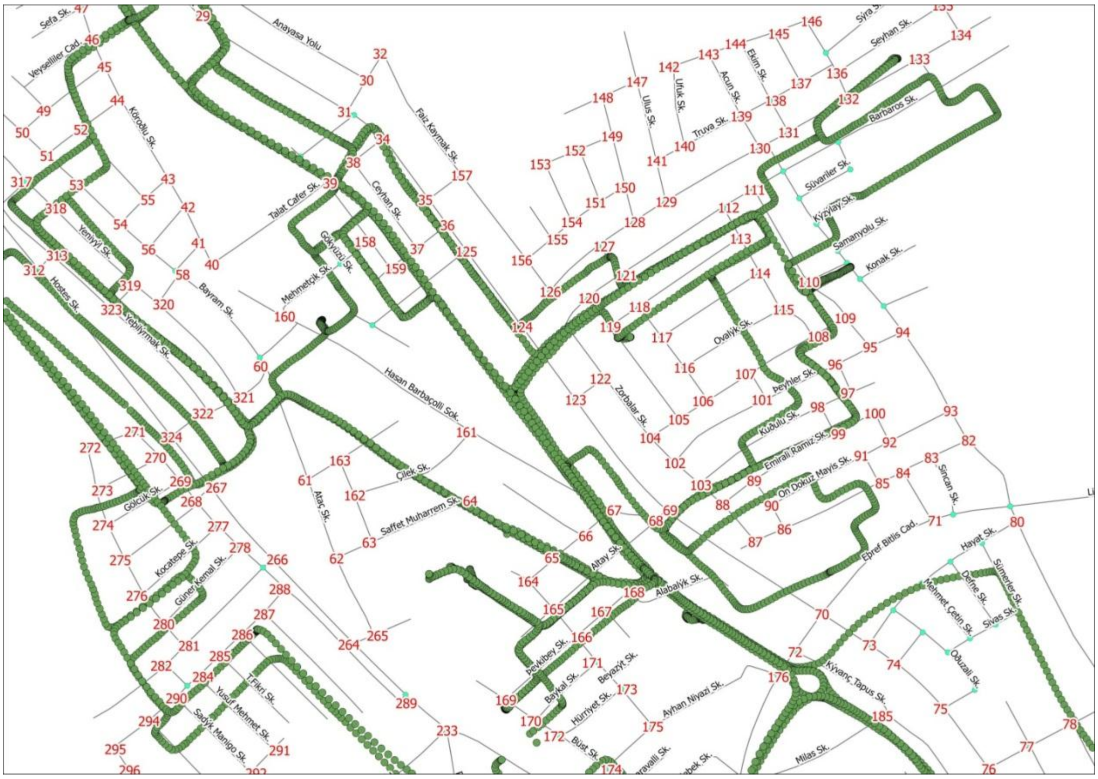

Figure 18: Re-analyzed data by GPS: node locations and seconds between them (nodes with red color) and seconds (in green numbers) with the scale: 1:11091

4.1.4 Fourth Step: Calculating the Speed of Travel

$S = D / T$ Speed is equal to distance over time. (6)

4.2 Routing Method for Shortest Path

Routing method in this study has been done through writing with Python program.

For travelling from one node to another which way is the fastest way? In other words, which path is the shortest path?.

The output of this program shows the best route from one node to another. Applying the referred node number, the best route between two nodes will be provided by considering the least travel time (highest probable speed) as in figure 20, the best route is shown in green color. For instance travel time from node 1 to node 305 is calculated as 81 seconds. But the travel time between these nodes from another path took more than 95 seconds.

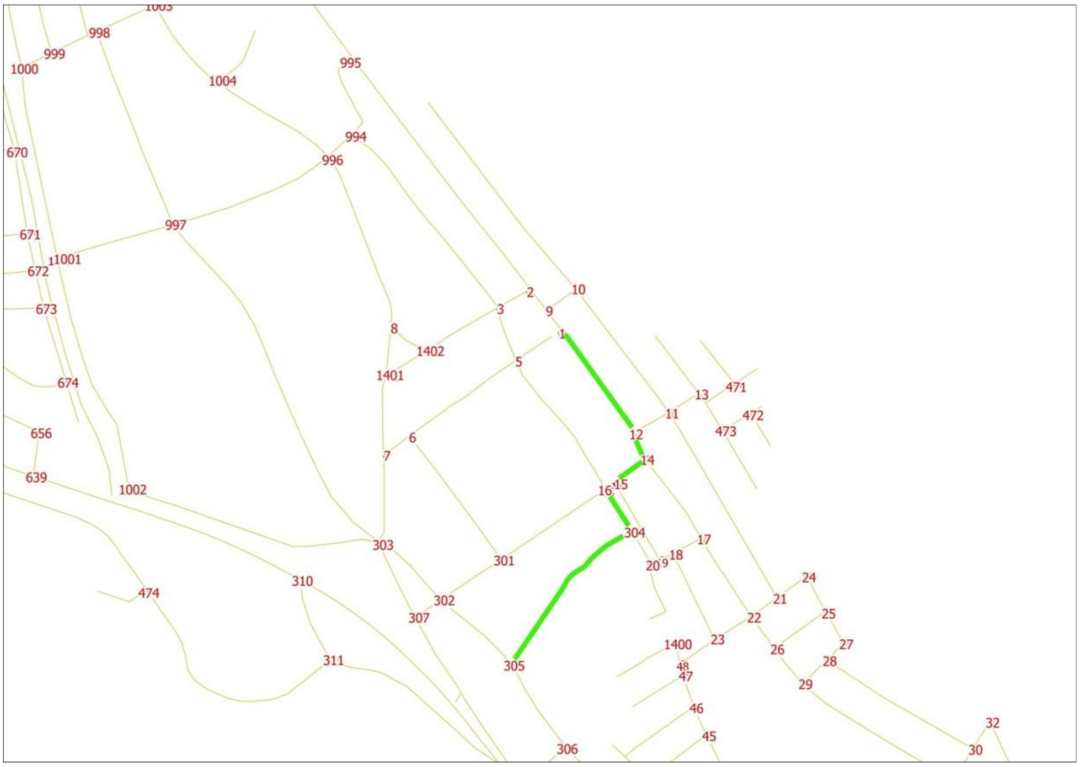

Figure 19: The best route defined by the routing software (scale: 1:2773)

4.3 Attribute Table of Famagusta Roads

Table below shows part of the road sections included in urban territory of Famagusta as well as the name of the roads, speed limit for each street and length of street.

Table 2: The name, speed limit and length of road sections in Famagusta

Attribute table - Famagusta_Roads :: 0 / 1018 feature(s) selected

	ID	ROAD_CLASS	NAME	SPEED_LIMI	LENGTH
424	0	Street	S.Simavi Sk.	40	62.42715
425	0	Street	Adem Yavuz Sk.	40	112.93011
426	0	Street	Vatan Sk.	40	144.09771
427	0	Street	Ankara Sk.	40	86.41648
428	0	Street	Vali Sk.	40	96.53985
429	0	Street	Donanma Sk.	40	87.75191
430	0	Street	Cafer Paþa Sk.	40	223.48003
431	0	Street	Muzaffer Paþa ...	40	284.95025
432	0	Street	Girne Sk.	40	84.82361
433	0	Street	Yeni izmir Sk.	40	90.734
434	0	Street	Zeybek Sk.	40	62.07018
435	0	Street	Dershane Sk.	40	195.26641
436	0	Street	Kuðulu Sk.	30	69.76125
437	0	Street	Klinikler Sk.	30	328.51544
438	0	Street	Deniz Sk.	40	123.25689
439	0	Street	Hititler Sk.	40	137.67029
440	0	Street	Etiler Sk.	40	131.01265
441	205	Secondary_Road	Serbest Liman Y...	40	372.6281
442	0	Street	Barýþ Sk.	40	372.1374
443	0	Street	Yolcu Sk.	40	278.24974
444	0	Street	Doktorlar Sk.	40	127.04386
445	0	Street	Þevkat Hepþen ...	40	163.36624
446	0	Street	Narlýk Sk.	40	639.49217
447	0	Street	Kurtuluþ Sk.	40	353.56428
448	0	Street	Ýnkilap Sk.	30	142.88249
449	0	Street	Zafer Sk.	40	294.30506
450	0	Street	Kardeþ Sk.	40	59.22735
451	206	Secondary_Road	Savaþ Sk.	40	252.91442
452	0	Street	Ali Ýhsan Kalm...	40	183.34746
453	0	Street	Fuat Yusuf Sk.	40	157.7577
454	0	Street	Nane Sk.	40	103.31257
455	0	Street	Þair Nedim Sk.	40	201.3731
456	0	Street	Karanfil Sk.	40	180.6984
457	0	Street	Açelya Sk.	40	59.20802
458	0	Street	Asena Sk.	40	210.81433
459	0	Street	Yalýn Sk.	40	58.44715
460	0	Street	Gülümser Sk.	40	336.98694
461	0	Street	Gülseren Sk.	60	292.94511

4.4 Contour Map

For defining the contour map, a Python code was written. As a sample, node 400, in the map was applied to the Quantum GIS software which provided layers with different colors that represented the response time contours in minutes if the fire station is located at node 400.

The first region in the map is in blue in which the NOD400 is located.

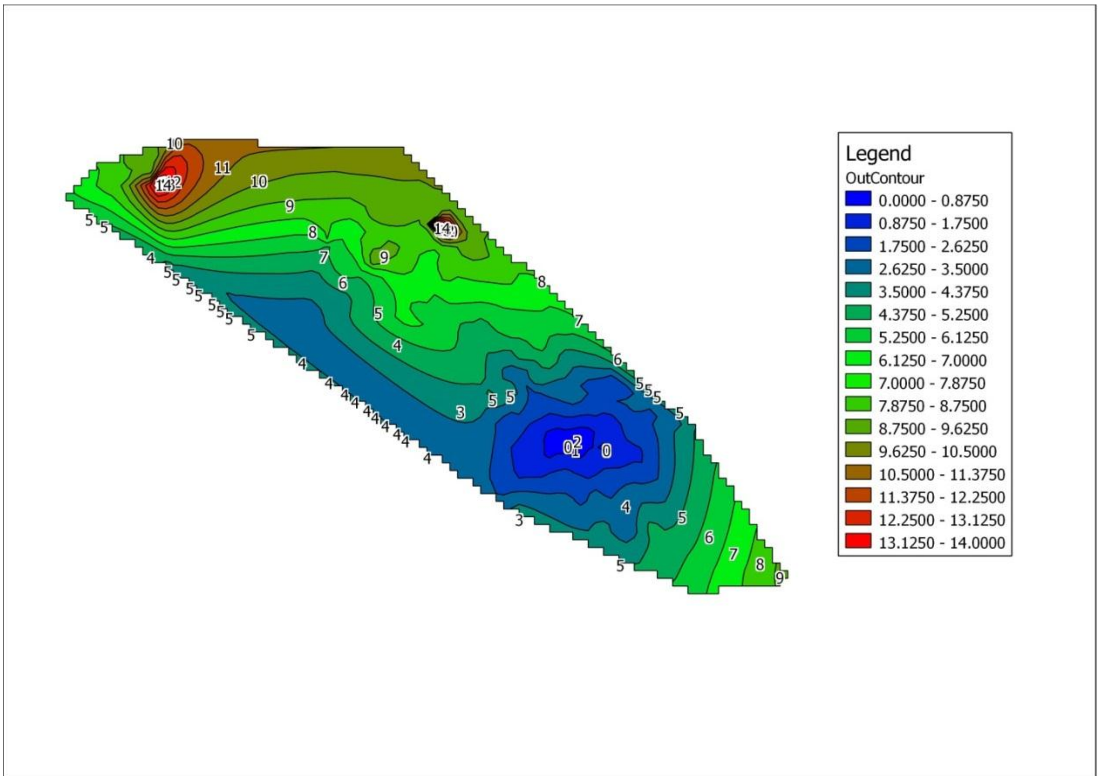

Figure 20: Travel time contour if the fire station is at node 400

It should be stated that, on each node, a numerical figure is shown representing the travel time between that nodes to the NOD 400 (in seconds). The figures 20, 21 show these data. The red colored area is the longest distance area with longest travel time (between 900 and 1000 seconds). Other color limits are classified on right side of the figure.

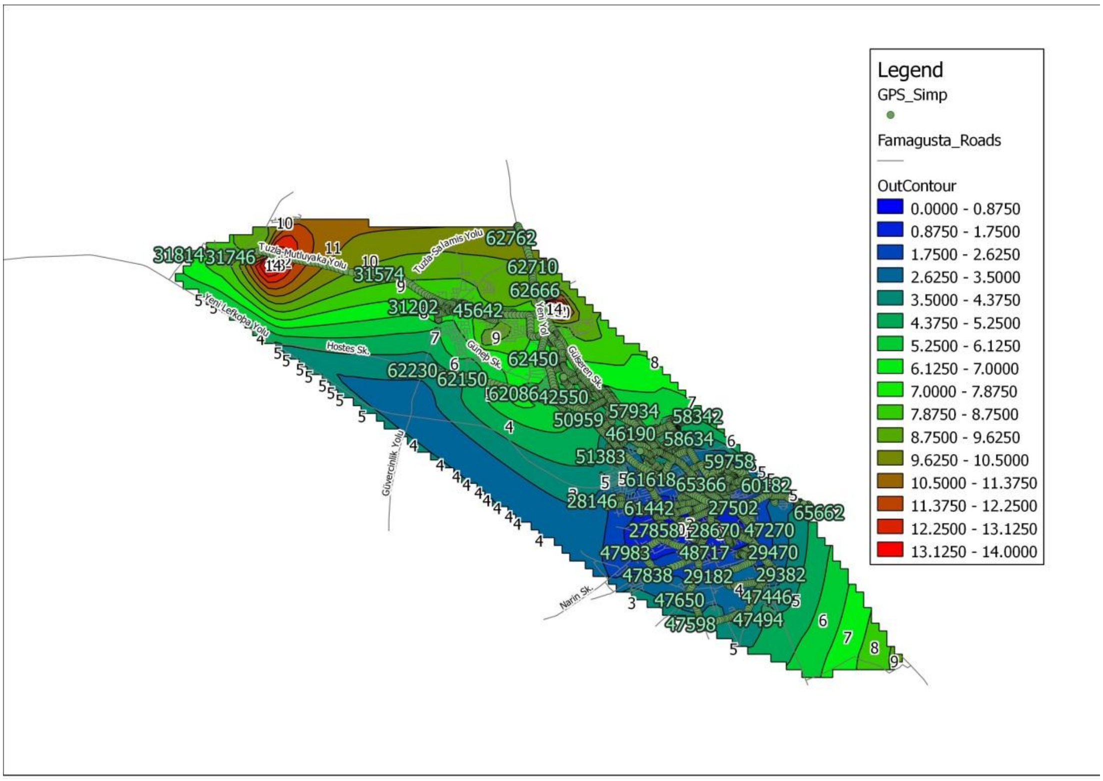

Figure 21: Contour map with detailed numerical data

The following figure provides a close picture toward the zoom. For each node, the time period to the nod 400 is shown.

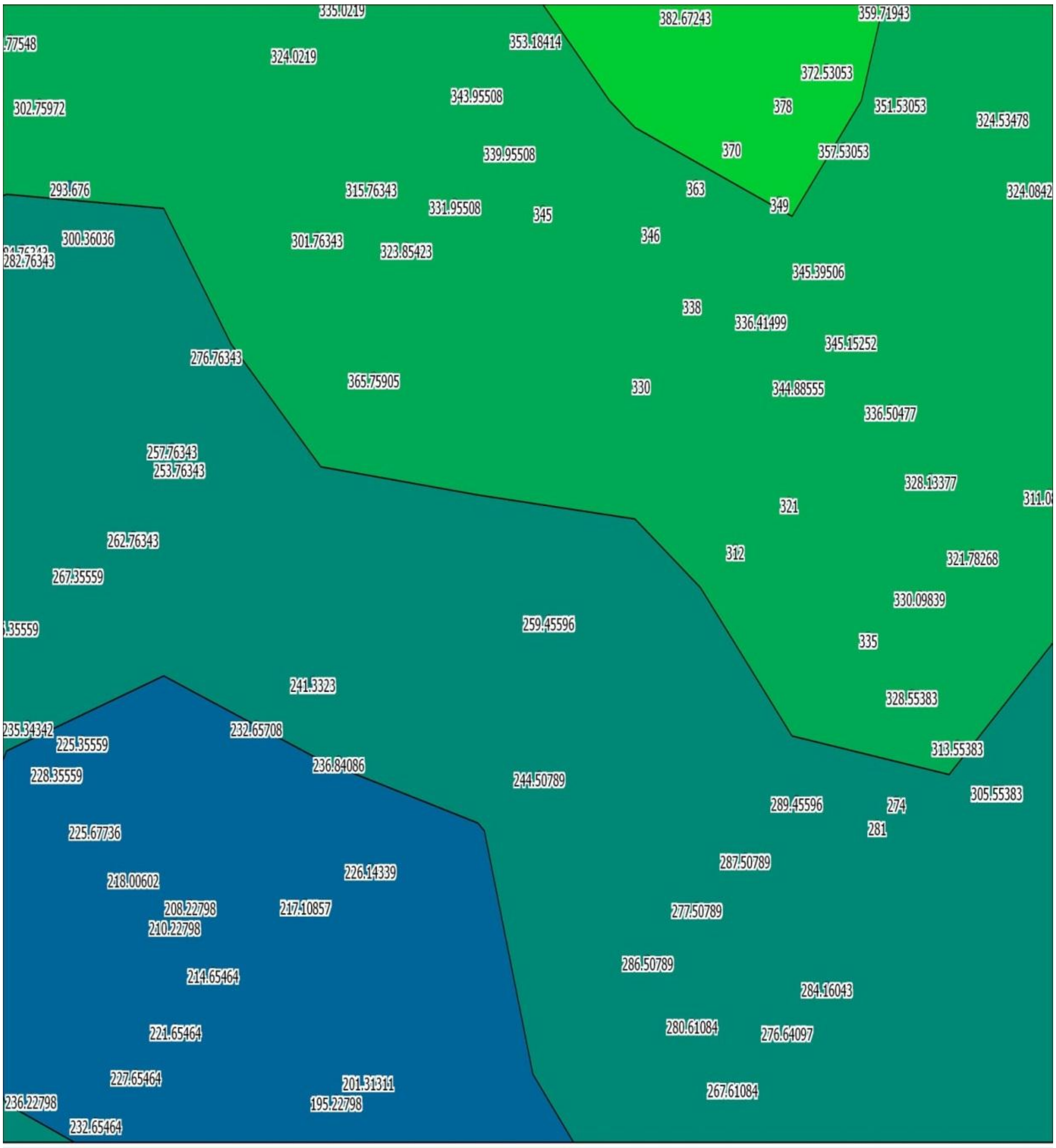

Figure 22: Zoomed of the contour map

4.5 Scenarios used in the Study

Three scenarios assigned in this study including (a) Defining the best location for only one fire station in city, (b) Defining the best location for one fire station when several other fire stations are also located in the city and (c) Defining the best location when two fire stations are active concurrently.

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

In this step, a Python code is written based on which the following process is followed:

One node is selected randomly and the program will calculate the time period to other remaining nodes. This sequential process will be performed for all nodes. Finally, the node with lowest time period (in seconds) and the lowest total number of out ranged will be selected as the best location.

According to the final results, the best location for fire station in Famagusta is the node 230 and after that the node 231 will be selected as the best location. This shows that, establishing a fire station in these nodes will cover the whole city in the fastest time. Only four nodes were out of range in this step.

4.5.1.1 Results from Quantum GIS

Referring to this result, it is shown that the best location is related to the blue color (between 0 and 0.8750) in which the nodes 230 and 231 are located. Different colors are shown in which the range of travel time is defined in the right side of the figure.

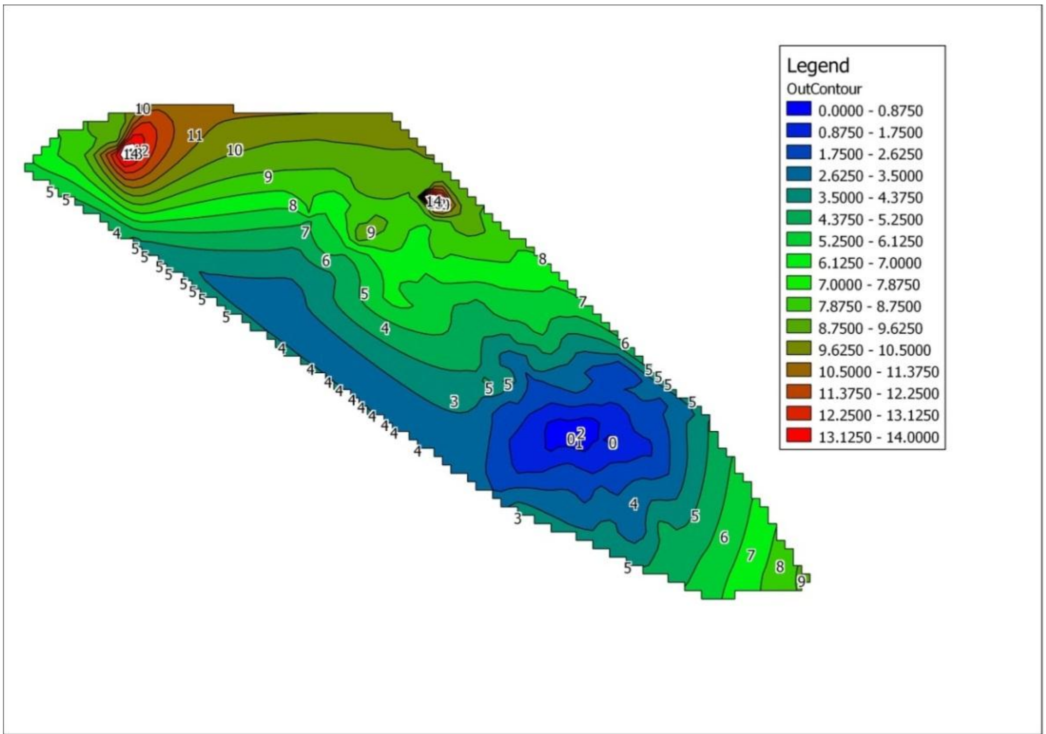

Figure 23: The best location shown with blue color (between 0 and 0.8750)

The table 3 is an attribute table which shows the best nodes travel time (best locations) in seconds. For instance from top of table the best nodes related to 230 and 231 with the lowest time and minimal nodes out of range.

Table 3: Attribute table for best location travel time

Attribute table - out :: 0 / 1473 feature(s) selected

	Node	Sec	NofOutRange
0	230.0	350501.76882	4
1	231.0	350852.79955	4
2	229.0	352782.60418	4
3	226.0	353710.03548	6
4	232.0	354176.74208	4
5	227.0	354209.04523	5
6	223.0	355680.53267	7
7	233.0	356193.44982	5
8	1274.0	356193.44982	5
9	1332.0	358315.48484	4
10	238.0	359269.98628	4
11	1333.0	359680.16984	7
12	242.0	359783.43262	4
13	222.0	360780.58115	10
14	228.0	362815.74343	8
15	234.0	364131.17815	5
16	325.0	364432.5599	13
17	1341.0	365222.44661	4
18	210.0	365848.88419	6
19	326.0	367359.57213	13
20	178.0	367554.95495	4
21	224.0	368307.56396	9
22	235.0	368409.61958	5
23	263.0	369011.48885	5
24	237.0	369616.63292	5
25	289.0	369858.05099	5
26	225.0	369885.55523	8
27	335.0	370255.47012	9
28	327.0	370531.86266	14
29	251.0	370697.58543	5
30	264.0	370938.93803	5
31	966.0	371426.35661	12
32	1342.0	371663.82657	4
33	236.0	372947.75527	5
34	328.0	373106.81232	14
35	241.0	373805.01216	4
36	254.0	374755.57742	4
37	239.0	375125.78576	5

Another node (node 1274) has also been found in the northern part of the city. This node is also the best one for establishing a fire station because of its fast coverage. This node was also defined by the software program.

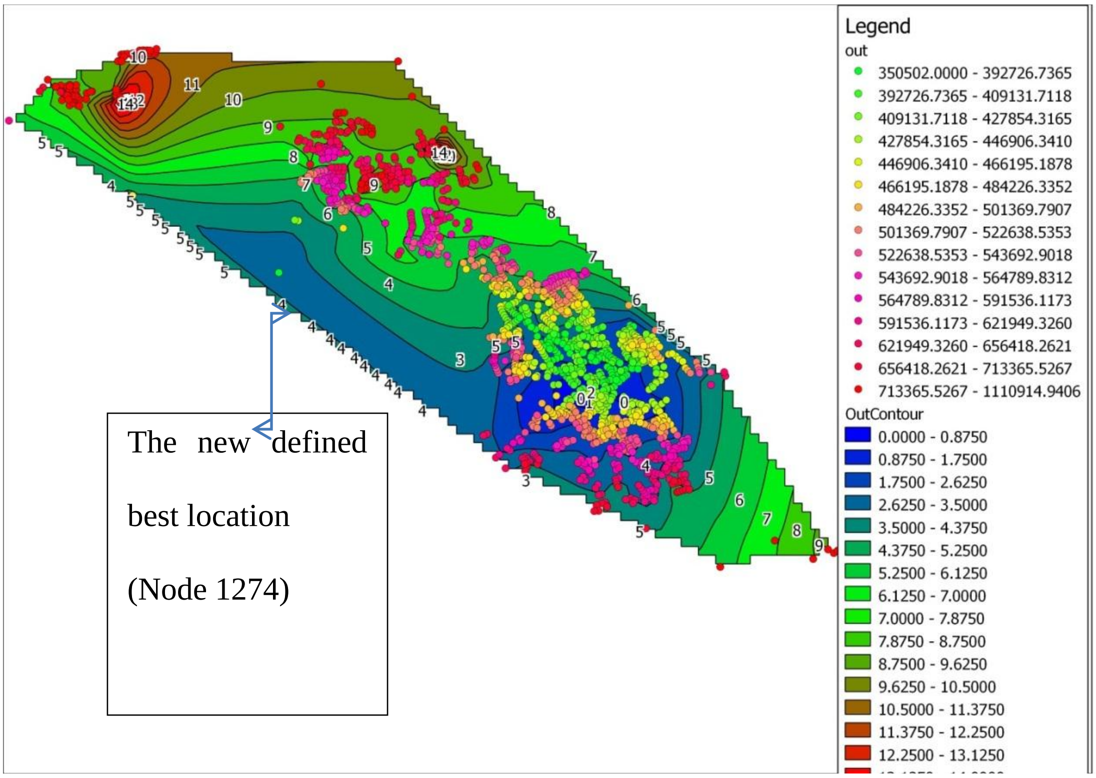

Figure 24: New defined best node (scale: 1:44361)

In figure 25 is shown a closer view of node 1274. This node placed in intersection between Yeni Lefkopa Street and Guvercinlik Street.

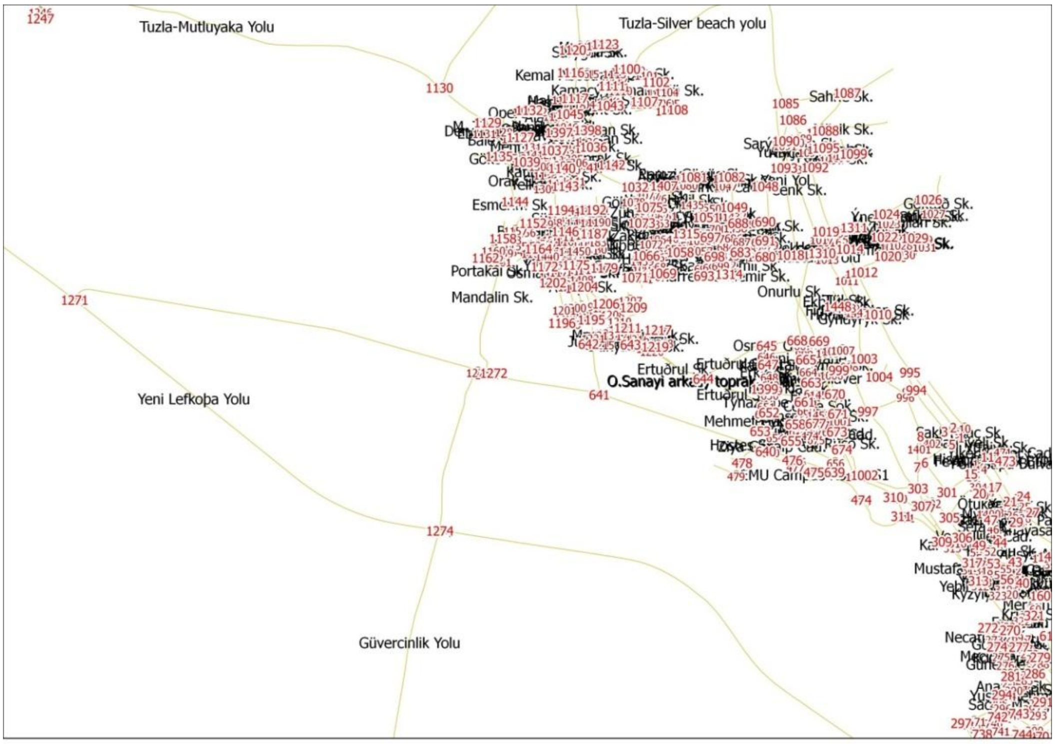

Figure 25: Closer view of node 1274

In the figure 26, these nodes are shown in Famagusta roads. For example in top of the column, the green nodes are the best nodes with the lowest seconds. In other words, the total time from these nodes to all of the nodes is between 350502 and 392726.7365 in seconds. Also the poor nodes related to the bottom of column with the green nodes.

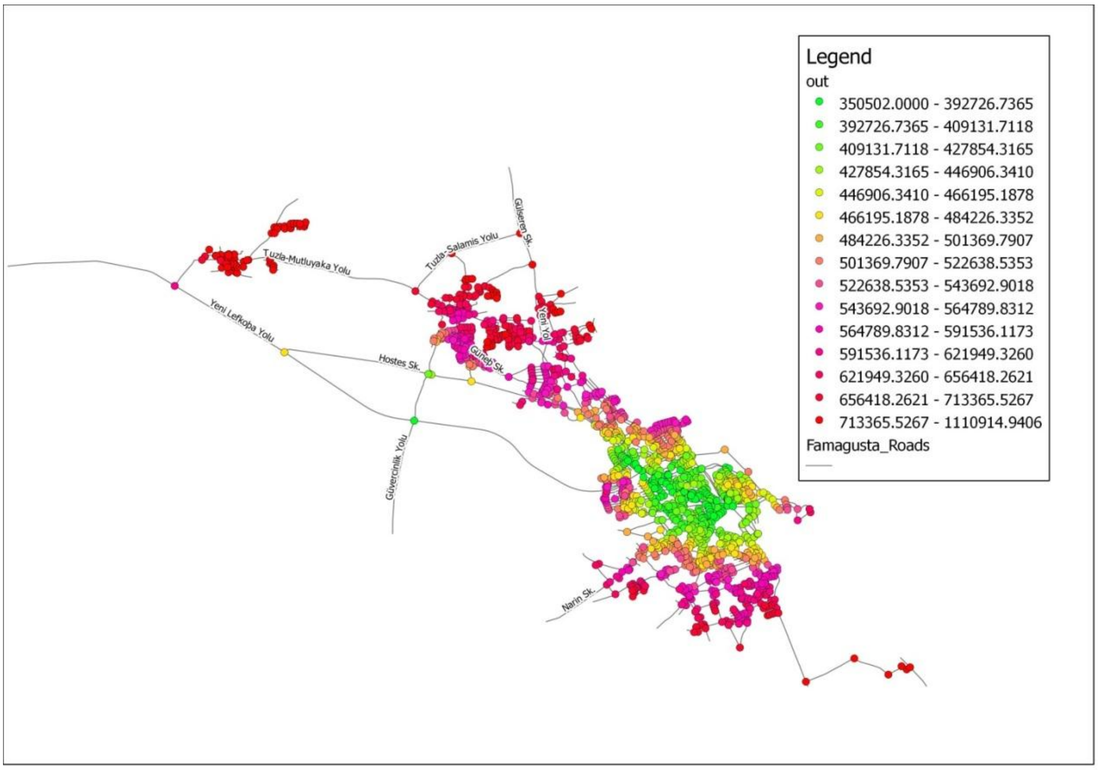

Figure 26: Nodes shown on Famagusta road network (scale: 1:44361)

4.5.1.2 Comparison of the New Defined Best Locations with the Current Site of the Fire Station

Current fire station is located on node 1348 and its difference with new defined best location is presented through the following results:

Table 4 illustrate the total seconds from the best location (node 230) to all of the nodes will take 350501 seconds and only 4 nodes are out of range. But from current fire station (node 1348) to all of the nodes the total seconds are equal 428956.503 (s) and 35 nodes are out of range.

Table 4 : Comparison of current fire station with the new defined station in the best location study

```
From Node 230.0, Total Seconds = 350501.76882 (s), Total Number of out ranged nodes = 4

From Node 1348.0, Total Seconds = 428956.503 (s), Total Number of out ranged nodes = 35
```

Travel time from the best location (node 230) and also from the current fire station location to the Node 1232 was calculated and the difference is shown in table 5 and 6.

Table 5: Calculation process from node 230 to node1232

```
From 230 to 1232

IDLE 2.6.5

>>> ================================ RESTART >>>

 [230, 231, 232, 233, 234, 264, 266, 267, 324, 312, 309, 310, 639, 476, 640,
641, 1272, 1273, 1271, 1270, 1234, 1233, 1232]

347 (s)
```

Table 6: Calculation process from node 1348 to node1232

```
From 1348 to 1232

>>>                 ================================                 RESTART
================================

>>>

 [1348, 985, 972, 968, 967, 966, 222, 223, 227, 226, 229, 230, 231, 232,
233, 234, 264, 266, 267, 324, 312, 309, 310, 639, 476, 640, 641, 1272, 1273,
1271, 1270, 1234, 1233, 1232]

497 (s)
```

Table 7: Calculation process from node 1348 to node1083

```
From 1348 to 1083

IDLE 2.6.5

>>> ================================ RESTART ================================

>>>

 [1348, 985, 972, 968, 967, 966, 222, 223, 227, 226, 229, 230, 231, 232, 233, 234, 264, 266, 267, 324, 312, 309,
310, 674, 673, 672, 671, 670, 669, 678, 1018, 1085, 1084, 1083]

669 (s)
```

Table 8: Calculation process from node 230 to node1083

```
From 230 to 1083
>>> ================================ RESTART ================================
>>>
 [230, 231, 232, 233, 234, 264, 266, 267, 324, 312, 309, 310, 674, 673, 672, 671, 670, 669, 678, 1018, 1085,
1084, 1083]
519 (s)
>>>
```

The table 9 shows the travel time variables from the current fire station (located in the node 1348) to other nodes ranked based on the time (in seconds).

For example it takes 4 seconds from the node 1348 to the node 985. About 100 nodes in this table are more than 10 minutes and the furthest node from current fire station is related to node 1261with the 724 seconds.

Table 9: Travel time variables from the current fire station (located in the node 1348) to other nodes ranked based on the time (in seconds)

	Node	Sec
0	1348.0	0
1	985.0	4
2	986.0	11.31578
3	1349.0	14.31578
4	984.0	15.4778
5	972.0	18
6	987.0	24.93768
7	968.0	27
8	971.0	28.14005
9	1300.0	33
10	969.0	35
11	1299.0	35
12	970.0	37.90001
13	1410.0	43
14	967.0	50
15	410.0	50.39322
16	412.0	51
17	409.0	57
18	411.0	57.39322
19	966.0	58
20	974.0	58
21	413.0	60
22	878.0	64
23	965.0	64
24	973.0	66
25	976.0	68
26	879.0	70
27	408.0	72
28	944.0	72
29	222.0	73
30	1406.0	74
31	943.0	74
32	975.0	74
33	1373.0	76.00352
34	422.0	76.42756
35	325.0	78
36	407.0	78.39322
37	845.0	79

1440	1068.0	603.49835
1441	1104.0	604.46806
1442	1109.0	604.51893
1443	1106.0	604.67007
1444	1099.0	609.37797
1445	1246.0	609.71902
1446	1069.0	611.6233
1447	1105.0	612.78305
1448	1226.0	614.30001
1449	1247.0	617.53554
1450	1070.0	619.08781
1451	1084.0	619.7519
1452	1108.0	620.68488
1453	1383.0	622.94416
1454	1071.0	627.12499
1455	1301.0	627.60858
1456	1249.0	630.66775
1457	1250.0	638.29444
1458	1253.0	645.98157
1459	1251.0	646.52141
1460	1252.0	657.87425
1461	1254.0	662.70192
1462	1083.0	669.7519
1463	1256.0	671.27479
1464	1255.0	675.92264
1465	1257.0	678.96077
1466	1258.0	687.46095
1467	1259.0	696.11642
1468	1382.0	704.12767
1469	1260.0	713.02313
1470	1262.0	715.75857
1471	1263.0	723.16852
1472	1261.0	723.72392

Figure 27 shows the place of current fire station at the intersection between İlker Karter Avenue and İtfaiye Street, represented with an orange circle.

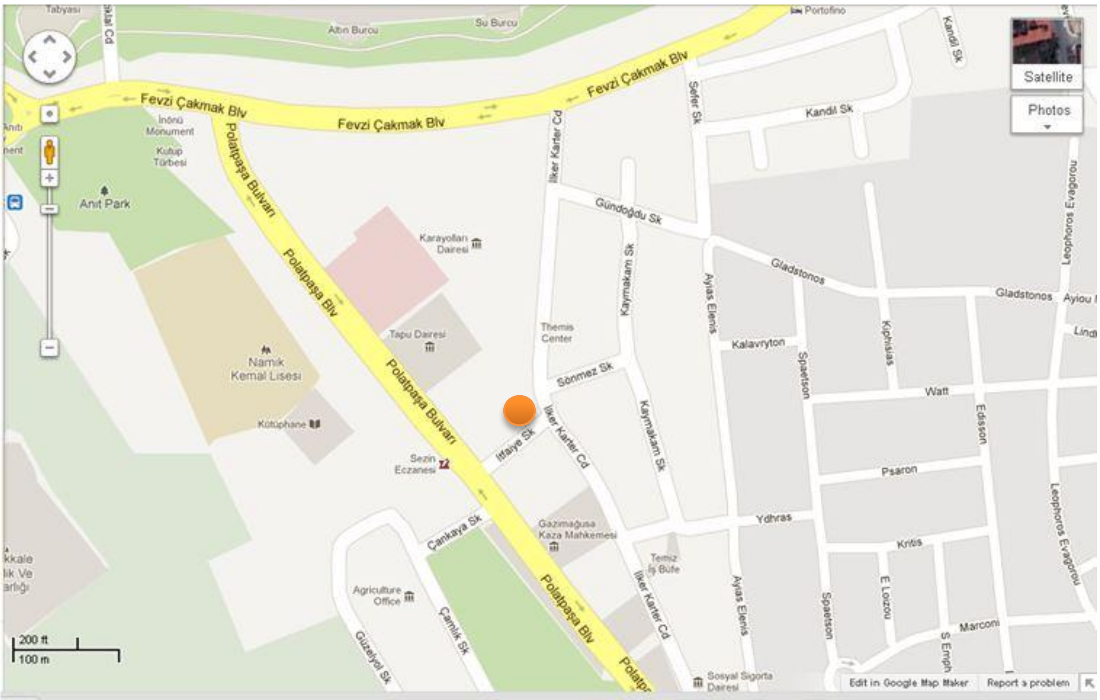

Figure 27: Location of current fire station

4.5.2 Defining the Best Location for one Fire Station when several other Fire Stations are also located in the city

In this second scenario, the Python code was written and tried to find the best location for a new fire station when the current station is also active in the city.

In this process, a fire event is assumed in one geographic site of the city and the coverage of each of the current and the new defined fire station will be calculated using the software developed for this goal. This process will find a total numerical value. The outputs of this program give the best route from one node to another one. Current fire station is in nod 1348 and best nodes are defined as nodes 230 and node 231.

4.5.2.1 Output of QGIS

Output of QGIS is shown in the following figure:

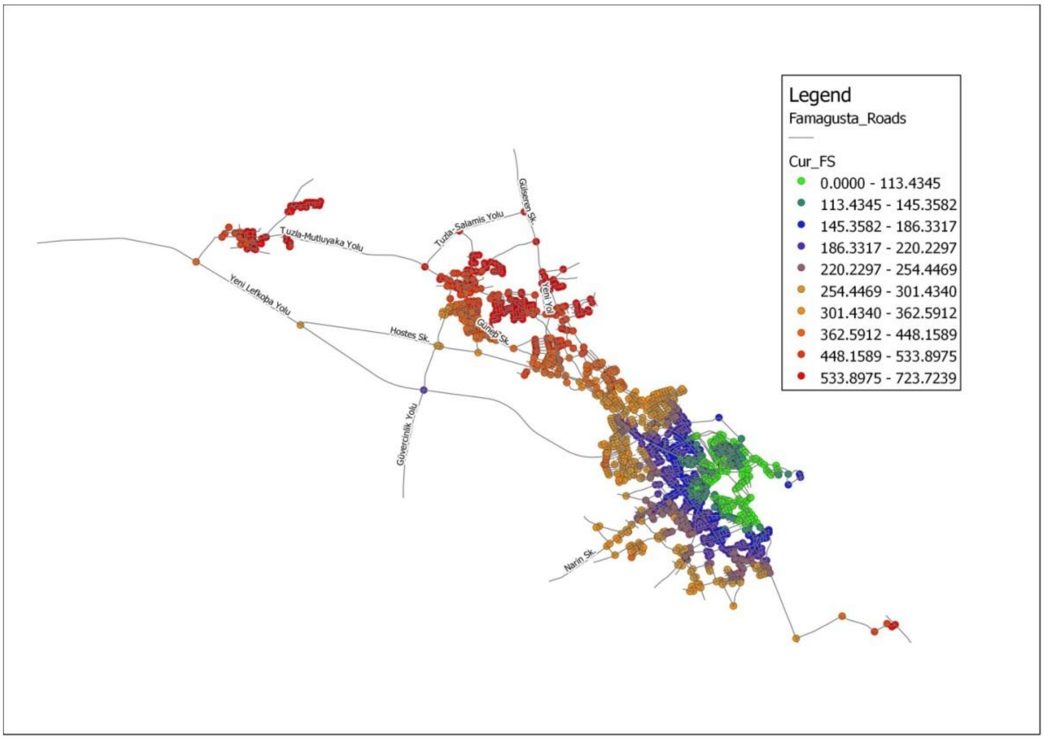

Figure 28: Coverage of the current fire station in road map

In the figure 28, current fire station can cover all nodes in green colored area in a time period between 0 and 114 seconds. Other colors show the other time periods that will be covered by the current fire station (defined in the right side of the figure). The best location for establishing a new fire station, when the current fire station is active, the area shown in green color in the following figure:

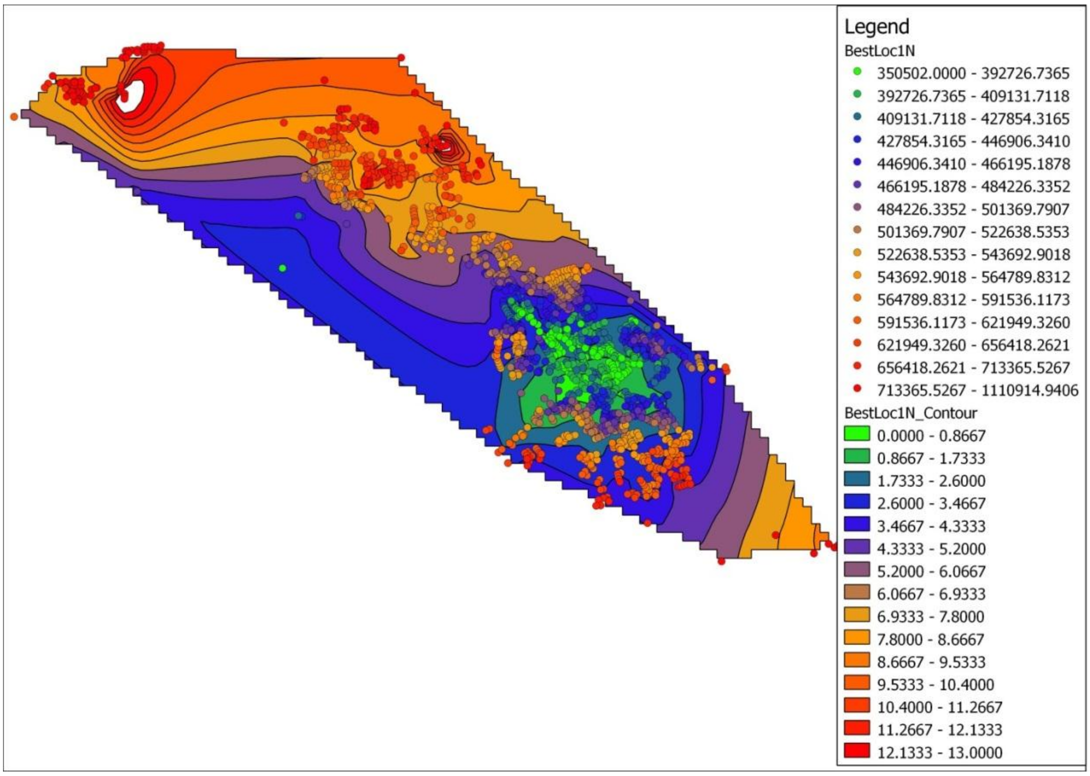

Figure 29: The best location for establishing a new fire station, when the current fire station is active (area shown in green color)

According to Figure 29, the best location for establishing a new fire station, when the current fire station is active, is the area shown in green color. On the other words, the total seconds from green nodes to other nodes is between 35502 and 392726.7365 seconds.

In the following figure the counter map designed in terms of current fire station which can give coverage to the entire of city. Also this figure shows the nodes with the different colors. The best nodes related to green nodes with the shortest time and the red nodes are the poor nodes with highest time.

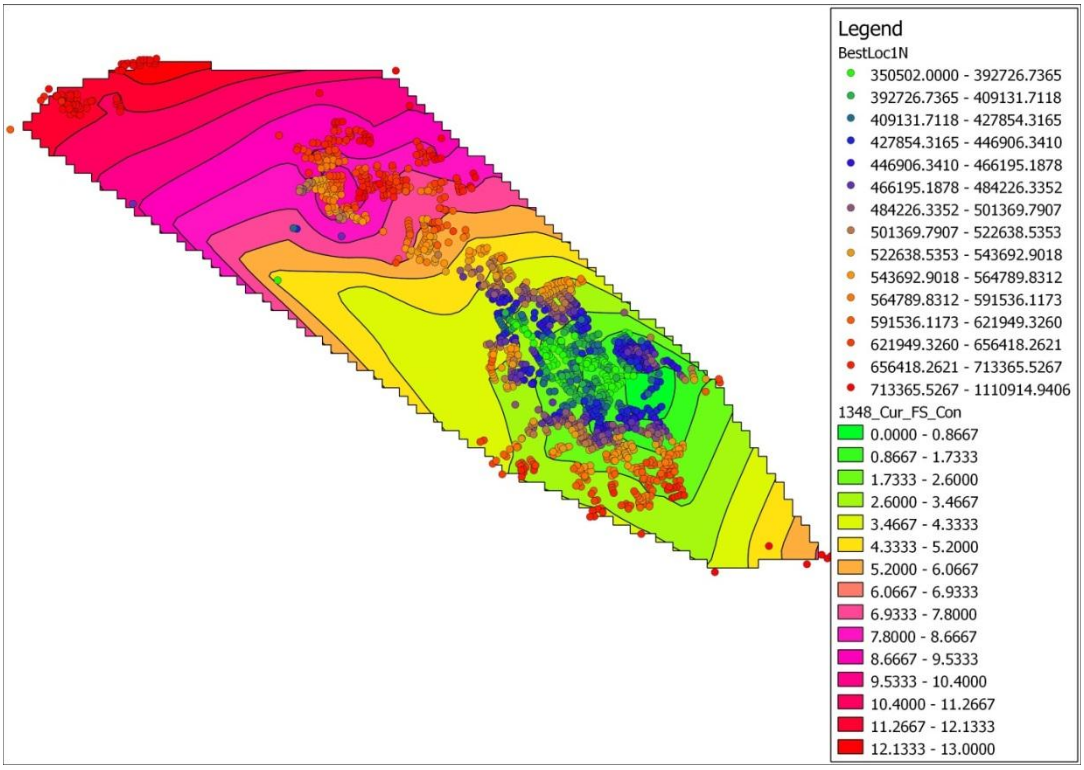

Figure 30: Best location when several other fire stations are also located in the city

4.5.3 Defining the Best Location when two Fire Stations are active

Here new software is developed to select two fire stations at the same time showing the total number of the out ranged nodes. We displaced fire stations randomly, find and sort the best locations. This program is not able to provide the most optimum result since it takes a lot of time to do the calculation for different situations. But the more the calculation time, the more the accuracy level.

This program capable give the closure links and sort them in an excel file. In table 10 illustrated which links are closed.

Table 10: Closed links

A1 f_x 1

	A	B	C	D	E	F
1	1	9				
2	3	5				
3	1242	1239				
4	1	2				
5						
6						
7						
8						

Running the Python program took 20 hours to get the results of the best nodes for the fire stations, which are nodes 1032, 18.

The best places for locating the fire stations are related to green area. One area is in northern part of the city.

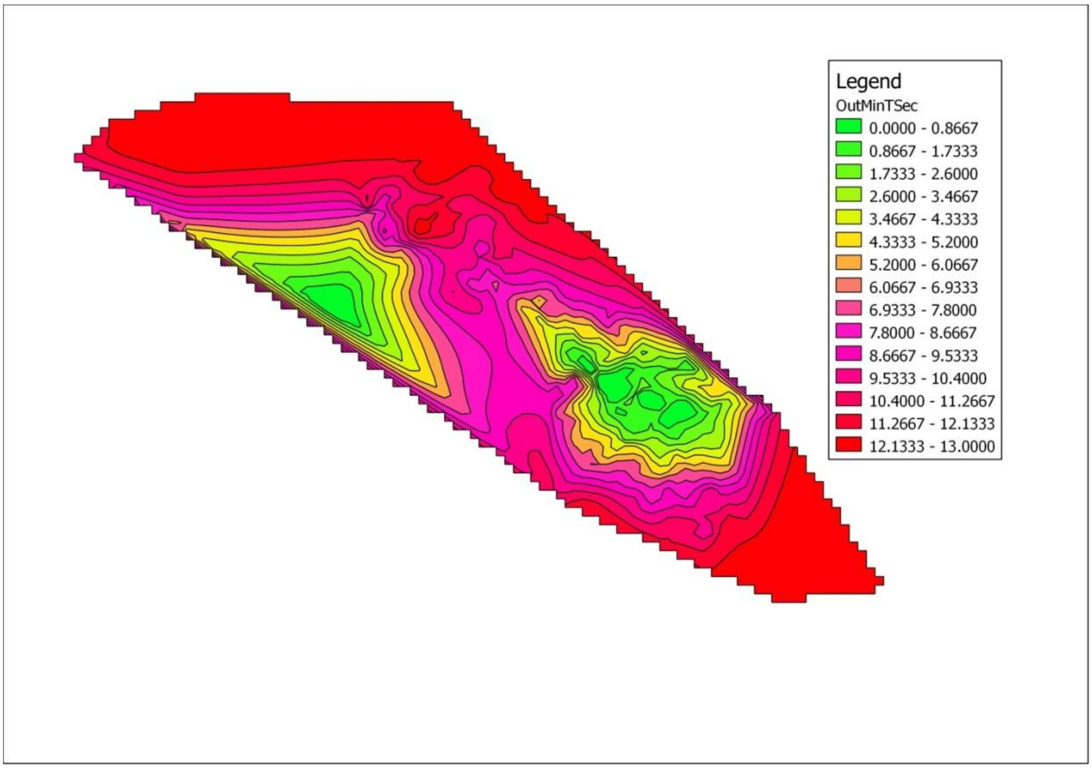

Figure 31: The best site for locating the fire stations

According to figure 31, the best location when two fire stations are active concurrently, are shown in green color.

4.5.3.1 Total Time Period

Total time period in second from nodes that are in green area to other nodes is between 350502 and 392727 seconds.

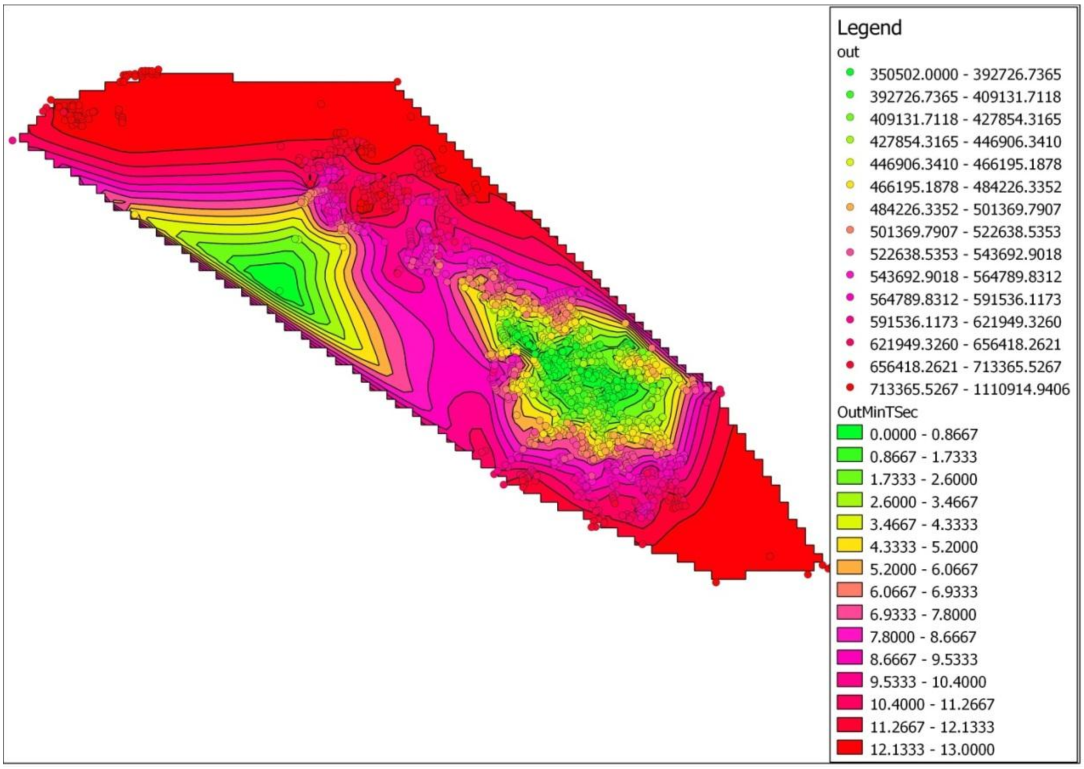

Figure 32: The best site for locating the fire stations when two fire stations are active concurrently

4.5.4 Defining Travel Speed

For defining the travel speed, a weigh based on Allowed Speed software is used that organizes a network of nodes. This software gives a weight to each node defined as travel time or distance between two nodes or a combinition of them.

Then the best locations based on allowed speed is shown in figure 33.

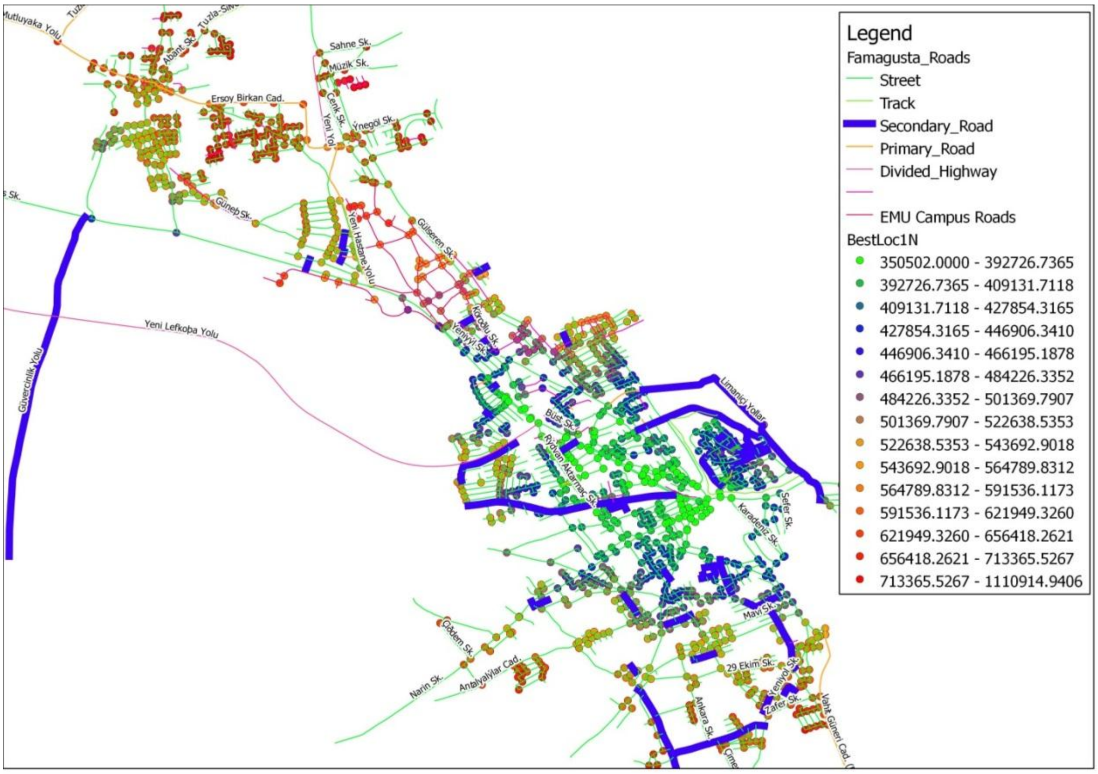

Figure 33: Best locations based on allowed speed

In following figure a closer picture is shown relating to the best locations based on allowed speed:

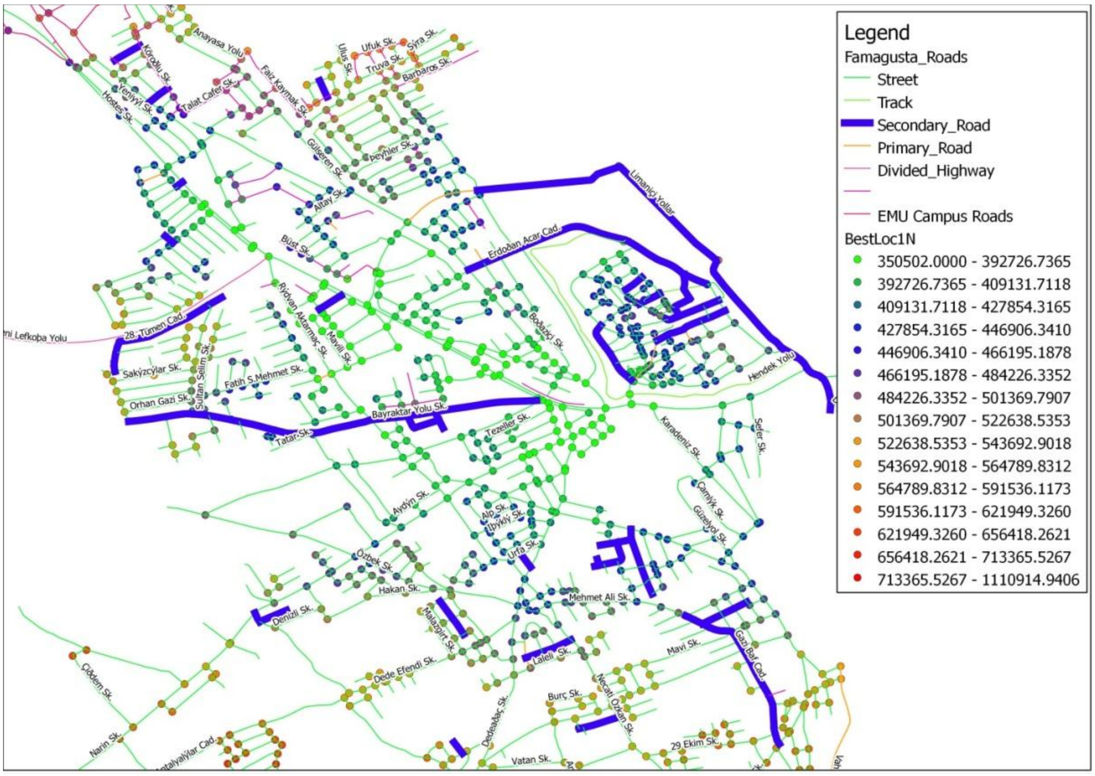

Figure 34: Best locations based on allowed speed (closer schema)

In figure 35, the best locations for current fire stations based on allowed speed are shown:

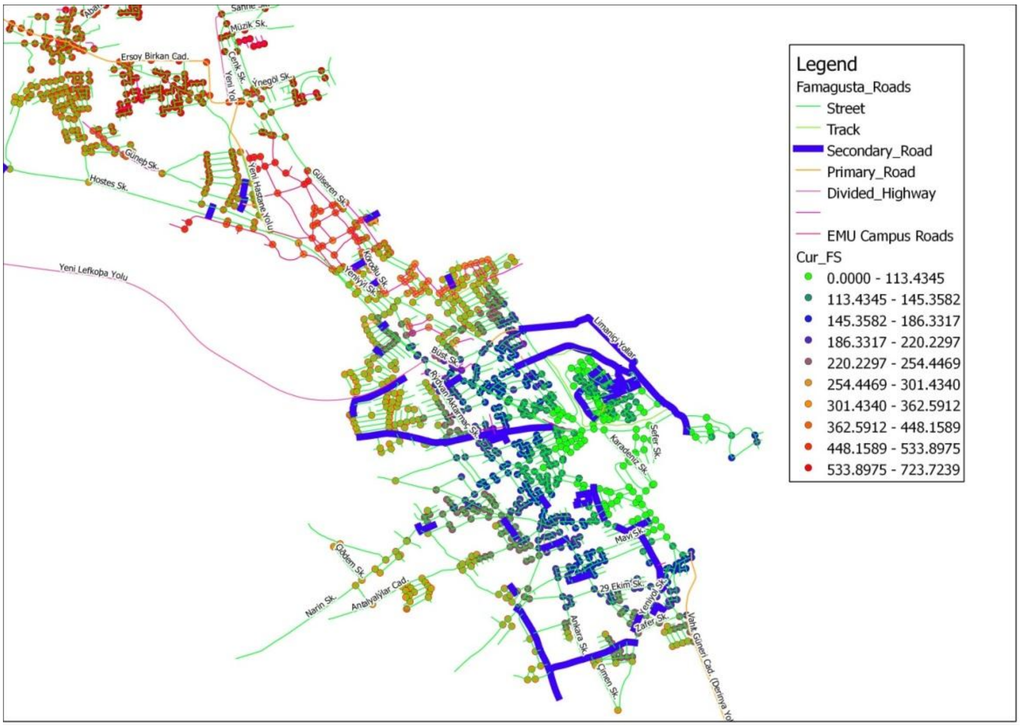

Figure 35: Best locations for current fire stations based on allowed speed

In figure 36 a closer picture is shown regarding to the best locations.

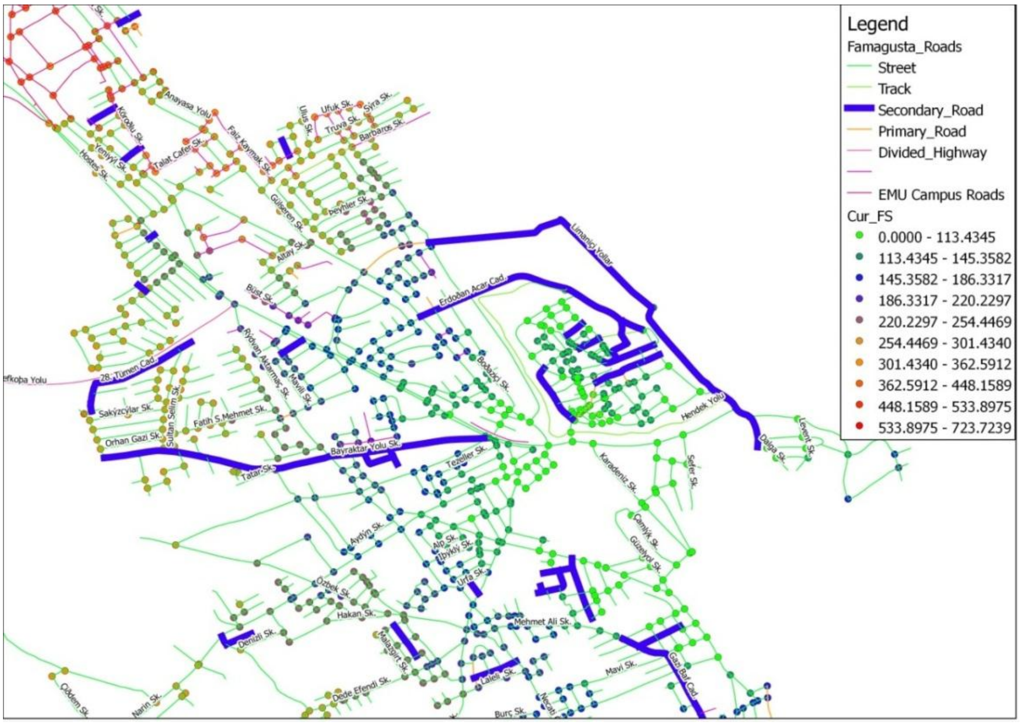

Figure 36: The best locations based on allowed speed

Chapter 5

CONCLUSION

As it was mentioned in chapter four, three scenarios are assigned in this study including (a) defining the best location for only one fire station in city, (b) defining the best location for 1 fire station when several other fire stations are also located in the city and (c) defining the best location when two fire stations are active concurrently.

Here, results for each scenario are presented.

5.1 Defining the Best Location for only One Fire Station in the City

Referring to Figure23, the best location is shown with blue color (with travel time between 0 and 1). It is shown that the best location is related to the blue color (between 0 and 1) in which the nodes 230 and 231 are located. Different colors are shown in which the range of travel time is defined in the right side of the figure 23.

Then in this situation, when only one fire station in city is assumed, nodes 230 and 231 are the most important. According to figure 24, another node (node 1274) has also been found in the northern part of the city. This node is also the best one for establishing a fire station because of its fast coverage. This node was also defined by the software program.

5.2 Defining the Best Location for one Fire Station when several other Fire Stations are also located in the city

In this situation, we should search for other possible fire stations. In this second scenario, the researcher tried to find the best location for a new fire station when the current station is also active in the city.

In this process, a fire event is assumed in one geographic site of the city and the coverage of each of the current and the new defined fire station will be calculated using the software developed for this goal. This process will find a total numerical value. The output of this software is shown in the following in which, the best route from one node to another one is shown. Current fire station is in nod 1348 and best nodes are defined as nodes 230 and node 231.

According to the figure 30, the best location for establishing a new fire station, when the current fire station is active, is the area shown in green color. (Green nodes = 350502-392727 Second).

These areas are related to node 230.Then node 231 is the best site for this situation

5.3 Defining the Best Location when two Fire Stations are active

Here, results for each scenario are presented.

Here new software is developed to select two fire stations at the same time showing the total number of the out ranged nodes. We displaced fire stations randomly and find and sort the best locations. This program is not able to provide the most optimum result since it takes a lot of time to do the calculation for different situations. But the more the calculation time, the more the accuracy level.

Referring to figure 31 shows the best location when two fire stations are active concurrently, shown in green color.

These areas are related to node 1032. Then node 18 is the best site for this situation.

In finally, this study improved about 3 minutes the time in comparison of the last model. Also there was near 100 nodes in the Famagusta city that the current fire station could not covered less than 10 minutes. But the best location that found in this study can cover the entire city less than 10 minutes. In figure 37 the places of node 230 and node 231 are shown. Node 230 is placed in Gazi Mustafa Kemal Street near the traffic light. Node 231 is placed in intersection between Gazi Mustafa Kemal Street and Topcular Street. In figure 35 is shown the locations of node 230 and node 231.

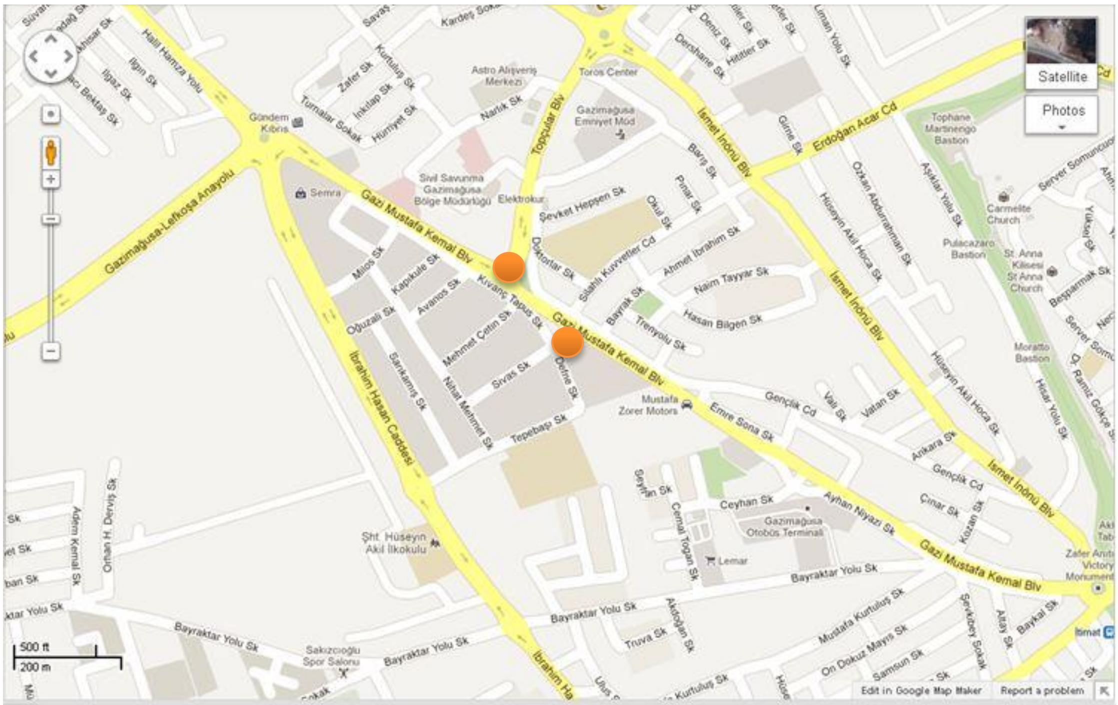

Fig 37: Locations of nodes 230 and 231

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APPENDIX

Guides for software, these words are used in the program

From: locates the fire station

r: variable that searches the node

G: the network X

w. record (From, TotalSec, NofOutRanges): Is for making a new layer

STR: changes the numerical cod to written comment

Try, except: detecting error

w. point (r. shape. Points [0][0],r. shape. points[0][1]):

(r. shape. Points [0][0], r. shape. Points [0][1]): Latitude and longitude

[0]: location of node

Allow speed = 10*60=10 min

NofOutRanges = refers to nodes with more than 10 minute travel