INTEGRATION OF PERSONNEL SERVICES WITH PUBLIC TRANSPORTATION: A CASE STUDY OF BOGAZICI UNIVERSITY

by

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To my family

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ABSTRACT

INTEGRATION OF PERSONNEL SERVICES WITH PUBLIC TRANSPORTATION MODES: A CASE STUDY OF BOGAZICI UNIVERSITY

To provide comfortable and reliable means of transportation, most of the employers offer personnel services to their employees. Although it is a commonly used concept, for both employers and employees, there are downsides. From employers' point of view, financial load of the concept is high for both private sector and state institutions. Extra budget spent on such systems leads to missed opportunities for other investments or researches. On the other hand, some employees have complaints about conditions of the concept. Purpose of this study is to provide a systematic approach for the optimization of personnel services and furthermore, integrating the concept with means of public transportation. In accordance with this purpose, two methods are represented in this study. The first method mostly focuses on optimization of service routes, latter, by building top of it, aims to integrate personnel services with public transportation. The study is conducted with data of current personnel system of Bogazici University, which is one of the most prestigious universities in Turkey. A Geographic Information Systems (GIS) software was used to enable the purpose of the study. Study has shown that, compared to conventional approach to the concept, offered methods have better results. Besides providing improvements to a single case, in the long term, by spreading the methods of the study, it is believed that improved traffic conditions may be provided.

ÖZET

PERSONEL SERVİSLERİNİN TOPLU TAŞIMA İLE ENTEGRASYONU: BOĞAZİÇİ ÜNİVERSİTESİ VAKA ÇALIŞMASI

Birçok işveren, çalışanlarına rahat ve güvenli taşıma sağlamak amacıyla servis hizmeti imkânı sunar. Bu çok yaygın bir hizmet olmasına rağmen yine de bazı olumsuzlukları da bulundurmaktadır. Hem özel sektör hem de devlet kurumları için işverenler açısından bu konseptin finansal yükü fazla olabilmektedir. Bu hizmet için ekstradan harcanan para başka fırsatların kaçırılmasına sebebiyet vermektedir. Diğer taraftan bazı çalışanların da bu hizmetin şartlarından şikayetleri vardır. Bu çalışmanın amacı servis hizmetleri optimizasyonu için sistematik bir yaklaşım sağlamakla beraber, sistemi toplu taşıma ile de entegre etmektir. Bu amaç doğrultusunda çalışmada iki metot sunulmaktadır. İlk metot genel olarak servis rotalarının optimizasyonuna odaklanırken, ikinci metot ilk metotun üstüne koyarak servis rotalarının toplu taşıma ile entegrasyonunu sağlamayı amaçlamaktadır. Çalışma, Türkiye'nin en prestijli üniversitelerinden biri olan Boğaziçi Üniversitesi'nin güncel personel servisi verisi ile gerçekleştirilmiştir. Çalışmanın amacına ulaştırılması için bir coğrafi bilgi sistemleri yazılımı kullanılmıştır. Çalışma şunu göstermiştir ki, geleneksel yöntemlere kıyasla önerilen metotlar daha iyi sonuçlar vermektedir. Buna ek olarak, tek bir vakadaki iyileştirmelerin yanında, uzun vadede eğer çalışmada kullanılan metotlar yaygınlaşırsa, trafik koşullarında da iyileştirme sağlanacağı düşünülmektedir.

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1. INTRODUCTION

Transportation systems are one of the most important dynamics of a city. In daily life, most people make multiple trips between different parts of the city. These trips show varieties in terms of their purpose, however, they all take place in the same transportation facilities. In this situation, having a proper public transportation system has massive importance for each city. In most of developed countries, cities provide multiple transportation solutions for trips of their residents whereas in other countries transportation is a huge problem. Crowded and poorly planned cities' lack adequate public transportation lines and their transportation web cannot reach every part of the city. Even there are available means of public transportation, during the rush hours they serve in full capacity. Under these circumstances, some people choose to use their private vehicles as it is more comfortable, however, this causes long traffic congestions in main arterials. To solve this dilemma, there is a concept called personnel services. These services act like a mean of public transportation and provide comfort for employees of a given workspace. Many employers offer these services to their workers free of charge. In both private sector and state institutions these services are commonly in use, as is the case in universities.

At a very first glance, university campuses are not considered as highly populated employment centers. However, number of employees in a university may reach to a substantial amount. Academicians, research assistants, supporting staff and other personnel create a huge group of employees. This group have a demographic structure that varies widely. Factors such as, level of income, life expectancy, social status and family structure differ in this large group. Such factors affect living conditions of the personnel and somehow, they do not get the chance to live near to their workplace with respect to these factors. Accepting that university personnel are spread into different parts of the city and since they must come to work and do their job every weekday, it can be interpreted as follows; a university campus is an attraction point for personnel from every part of the city.

According to the council of higher education in Turkey, there are 60 state or private universities in Istanbul. Most of these universities are small scaled and have low numbers of personnel; however, some of them are well-established education institutes and they can be

considered as large employment centers. In the following table, staff numbers of some of these universities are listed and an illustration is created to give an idea about their attraction.

Table 1.1 Number of personnel in some universities in Istanbul.

University Name	**Number of academic and administrative staff**
Bogazici University	1764
Istanbul Technical University	2062
Yildiz Technical University	2357
Marmara University	3416
Sabanci University	768
Istanbul University	3515

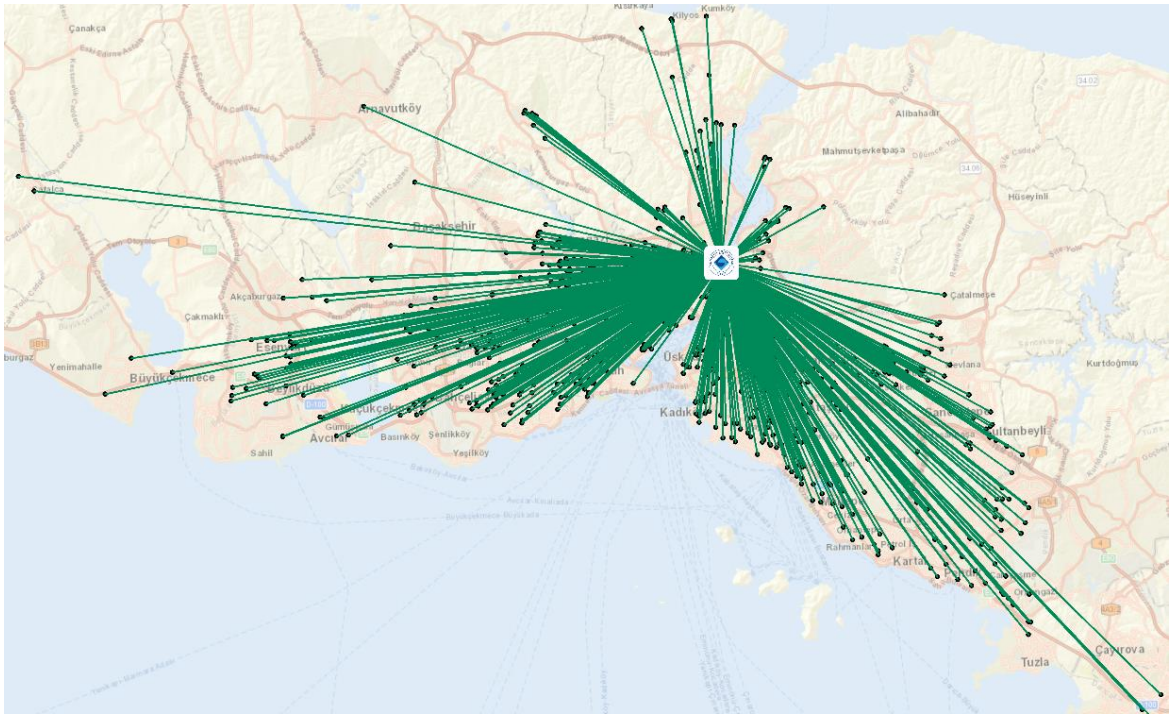

Figure 1.1 Attraction map of Bogazici University.

It is obvious that a university creates much more attraction for its students than it does for employees. Digest of Education Statistics which is a study prepared in US with the help of data that is gathered from National Center for Education Statistics (NCES), showed that about 3.9 million people were employed in colleges and universities, whereas there were 19.8 million students in fall 2016. These numbers may give insights about student/staff ratio

in western civilizations. However, at this point it is beneficial to mention that attraction that caused from students is not considered since the study is concentrated on transportation of university personnel.

As of 2018, Istanbul has a population of 15 million and is the highest populated city in Europe (TUIK, 2018). Traffic in Istanbul causes average of 46 minutes a day and 175 hours a year delay. These delays increase further in rush hours and can reach up to 91% longer travel times (Tomtom, 2016). Under these circumstances, to be able to provide connection between different parts of the city, every city administration aims to have well-organized and reliable transportation systems. These systems must provide both mobility and accessibility. Not only does the transportation system provide opportunities for the mobility of people and goods, but also over the long term it influences patterns of growth and the level of economic activity through the accessibility it provides to land (Banister, 2002). Developed countries may achieve this goal with a well-organized transportation master plans, however, it is not an easy task to deal with in large cities since there are many effecting components such as high population, logistic problems and land-use restrictions. At this point, public transportation has a key role as it offers a high passenger capacity, low fares, mobility and accessibility for citizens.

A comprehensive public transportation system is indispensable for every city since it helps people to reach their destinations with low fares regardless of using their own vehicles. Additionally, system helps to relieve traffic congestions of the city by reducing number of vehicles in traffic, thus, it saves time for each citizen who are in this regulation every day, and provides economic and environmental benefits (Edwards, 2008; Litman, 2010). Even though it seems beneficial in both individual and community levels, in practice, not every individual is willing to use public transportation if it is not necessary. Citizens with lower incomes tend to use public transportation more compared to high-income personnel due to low fares (Manaugh, K., *et al*, 2012). Level of income and demand for public transportation have inverse proportion (Paulley, N., *et al*, 2006). With the increasing income, people gain a different mindset and they give more importance to their comfort. According to Bureau of Transportation Statistics, in 2017, 76.6% of workers use their self-automobiles as their principal means of transportation. They tend to evaluate public transportation means

as crowded and insufficient. This is where personnel services concept is introduced into the system.

1.1. Contribution of the Thesis

Today, there are some implementations which are traditionally regulated by human's knowledge manually without usage of computer-based technologies. Since technology is now in every part of people's life and it benefits in almost every aspect, in this thesis, by addressing the concept of personnel services, it is aimed and showed that these mentioned implementations can be optimized and can be more feasible by the help of computer technology.

Main contributions of this thesis are systematic optimization of personnel services and their integration with public transportation. Technology of GIS (Geographic information systems), which will be described in detail later, is the main tool to provide such contributions. In addition, side contributions can be listed as follows;

(i) Improving environmental conditions by emitting less carbon,
(ii) Relieving traffic conditions by providing less vehicle in traffic,
(iii) Saving budget of the university by reducing personnel service expenditures,

1.2. Goals and Objectives

Boğaziçi University is a very successful and well managed university and academically one of the most prestigious and leading universities in Turkey. However, due to adverse economic conditions it is hard to keep up with all the expenditures of the university and keep academic research on going. There are lots of expense items that must be met by the budget of university and personnel service expenditures are covering an important part of it. This study may help to university administration by reducing cost of personnel services.

The objective of the thesis is that making a literature review about personnel service systems in the world. Following this literature review, by introducing a new approach,

integrating the system with public transportation without losing comfort of the employees will be provided. However, study is aimed to achieve a greater benefit if it is not limited to this case study. Spreading the idea beneath the study to the other employers or other universities will help to decrease the disadvantages that are mentioned in the following sections.

The reason why Bogazici University was selected for this study is that it is easier to adopt a new approach in a university because university communities are more open-minded than other communities in the society. Another incentive for the selection is that influence and guidance power of university communities to the rest of the society (Miller, 2001).

The study contains two separate ideas to enable given objectives. In the study, benefit of all elements; society, employees and employers are prioritized. Both methods will be described in methodology section later.

1.3. Outline of the Thesis

The remainder of this thesis is organized as follows:

In the next chapter, information about personnel services and previous studies related with the topic are provided. Later, Chapter 3 contains the theory and related studies that is conducted by GIS. Then, information about Bogazici University which is the case study of this thesis is given in Chapter 4. It is followed by the methodology and then analysis and comparisons in Chapter 5 and Chapter 6. Finally, conclusions and recommendations are provided in Chapter 7.

2. PERSONNEL SERVICES

2.1. Concept of Personnel Services

In a crowded city like Istanbul, it is hard to reach from residence to working place. With respect to time of the day and origin and destination of the travel, it may take up to hours to complete the trip. Spending this time in means of public transportation may be difficult and uncomfortable due to crowd. Also, for some members of working society such as, elderlies and individuals with physical disabilities are having hard times while using public transportation.

In such situation, as it is mentioned above, to meet the transportation need of the personnel, very common and convincing concept which is called personnel services that carries personnel from their residence to their workplaces is introduced. These services consist of different sized vehicles, depending on the number of employees, their residence addresses and locations of working places.

The concept is aimed to serve as a comfortable way of transportation to private sector and state institutions. Companies offer this system to their employees free of charge. It is very common and accepted concept among both employers and employees. Moreover, it is crucial to provide personnel services since people look for such service before they apply for any job.

Personnel services provide a decrease in the number of vehicles in traffic as they reduce the use of private vehicles, thus, personnel services can be considered as means of public transportation for only determined group of people. Like the method presented in this thesis, some cities research innovative systems that combines personnel services with the public transportation systems. By a research conducted in Seattle, it was observed that collecting personnel from bus stops does not affect bus schedules negatively (Lewis, E. O., *et al*, 2018). For the passengers in Utah, a last mile shuttle route was offered to connect them to the railway system. By doing so, it was aimed to prevent the use of private vehicles (Johnson, *et al*, 2015). In a different study, which uses meta-heuristic methods, routes, which

minimizes the cost for both the shuttle service users and providers, were created for shuttle services that traveling to metro stations (Xiong, *et al*, 2013). Considering given examples, communities that use concept of personnel services are aware of the importance of combination between the personnel services and public transportation, which is essential for an efficient transportation system.

There are also alternative utilizations of personnel services. In some countries, for passengers who live in a low-density area and require a more flexible schedule to arrive to their workplaces, Demand-Responsive Transit (DRT) options are available. The demand for a Personalized Demand-Responsive Transit (PDRT) service in the San Francisco Bay Area is analyzed (Khattak, 2005). The results imply that approximately 60% of the participants are willing to consider PDRT as a transportation option and 12% of the participants are very interested to use the system. In addition, a significant portion of these passengers value scheduling flexibility of this service and are willing to use the service.

Since universities are huge employment centers, they also must adopt innovative concepts as they have budgets to be able to afford such systems. Multiple approaches for concept of personnel services were used in time for transportation of university employees and none of them proven its superiority among others (Miller, 2001). One can induce that there is still room for improvement for the concept. It is mainly the starting point of the idea behind this thesis. Such improvements can be achieved by finding the best route and providing the right capacity.

In the literature, there are two types of routing problems related with the concept. First one can be named as dynamic routing as it changes every day like the case in cargo companies. Destinations and packages change every day and routes must be arranged accordingly (Koubaa, *et al.*, 2016). Whereas, services for employees are more static, after once it is arranged, they work on the same route for one education year, unless there is no change in personnel.

According to one comprehensive study (Miller 2001) which was conducted in US, University administrations have different attitudes towards the concept. Study showed that there are 3 main organizational forms; University-operated systems, operated agencies by

local governments and private transit companies which is eligible for the transportation job. Decision between these forms is made in accordance with the economic and administrative conditions. One outcome of this study is that universities does not prefer to be involved directly into operating such systems instead they prefer hiring private companies for transportation. This idea also prevails in almost all universities in Turkey such as Bogazici University. However, to be able to protect their own interest, universities must be more involved in such systems.

From wider perspective, providing a service system that is appreciated by students is important, as they have chance to be “movers and shakers” in society (Limanond 2011). Tolley (1996) suggests that the campus administrators should target to provide a well-organized transportation system to conduct affective transportation habit among the students as students will progress to occupy influential roles in government, companies or other organizations.

In this thesis, concept of personnel services for employees of Boğaziçi University will be discussed and new approaches will be introduced to optimize the current system.

Although personnel services concept is widely used and accepted, these services are economic burden for universities that have huge numbers of academicians and supporting staff. Since the budget of universities are limited, university administrations must lower the expenses other than the ones which are made for the academic purposes. Especially rising costs for personnel transportation might cause a slowdown on academic mission of the university (Balsas 2002). For this reason, many universities have tried or still trying to find new policies to optimize means of transportation to university (Miller 2001).

2.2. Advantages and Disadvantages of Personnel Services

In terms of transportation equity, personnel services contribute positively. Equity refers to the distribution of impacts (costs and benefits) and whether that distribution is considered fair. Transportation planning judgements can have important and various equity impacts: Available transportation facilities affects people’s social and economic opportunities (Handy and Niemeier, 1997; Litman, 2002; Niemeier, 1997). Improving

transport accessibility is important to cope with social inequality. One focus of transportation equity issues is surely job accessibility (Cheng and Bertolini, 2013; Grengs, 2012; Holzer et al., 2003). In this case, it is significant that the personnel services are equally offered to all without separating anyone.

In addition, transportation with personnel services promises great comfort to personnel in every mean. Concept provides opportunity to save time and energy in many cases. A study, which took place among staff of Bogazici University to provide insights about their travel behaviour, showed that majority (50.47%) of the staff prefer personnel services.

Unfortunately, besides of its advantages, concept also has disadvantages. Some other results of the same study showed that 25.3% of the registered users did not use the system, also 23.87% of the staff, who did not prefer to use personnel services, stated that shuttle routes were not favorable. Results indicate that the current system lack efficiency and there is a route planning problem (Bayrak, 2016). When the reason of this situation was asked to staff, most common answers were as following;

(i) There are faster alternatives,
(ii) Service routes are too long,
(iii) Services pick up employees too early.

The problem is that there is no mechanism to control and analysis the routes. One of the aims of this study is to provide an analysis mechanism to optimize the system. In long term, this mechanism may be sustained with the help of university students or some professionals may be assigned for this task.

Concept is an economic burden for universities. As the number of personnel increases, more money is spent on system and this leads to the interruption of the money will be spent for academic research. In Turkey, government provides fund for personnel services in universities, however in 2015, administration of Bogazici University had to allocate its own budget to fund the system.

In addition, impacts of the system must be examined on community level. Operation times of these services coincides with rush hours which are already the busiest times of the day. These services put extra burden on currently busy traffic, during their operation time. In such case, adopting new technologies and innovations to solve these adverse conditions is necessary (Miller, 2001).

Furthermore, service vehicles are only used twice in a day between residences and working places. In any other time, they are not in use and especially at the end of the shift they create huge parking problems in some working areas. Especially as the end of the work hours gets closer, business districts become crowded intensively and this causes serious traffic problems.

Environmental effects also must be considered. In developing modern engines emissions of pollutants such as HC, CO and NO_x are well controlled, whereas CO_2 emission and fuel consumption rates are still threatening during rush hour congestions (Zhang, *et al*. 2011). As personnel services operate during rush hours, their negative impact on environment must be considered.

2.3. Current Status of Personnel Services

Current system works as follows; personnel service companies determine service routes according to locations of personnel and assign each personnel to the closest service. During determination of service routes, there are no systematic method, decision-making mechanism is simply depended on experiences and knowledge of the responsible employee.

Afterwards, they calculate the total distance travelled by personnel services and determine a fee according to that distance. After bids has been made, company or university who receives the bids evaluates each one and reaches an agreement with the most feasible option.

Calculation method of proposal fee is the key at this point. The fee is calculated based on total distance travelled by all service vehicles combined. Meaning that, if the total distance increases, companies put higher bids for the job as service vehicles consume more

fuel in longer distances. Every company has different pricing policies, but they are all based on fuel consumption in the end. This situation only harms companies or universities that receives the bid because bidder always keeps the profit margin constant. In such case, bidder do not prefer to spend time on optimizing routes, since more and longer routes are on their favor. By the help of improved technologies, such as Geographic Information Systems (GIS), it can be considered as a simple task.

3. GEOGRAPHIC INFORMATION SYSTEMS

Definition of GIS which is made in the early 90s is that, GIS is a data base management system capable of storing, retrieving, analyzing and displaying locational data. It is different than traditional databases because, it contains geographic and spatial data in addition to attribute data (Prastacos, 1991).

Some authorities throughout the world have spent significant efforts to perform and manage Spatial Data Clearinghouses (SDCs). SDCs are major features of Spatial Data Infrastructures (SDIs) (Crompvoets et al. 2004, Clinton 1994, Federal Geographic Data Committee 1997, Onsrud 1998,), as they are the facilities to provide spatial data accessible to the society.

Due to its power of spatial analysis, decision makers can take advantage of GIS in city and transportation planning. GIS can facilitate a large set of participants in the planning process because of its visual support when addressing spatial issues (Al-Kodmany 2001).

In transportation studies, GISs are widely used by lots of transportation authorities (Zhong-Ren *et al*. 1998) and researchers use such systems more day by day. As the researches keep making studies about GIS, the usage of such systems growing rapidly on various subjects of transportation. Such studies can be either conducted to analyze current status or to obtain new planning ideas. In this section, examples of such studies will be mentioned.

Accessibility analysis is one of the important studies conducted via GIS. A region can be defined as car dependent when car accessibility is considerably higher than public transport accessibility. A study was conducted In Tel Aviv metropolitan area via GIS, for estimating car dependency to reach employment and other land uses. By the help of spatial analysis and GIS tools, study showed that transit-based accessibility is substantially lower than car-based accessibility which makes the area highly car dependent (I. Benenson et al., 2010). The results showed similarity to other studies that had been conducted in different parts of the world (Hess 2005; Blumenberg and Ong 2001).

Geographic Information Systems (GIS) has widely been used also in solving site selection problems for the last two decades. Planning and building new transportation facilities such as metro-rail systems are considered as crucial actions. Route/site selection has significant importance in such cases as locations of the facilities influence economies of cities. In a study, Farkas (2009) states that the analytical capabilities and the computational functionality of GIS promote to produce policy relevant information to decision makers. Same study aims to determine route/site of a planned metro-rail network through GIS and spatial Multi-Criteria evaluation. By comparing proposed three routes, the best option in terms of the total impedance and the length of the line is determined at the end of the study.

Route optimizations are also carried out with the help of GIS, as the case in this thesis. In Trabzon, to decrease collection/hauling costs of a solid waste management system, which consist of 85 % of total disposal expenditure, a route optimization was carried out. For optimization, truck type and capacity, solid waste production, number of inhabitants and Global Positioning System (GPS) data for each route were collected and analyzed. After creating the routes, optimized routes were compared to current routes. Study resulted with 24.7% decrease in total distance that is travelled by trucks (O. Apaydin and M.T. Gonullu, 2007).

A similar optimization study was conducted to reduce fuel consumption and increase energy efficiency using GIS and GPS technology. In the study, all paths of communal vehicles were recorded and allocated in a database. Routes were analyzed by using ArcGIS, a leading GIS software. Results showed that possible savings for one vehicle may reach up to 2700 km per year. Thus, total savings could be 20% in costs and the associated emissions. (M. Jovicic, et al., 2010)

3.1. Definition of GIS

A geographic information system (GIS) is a framework for gathering, managing, and analyzing data, according to ESRI which is the largest GIS developer in the world.

A GIS user can enter georeferenced data into system to analyze it in various ways, and to produce maps from the data. Georeferenced data is spatial data that is referenced to a

location on the earth's surface according to United States Geological Survey. System includes different kinds of coordinate systems and transformations between them.
GIS provides the following four sets of capabilities to handle georeferenced data:

(i) Data capture and preparation
(ii) Data management and maintenance
(iii) Data manipulation and analysis
(iv) Data presentation

3.1.1. Data Capture

In the recent years, as the technology of GIS spread rapidly, there have been a lot of research about various topics by using GIS applications. From agricultural development to city planning, or from market analysis to natural resource management, GIS is in use (Maguire 1991). To accomplish such researches, the very first step is data capture, which simply refers to the collection of any types of data. According to purpose of study and available means, different types of data capturing are possible. For instance, if there is a previously printed map which may benefit the study, the one can digitize or scan the map to make analysis in computer. However, if the printed map is old, the data may not be up to date and this would mislead the analyst. Hence, to eliminate possible errors and to get a more accurate product, methods which enables to enter up-to-date data directly in digital format are preferred. Global positioning systems, remote sensing and LiDAR technologies are most common and efficient tools to collect up-to-date data. Besides all these data capture methods, geocoding, which is basically converting descriptive locational data such as a home address or a named place into a geographic reference, is an important tool to capture spatial data. Geocoding forms a fundamental component of spatial analysis in a wide variety of research disciplines (e.g., computer science [Hutchinson and Veenendall 2005b, Bakshi et al. 2004]; health [Boulos 2004, Rushton et al. 2006]; crime analysis [Ratcliffe 2001]; political science [Haspel and Knotts 2005]).

3.1.2. Data Management

Structure of GIS data is more complex compared to “classical” data in Cartesian structures. It is a spatial data, which includes location, shape and orientation. These types of data describe a wide range of objects, such as roads, buildings, terrain and infrastructure. These objects can be described in terms of lines, polygons and points and attribute tables of these objects consists the tabular portion of geospatial data.

In addition, there are also unstructured data which is mostly raster imagery in GIS. These types of data can be geocoded and digitalized via GIS software and can be converted to into geospatial data.

Thus, the management of GIS data gains importance. Traditional tabular data can be more understandable at first glance unlike raw GIS data. However, GIS software converts such complex data, which is often fragmented in source and format, into maps and make them meaningful.

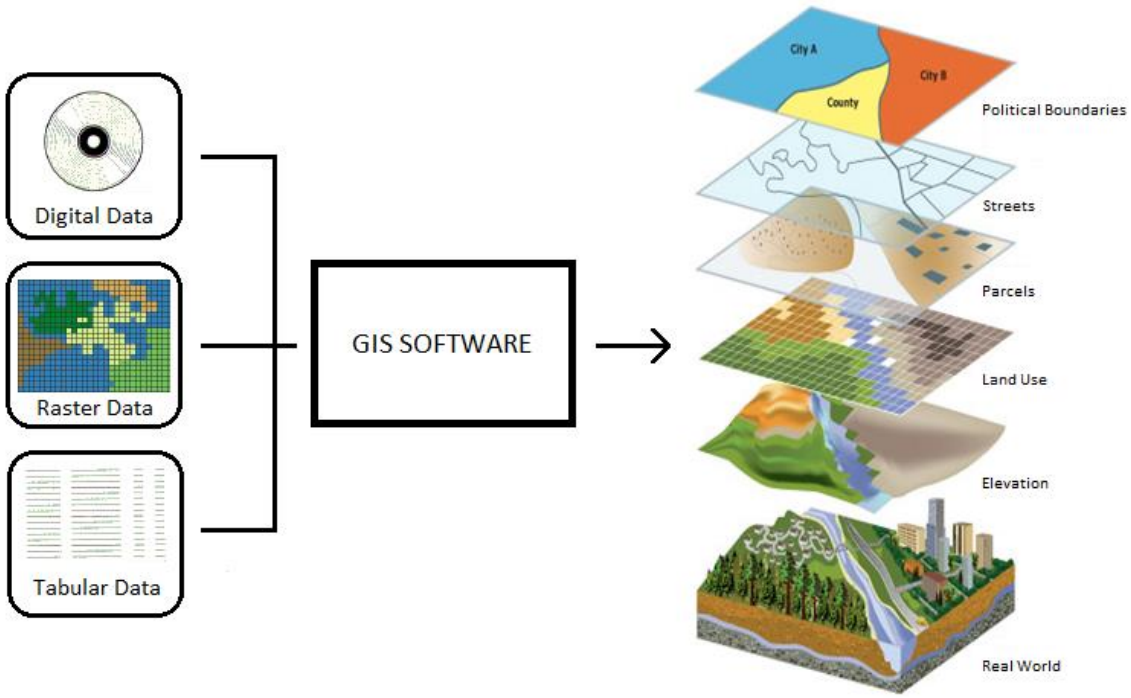

Figure 3.1 Process between raw data and map.

In geospatial data structure, for each component of a geographic object, set of files containing one record is created. For instance, a road segment would be one record that contains an ID, shape ID and non-GIS attributes (such as name, width, material, etc.). This type of data is known as vector data. All vectors are represented as points, lines and polygons.

Figure 3.2 Representation of each road segment in Istanbul (taken from ArcGIS).

Each object in a geospatial database would be grouped into object classes. For instance, road sections form road class, buildings form building class. A GIS software integrates these different datasets into single representation and allows user to manipulate and analysis the data.

Metadata is the key in GIS. Properly overlapping each dataset from different sources is possible with the help of metadata which contains the coordinate system and projection information of each dataset.

3.1.3. Data Manipulation and Analysis

Once the data is prepared and ready to use, data manipulation and analysis process can be conducted. Before making the analysis, data manipulation is necessary to have correct and desired results. Depending on condition of the data, reprojection must be considered at first. For instance, if there are two different layers which have two different coordinate systems, these layers won't match correctly, and this may lead to incorrect results. By using geometric transformations, these two layers can be assigned to same coordinate system which would avoid any misleading result.

After ensuring the accuracy of data, manipulation is important to make the map serve to purpose of the study. Clipping or merging data, assigning different values to different objects, creating buffer zones, adding new threshold values, calculating new values from existing data and creating new maps accordingly etc. are just few examples of data manipulation.

When data manipulation has been completed, analysis of spatial data, which can be defined as computing new information that provides new insights from the existing, stored spatial data, can be made (Huisman, 2009).

Analysis in GIS can be various, one can use SQL queries or tools in GIS software to make an analysis. Most important feature of GIS is combining tabular information with the spatial information. This study can be given as an example to spatial analysis. Study combines spatial data (personnel addresses) with tabular data (names) by using tools (buffer tool, selection tool, etc.) of a GIS software and aims to solve given issue.

3.1.4. Data Presentation

Visual information is essential in GIS studies. Different types of maps are required for different purposes. After conducting the analysis, maps should be created to support the analysis. Presentation of spatial data, whether in print or on-screen, has influence on decision makers.

4. CASE STUDY OF BOGAZICI UNIVERSITY

This study is conducted at Boğaziçi University, one of the most prestigious universities in Turkey, which founded in 1863. University has six campuses that are spread into different districts of Istanbul. Kandilli campus is located on Asian side of the city, the other five campuses; Kuzey, Guney, Hisar, Ucaksavar and Saritepe are located on European side.

4.1. Campuses of Bogazici University

There are 62 personnel services for 1166 registered personnel in current system, this number indicates that almost 60% of all personnel prefer personnel services since there are 1923 personnel in total. For more detail, personnel services can be separated according to their destinations. There are 5 personnel services for Kandilli campus and 2 for Saritepe campus. The largest portion of personnel services belongs to Guney, Kuzey, Hisar and Ucaksavar campuses with 55 services. Since they are very close to each other, current system of personnel services accepts all 4 destinations as one and adjust service routes accordingly. This simplification also will be used in this study. Personnel who work in these 4 campuses will be named as Guney campus personnel in methodology section as the main campus of the university is Guney campus.

In this section, information about campus locations and structures will be given to understand distribution of personnel.

Saritepe campus is in the north side of the city and is relatively distant compared to other five. Only preparatory classes are held in the campus. Accordingly, campus does not have a high number of personnel. In addition, there are personnel dormitories in campus and most of the personnel who work in campus prefer to stay in dormitories as the campus is far from the city center. Therefore, there is only 2 personnel service operating for campus in current system.

Kandilli campus is the one on the Asian side which is located near to Fatih Sultan Mehmet Bridge. Faculties such as Earthquake Engineering, Geodesy and Geophysics are facilitated in the campus. Campus serves graduate students more than it does to undergraduate students.

Remaining four campuses are on the European side, in Hisarustu region. These campuses are considerably close to each other. These campuses are also very closely located to Fatih Sultan Mehmet Bridge. University administration, library, student clubs, student affairs, faculties of social sciences and engineering and football field are in these campuses. That is why, a large proportion of the personnel are serving in these campuses.

5. METHODOLOGY

In this part, two methods that are used in the study will be explained broadly. The first one is intended to optimize routes of personnel services with some additional set of rules to current system. The latter can be mentioned as the main approach of this study as it tries to combine both public transportation and personnel services. It is preferable to successfully implement the second method, since it is valuable to encourage people to use public transport.

Increasing number of public transport users is important for several reasons. First, high levels of car dependence can have harmful effects on both people's health and the environment (Shannon et al., 2006; Litman, 2003). Traffic accidents (Litman, 2003), traffic congestion (Litman, 1999), and physical inactivity related disorders (Sallis et al., 2004) have all been related with increasing levels of private car use.

In the existing system, personnel services pick up the employees from their houses. To do this, they must enter the residential roads and extend their routes. In such case the increase in the distance covered causes the university to spend more money. That is why reducing the total distance is an important objective. Two methods that are presented in the study are built on this fact.

For that objective, the first method aims to reduce the number of service vehicles, and to create more suitable routes. Method can be simply expressed as optimization of current routes. Whereas the second method is a more comprehensive one compared to the first method as it combines the system with the public transportation.

5.1. Current Routes

Information about existing routes and number of passengers for each personnel service is collected from *infomobil.com.tr* for a preliminary analysis.

Figure 5.1 Current status of personnel services.

At first sight it was observed that most of the services were operating at low capacities and there was plenty of room for optimization. Some examples are shown in the following table.

Table 5.1 Number of passengers in some service routes.

Service Name	Number of passengers	Service capacity
Kurtkoy - Guney	8	16+1
Esenler - Guney	8	16+1
Ziverbey - Guney	8	16+1
Kozyatagi - Kilyos	2	16+1
Kucukcekmece - Kandilli	3	16+1

5.2. Obtaining Data

To be able to make a comprehensive analysis, addresses of every personnel service user is also collected from *infomobil.com.tr*. By the help of geocoding, these addresses are converted into a map.

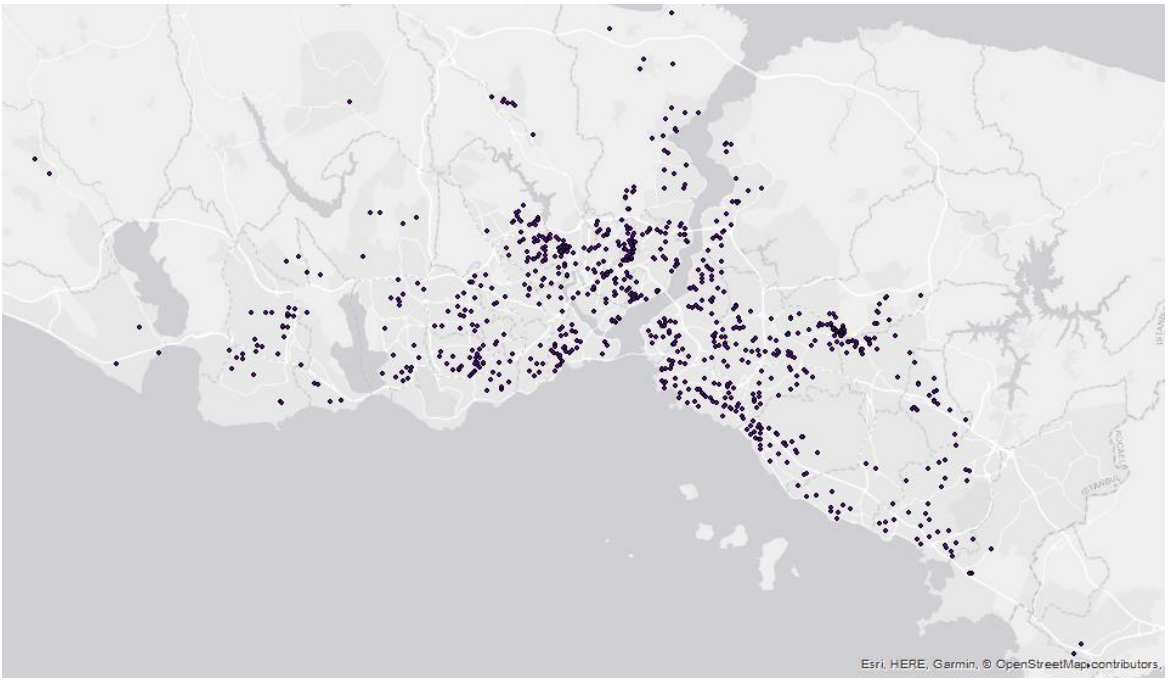

Figure 5.2 Visual representations of personnel locations.

5.3. The First Method

In the first method, the idea is that the personnel services will only operate on primary, secondary or collector roads and will not enter residential roads. In such case, employees need to reach to the closest point on the service route to meet their personnel service. Each employee will come to meeting point through their own means. They can prefer walking, cycling or a short trip with their own vehicles. For the ones who plan to reach to the meeting point on foot, a maximum distance that can be travelled is assumed as 1 kilometer. Instead of Euclidean distance, transport network distance is used for this regulation. Meaning that each employee may walk up to 1 km depending on their location and service route. If personnel are more than 1 km away from designated service route, the route will be arranged again to reduce the distance between service route and the personnel to 1 km. In such exceptional situation, service vehicles may enter residential roads.

Areas of influence, an important parameter of public transportation, which is defined by American Public Transport Association (APTA) as the area within a certain distance of public transport stops and, has a high potential for providing passengers (Apta, 2009), was

effective to select such implementation. Instead of stops, this area accepted around whole route and, as it is mentioned, radius of the area was chosen as 1 km.
In previous studies researchers similarly have used walking distances of 400 m (0.25 mile) and 800 m (0.5 mile) for estimating the distance people will walk to a transit stop or station. (El-Geneidy et al., 2009; Hess, 2009; Hsiao et al., 1997; Kimpel et al., 2007; Lovett et al., 2002) although other distances have also been used (e.g. 500 m (Chapleau and Morency, 2005)).

The ones with physical disabilities are excluded from regulation. Services will pick them up from their doorstep.

5.4. A rule for Crossing Bosphorus

Istanbul is a city that lies in two continents; Asia and Europe. Since University personnel are spread into different parts of the city and university campuses are located on both sides of Bosphorus, there must be crossings in both directions. There are several options for vehicles to transport between one side to another. Currently, an underwater tunnel and three bridges cross the Bosphorus.

Personnel services can use any of these four options. However, Fatih Sultan Mehmet Bridge will be used for all Bosphorus crossings as traffic conditions are better and locations of the campuses makes it more suitable.

There is one exception; services that take personnel from Uskudar will be using The Bosphorus Bridge due to its location.

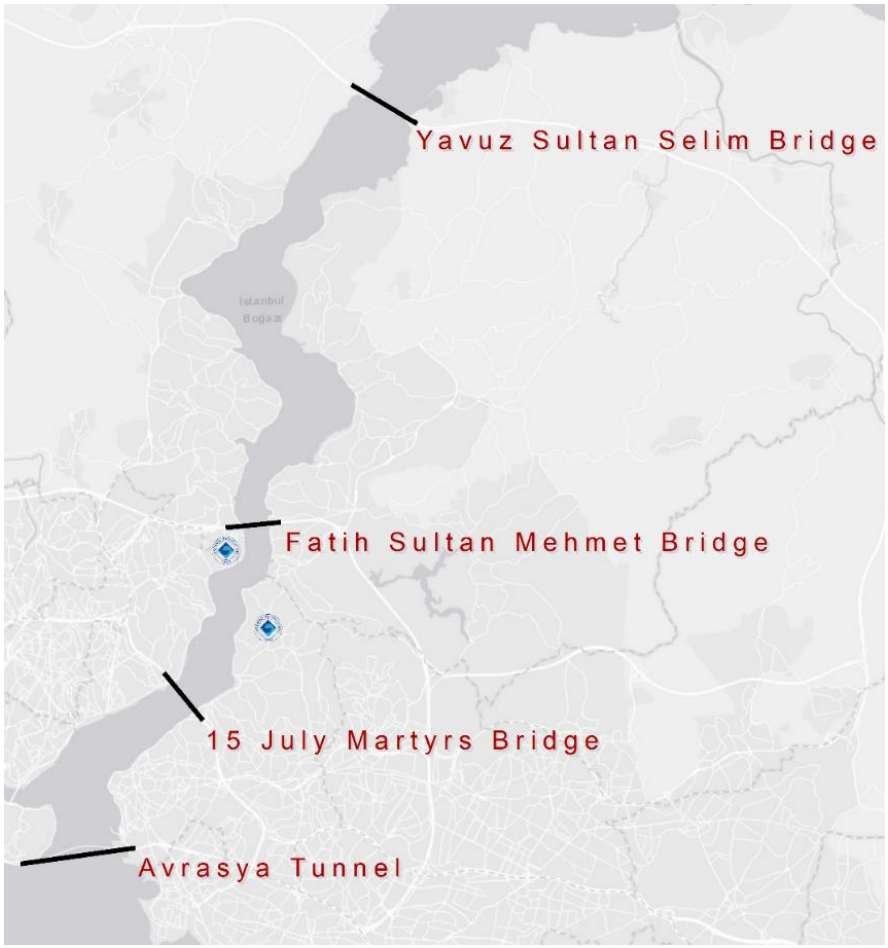

Figure 5.3 Locations of Bosphorus crossings and campuses of university.

5.5. Application of the First Method

After setting up the rules and preliminary analysis, route creation has begun. According to the information obtained from preliminary analysis, new routes have been started to be formed. None of the old routes are used except the ones that operates towards Saritepe campus. Services for Saritepe campus are not changed because there were only two services operating and there was no room for further improvements.

To create the first route, all personnel and all road sections in the city were projected to the map.

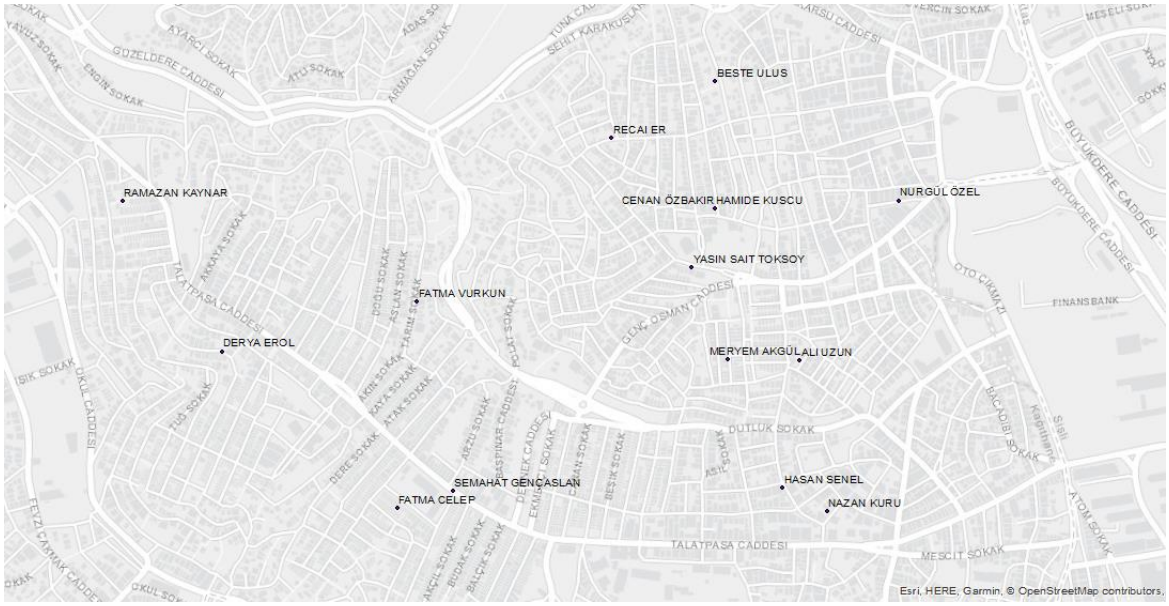

Figure 5.4 Road sections and personnel in given area.

While creating new service routes, personnel who will be picked up by the service was determined. The drawing of the routes was started from the beginning of the passengers' first point and continued until the campus. During the creation of the routes, attention was paid to both criteria that are mentioned earlier. Routes were drawn on primary, secondary and collector roads as much as it is possible. Only if the nearest main road section was more than 1 kilometer away from personnel, service would leave its route to reach the new meeting point which was located nearly 1 km away from the house of the personnel. After the personnel was taken, service would turn back to main road if there were not any other personnel near that location. This process continued until all personnel in the related region were taken by the service.

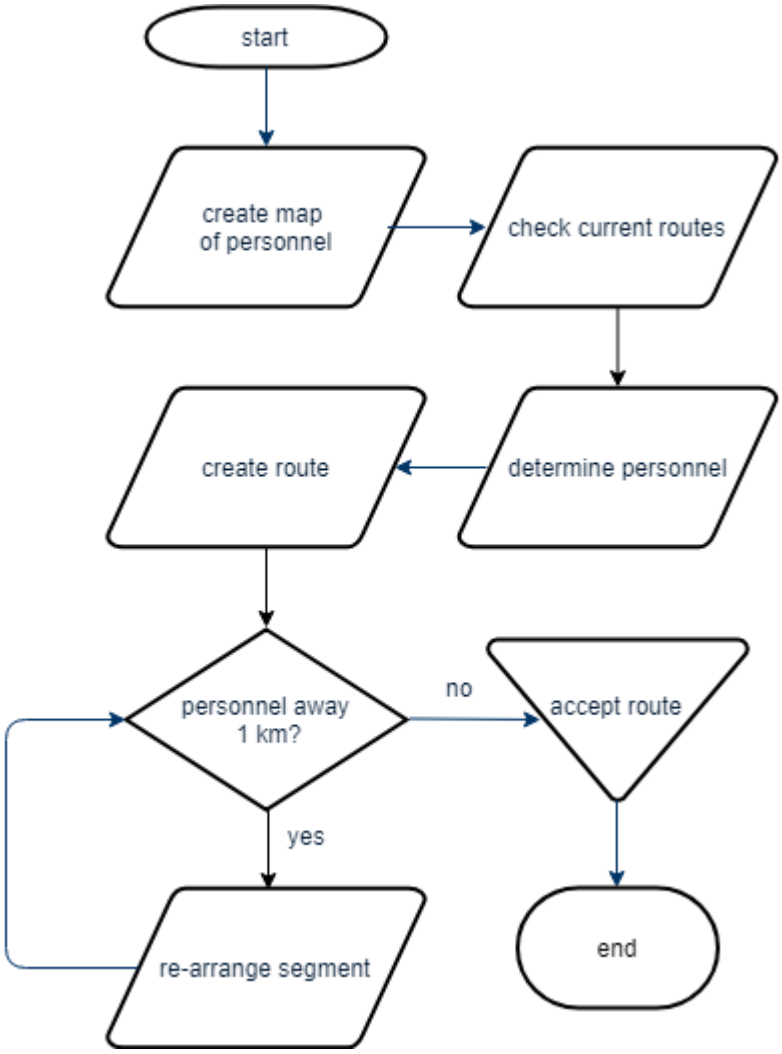

Figure 5.5 Flowchart of the First Method.

At this point, service capacities must be considered. Service vehicle capacities vary in a large scale. Personnel can be picked up by vans that carries 15 passengers or by buses that can carry 45 passengers. Service capacities were determined according to population density of the related region. If personnel were in a densely populated area, high capacity services would be arranged. For instance, if it is possible to take all personnel by one high capacity service instead of two lower capacity services, one service would be preferred. Travel times were also considered. If it took long time to pick up all personnel by one service vehicle, personnel would be divided into two separate groups and assigned to different services.

It is obvious that GIS technology provides a great advantage for the whole route creation process. It helps to analysis each personnel's distance to the created route. During

the creation of each segment of the route, personnel locations were considered, analysis were conducted and when the distance between route and personnel exceeded the 1-kilometer criteria, related route segment would be re-arranged. Tools to make such precise analysis are only available on a GIS software.

All advantages about GIS is mentioned above, the study is not limited by the software. For each route that has been created, opinions of a university personnel were taken who had the knowledge about current service routes, employees' physical conditions and traffic conditions at the operation time of services. Meetings were arranged at the times when both sides were available and some suggestions that were made by him were considered. For instance, at first, some routes were created without knowing which personnel had physical disabilities. After the first meeting, related routes were re-arranged to take the personnel from their footstep who had that sort of physical condition.

2 images below are an example of a decision that has taken during one of mentioned meetings. Each dot on images represent locations of personnel in the given area. The first image shows two different routes which was created before the meeting. In the second image it can be seen that routes have changed a little and the ones who were represented with green dots, were allocated to the other service route according to the decisions that were made in the meeting.

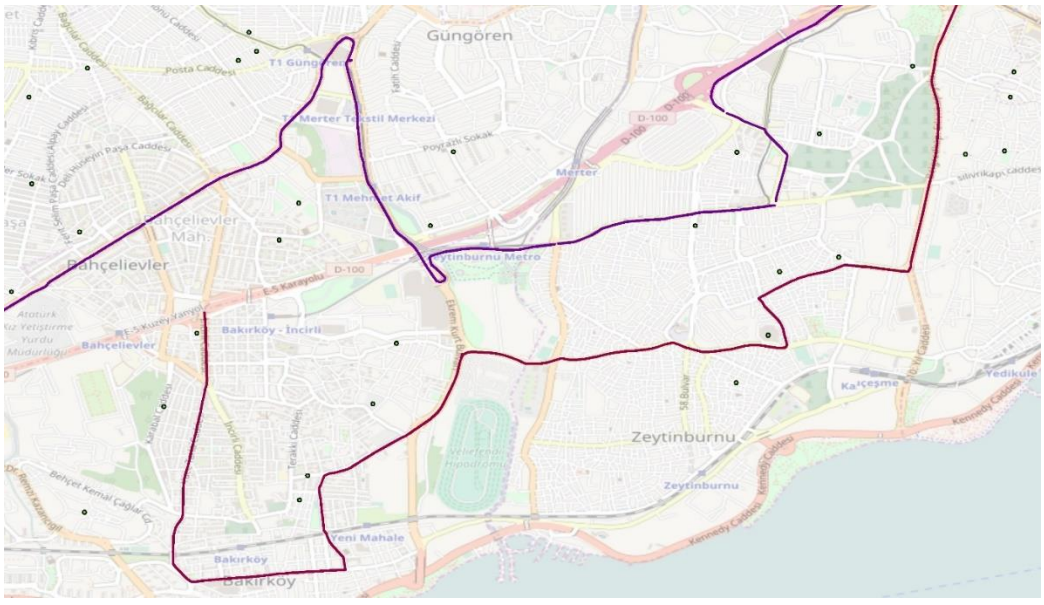

Figure 5.6 Representation of two routes created before the meeting.

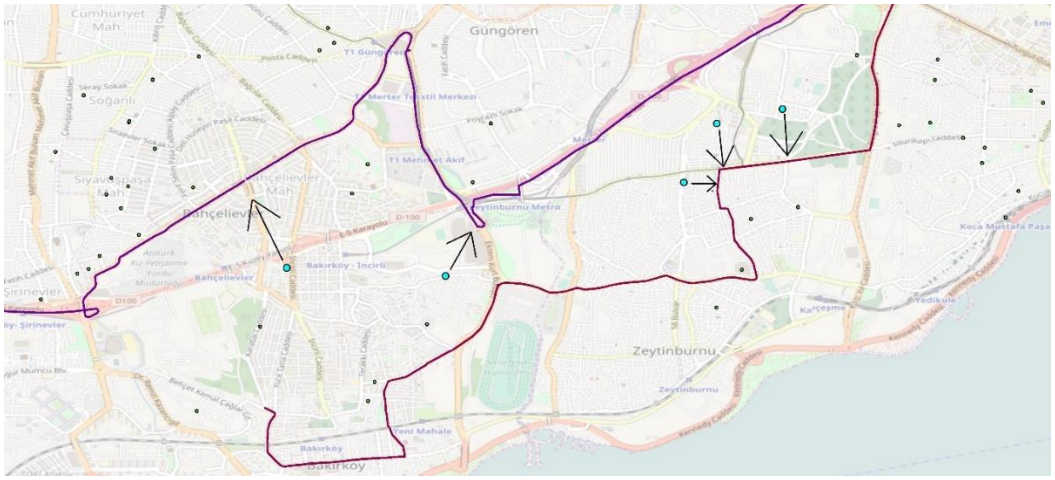

Figure 5.7 Representation of two routes created after the meeting.

The creation process of each road can be summarized as follows; checking each personnel's condition to see if they have any physical disability or not, accordingly, adding each route section on top of the previous section by checking the distance between the route and the personnel due to the one kilometer criteria. When a route was approved and all related personnel was assigned to a service vehicle, each dot that is representing that personnel is removed from the map in GIS software to prohibit any confusion. Simultaneously, an excel sheet was prepared for keeping the record of each service route.

5.6. Alternative Solutions for the First Method

To be able to reduce number of personnel services and total travelled distance accordingly, some precise implementations were made during the study which had not been thought at the beginning of the study. These implementations were made for Kandilli personnel from both Asian and European sides.

5.6.1. Kandilli Personnel from European Side

There are 17 personnel who live on the European side and working at Kandilli campus. Three different services; Kucukcekmece, Sarıyer and Yedikule, had been carrying these personnel to Kandilli campus in the current system. Services were travelling approximately 200 kilometers in total. An idea was developed to reduce that number; picking

up the related personnel to Guney campus with services which already were created to carry Guney campus personnel. After their arrival to Guney campus, they will be transferred to Kandilli campus with another service, which is only assigned for them. This implementation alone provided a saving approximately 175 kilometers.

Table 5.2 Current route lengths of Kandilli services in kilometers (in both directions).

Küçükçekmece – Kandilli	**Sarıyer – Kandilli**	**Yedikule - Kandilli**
90	56	52

Table 5.3 Route length between two campuses in kilometers (in both directions).

Guney Campus – Kandilli
25

5.6.2. Kandilli Personnel from Asian Side

Like the idea that was mentioned in section 5.6.1, an alternative was considered for some personnel who live on the Asian side and work in Kandilli campus. At first, 3 different routes which are Sultanbeyli, Goztepe and Tuzla were planned for these personnel.

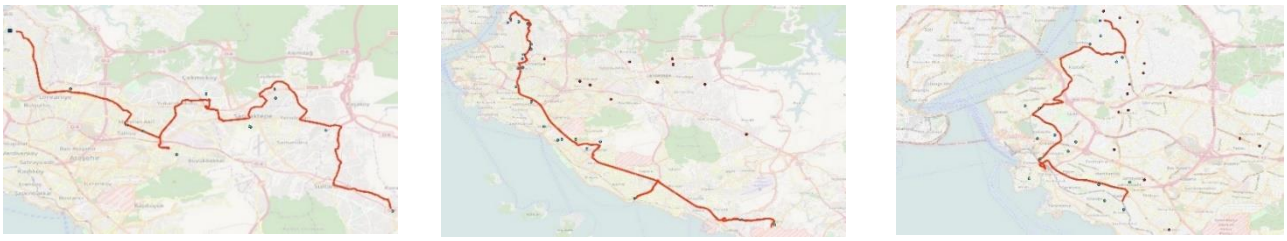

Figure 5.8 Three routes planned before alternative solution.

Table 5.4 Current route lengths of Kandilli services in kilometers (in both directions).

Sultanbeyli - Kandilli	**Tuzla – Kandilli**	**Göztepe – Kandilli**
72	96	60

After routes had been created, it had been seen that one of the prepared routes cannot be counted as an optimal solution since the personnel service on the related route has only

11 personnel and travels a long distance. That is why an alternative was developed. According to new solution, related personnel will be taken with services which already were created to carry Guney campus personnel, similar to method on 5.6.1. As it was indicated earlier, all Guney campus services from Asian side use Fatih Sultan Mehmet Bridge and all these services must pass through Kavacık interchange. At this interchange, Kandilli personnel will be transfer to another service which will be waiting for them at Kavacık to take them to Kandilli.

Figure 5.9 Kavacık – Kandilli Route.

Table 5.5 Route lengths in kilometers (in both directions).

Kavacik – Kandilli
12

As total distance covered by three service vehicles is equal to 228 km and Kavacık-Kandilli route is about 12 kilometers (in both directions), this alternative solution will save more than 200 kilometers.

This method shows that sometimes such manual implementations is a necessity, thus automated methods such as programming can be inadequate.

5.7. The Second Method

As it was mentioned earlier, it was considered to combine both public transportation and personnel services with the second method. Hub system, which will be described broadly in following sections, was used to make this combination work.

5.7.1. Terminology of the Second Method

Some terms need to be explained to facilitate the understanding of the method.

Transportation Hub: A hub is defined as "An airport, train station, etc. that is used by large numbers of people." according to Cambridge dictionary. In this method, hubs will be used as meeting points for large numbers of personnel.

At each hub, *Hub Services* will be waiting for the personnel and when a certain amount of personnel have arrived, they will be transported to university by these services.

These hubs are located at central points in the city. For instance; transfer points between metro lines, or intersection points between metrobus and metro lines are selected as hub points to make them easily reachable for personnel.

Local Service: These services will pick up the personnel from their houses and transport them to the nearest hub location.

Hub Service: These services will pick up the personnel from Hubs and transport them to campus.

Campus Service: These services will pick up the personnel from their houses and will transport them directly to campus.

Transfer Service: These services will transfer personnel to Kandilli and Saritepe campuses. They will be waiting at determined transfer locations and when all assigned personnel have arrived, personnel will be transported to Kandilli or Sarıtepe campuses.

Type-A lines: Bus lines which are directly going to university without need of any transfer to another line and M2 metro line which is connected to the university via M6 metro line.

Type-B lines: Metro and Metrobus lines which are directly going to hubs without need of any transfer to another line.

Routes of local and campus services will be designated with the same routing system as the first method. Meaning that, personnel may walk up to 1 km to reach these service routes.

In the following sections; mentioned zones, personnel who are in that zones and hub locations will be shown.

5.7.2. Zones of the Second Method

Zones in this method are created according to Type-A and Type-B lines that are defined in the previous section. Buffers which have radius of 1 km are created around these lines, thus zones were formed. The first buffer is created around Type-A lines which are bus routes that are passing through bus stations near the campus. Inside of the first buffer creates the *Zone 1*. In the very next image, *Zone 1* can be seen. Also, personnel in that zone are highlighted with cyan dots.

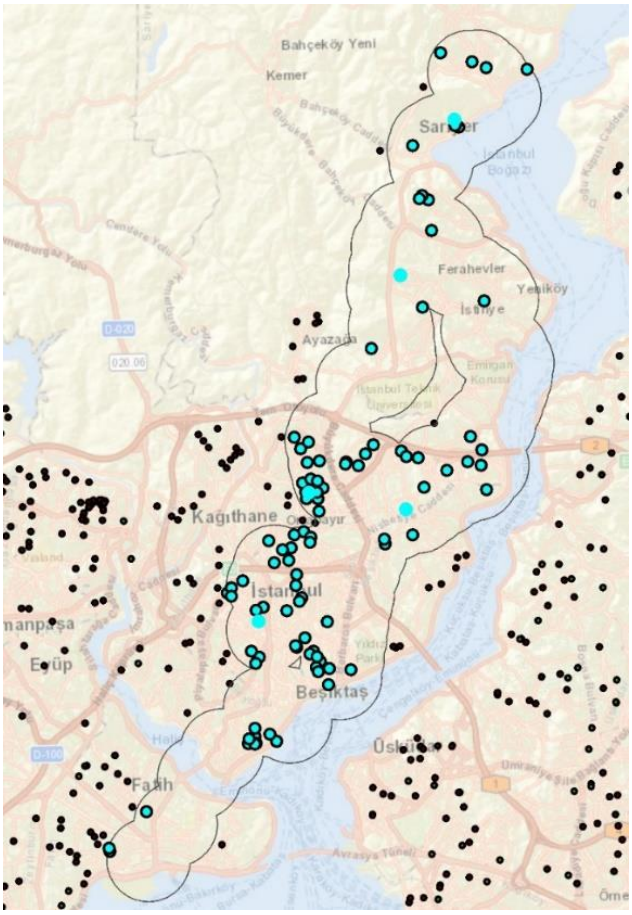

Figure 5.10 Zone 1 and personnel who are in the zone.

Table 5.6 Type-A lines.

43 R
59 R
59 RH
59 RS
559 C
M2 Metro Line via M6

The second zone, *Zone 2,* is created around Type-B lines by the same way as the first zone. This zone contains both metro and metrobus lines in the city. In the next image, borders of this zone and the personnel who are represented with green dots can be seen.

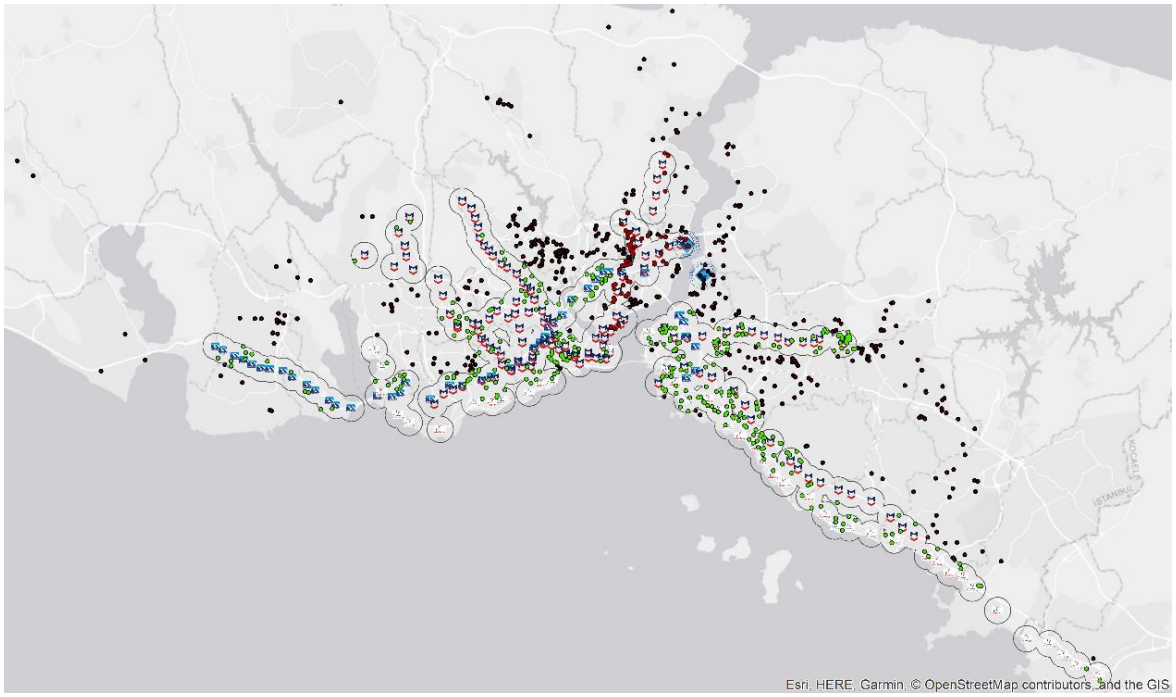

Figure 5.11 Zone 2 and personnel who are in the zone.

Table 5.7 Type-B Lines.

M1A Metro Line
M1B Metro Line
M3 Metro Line
M4 Metro Line
M5 Metro Line
Marmaray Line
Metrobus Line

After creating the first two zones, the third zone was formed automatically which signifies anywhere out of these first two zones.

5.7.3. Basics of the Second Method

For each personnel, there are three travel options available in this method. According to rules that was explained in sections 5.7.2, three zones were created for each three options. Locations of the personnel were used to determine who should be assigned to which option. Shortly, the personnel in the first zone will only use public transportation unless they are in

walking distance to the nearest hub point, second zone personnel will use both public transportation and personnel services from related hub points, the rest of the personnel, who are in the third zone have two options according to their locations; they either will be picked up from their houses via *local services* to be transferred to hub points and they will be transferred to campus by *hub services*, or they will be using *campus services* to directly reach to campus.

Second and Third options include *transportation hubs* which will be used as transfer station before reaching to university. Hub system is the key point of this method. Details of each combination and new terms that will be used in this method, such as *transportation hub*; *local services* and *hub services* etc. was explained in the terminology sections 5.7.1. It can be said that compared to the first method, the second method is more comprehensive.

There is a hierarchy between three options. *Zone 1* is at the top of this hierarchy. Meaning that, if personnel is in the first zone, he/she must use the first travel option; public transportation. He/she cannot be assigned to another travel option. If the personnel are out of the first zone, location of the personnel was checked if he/she is in the second zone or not. If the personnel is in *Zone 2*, then he/she must use travel option two. Otherwise he/she will be in Zone 3 and travel option 3 will be used. Following flow chart explains this hierarchy.

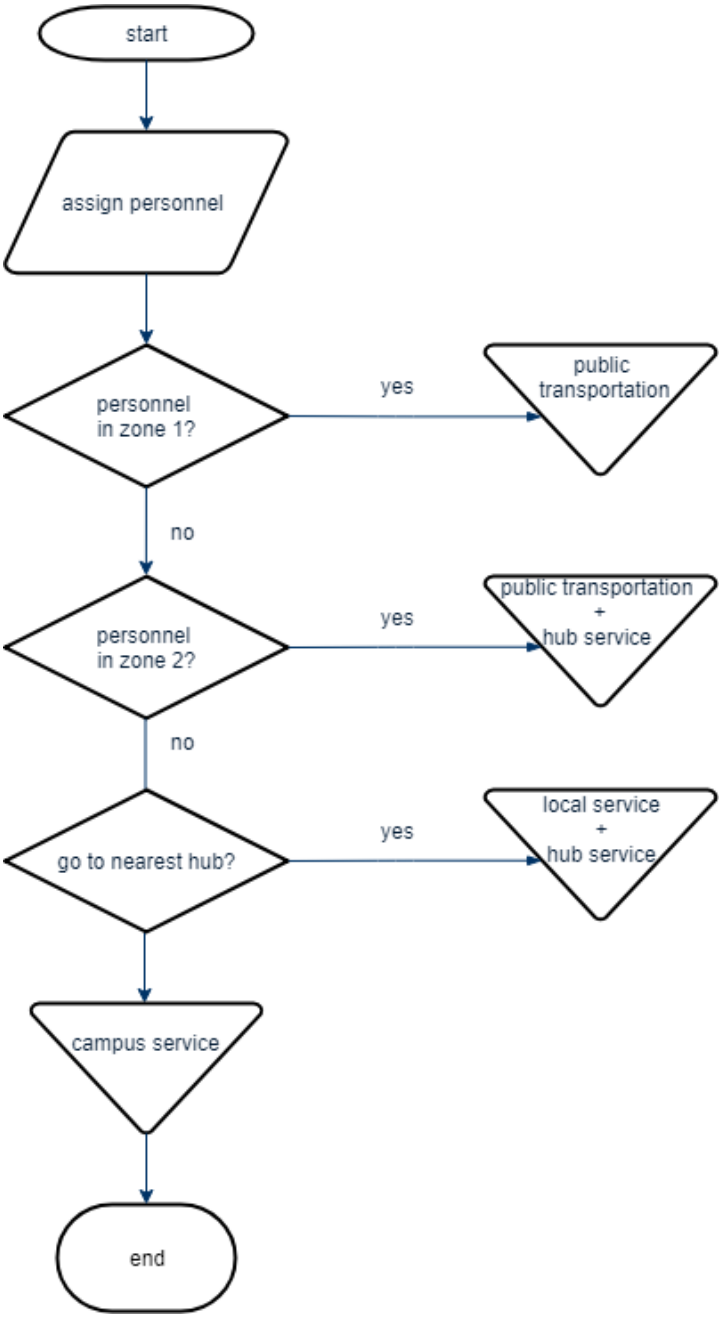

Figure 5.12 Flowchart of the Second Method.

At this point it is beneficial to mention that, personnel who work at Kandilli and Saritepe campuses will be picked up the same way which is mentioned in the section 5.6. Meaning that, they will be assigned to services that were created for Guney campus personnel and then transferred to Kandilli or Sarıtepe via *transfer services* at determined transfer locations. Transfer point for Kandilli personnel who live in the European side is determined as Guney campus. They will be transported to Guney campus like any other

personnel and then they will be taking to Kandilli campus via *transfer service.* For personnel who live in the Asian side, transfer points are determined as Kavacik and Beylerbeyi.

5.7.4. Hub Locations

There are some basic criterions for distribution of hubs. First, to make them reasonable, each hub point was selected in central parts of the city which were easy to maneuver for reasonably big vehicles in the system. In other words, intersections on the primary roads were preferred to provide mobility for both *hub* and *local services*. To make hub points easy to reach for *Zone 2* and some *Zone 3* users, some hubs were located at transfer centers of metro and metrobus lines. However, some other hubs, such as Cekmekoy and Kavacik, which were only serving for *Zone 3* users were selected at near centers to related personnel.

Table 5.8 Locations of Hubs.

Hub Locations	
Beylikduzu	Kozyatagi
Cekmekoy	Perpa
Edirnekapi	Umraniye
Gaziosmanpasa	Uskudar
Kavacik	Zeytinburnu
Kazlıcesme	

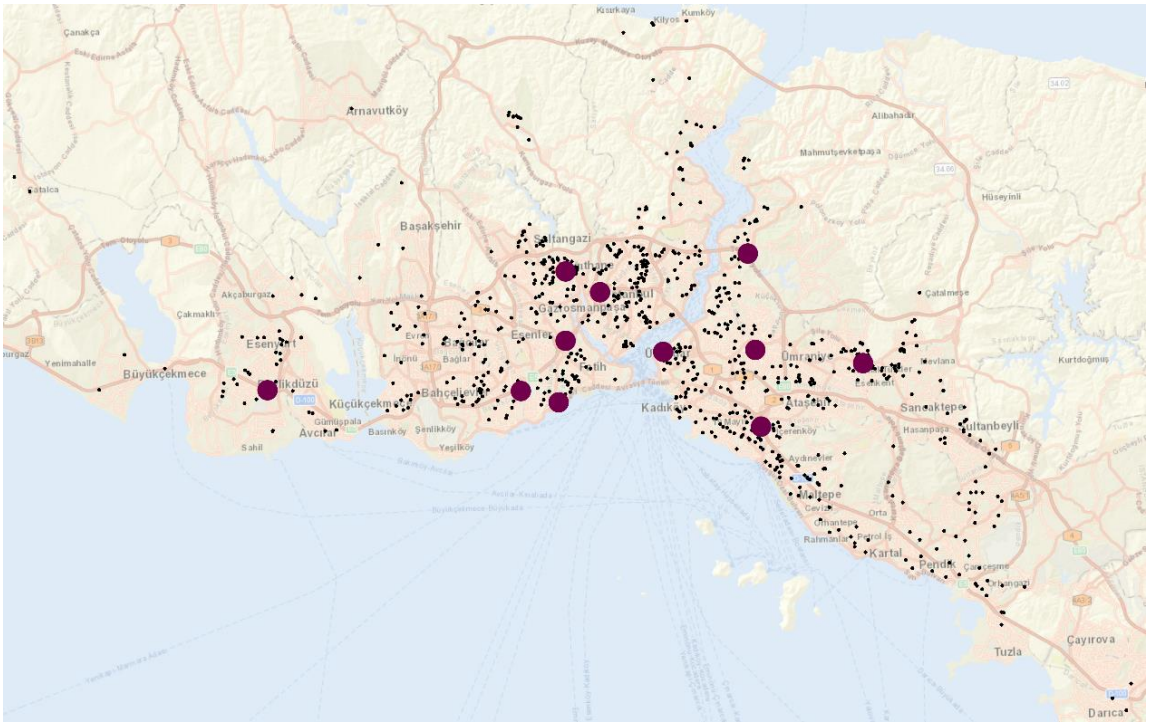

Figure 5.13 Distribution of hub and personnel locations.

Hub points have not been created for some personnel who live in districts such as Ortakoy, Kurucesme and Arnavutkoy as they are few therefore taking them to campus directly is more effective than creating a hub and collecting them there.

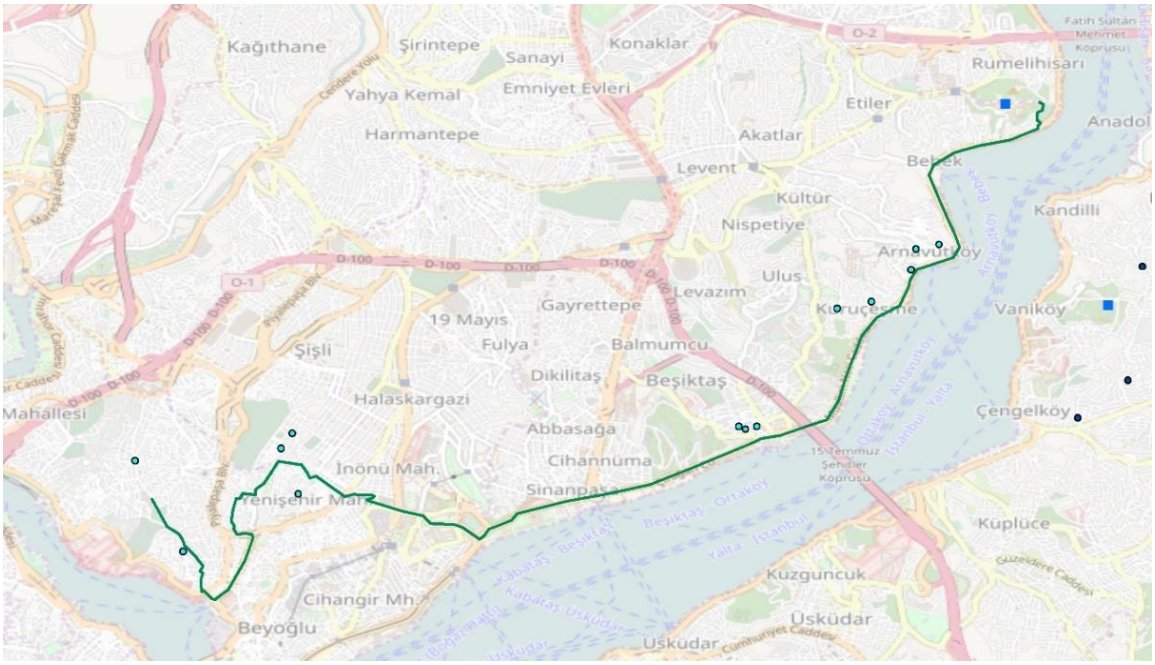

Figure 5.14 Route of a campus service.

5.7.5. Personnel Using Hub System

In this method, personnel from the second and third zones will be taken from designated hubs to be delivered to the campus. Personnel in these two zones will be assigned to the nearest hub and will be asked to reach that hub by public transportation if there is a Type-B line in 1 kilometer. Otherwise, when personnel are not able to reach a Type-B line, they will be assigned to a local service vehicle and these services will deliver them to the related Hub point. Although, there are some exceptions for personnel who are in the third zone which is explained in the next section.

5.7.6. Personnel Not Using Hub System

There are 2 different group of personnel in this category. First group, as it is mentioned, consisted of personnel who are in the first zone. Meaning that, if personnel locate 1 kilometer near to Type-A line which directly travel through university, related personnel will not be assigned to a service route and will be asked to use that line to reach to campus.

For instance; a personnel who is living in a residence 500 m away from the bus line 59R which is a Type-A line according to the study, will use that line and reach to university without being assigned to any service.

Second group not using the hub system is consisted of personnel who are in the third zone. As it is mentioned in the previous section, some of the personnel are transferred to the nearest hub. To decide which personnel will go directly to campus, locations of all personnel in the third zone is examined, district wise. For instance; some districts such as Gokturk is far away from the nearest designated hub point. In this case, instead of taking them to the nearest hub, they are directly transferred to campus by *campus services*.

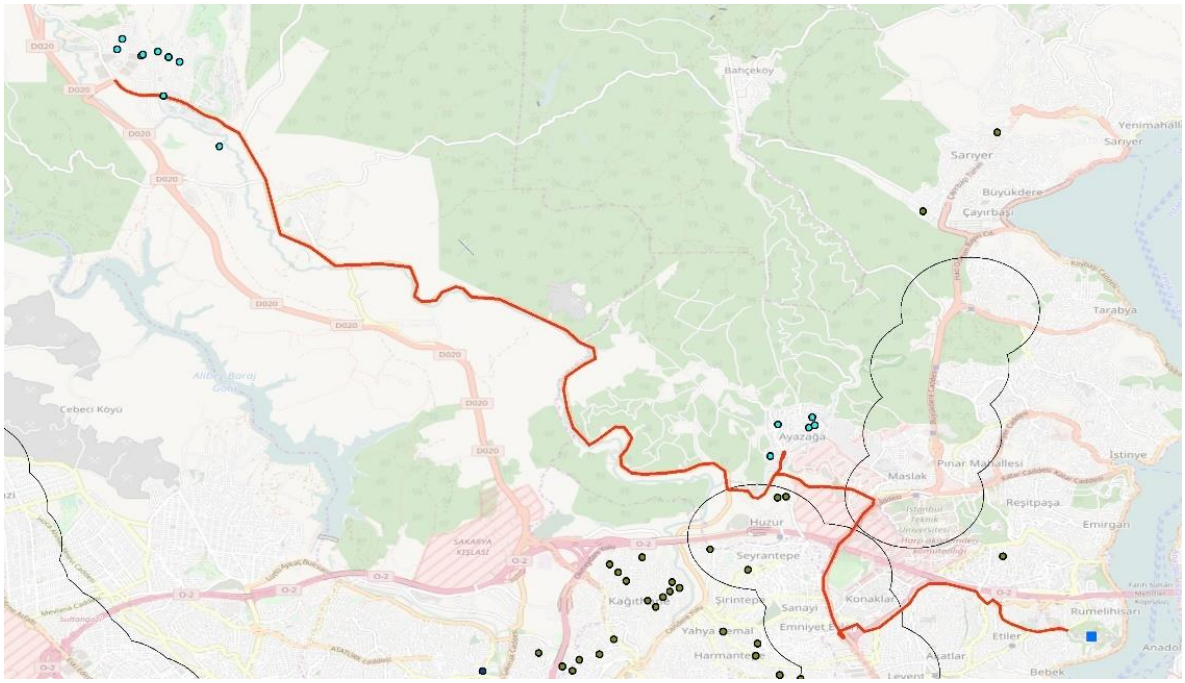

Figure 5.15 Gokturk service route.

5.8. Application of the Second Method

Whole application process of the first method lasted longer since lots of routes had to be created manually. However, in the second method, since map is divided into three different zones and some personnel are not assigned to any route, application lasted for a shorter time.

In the first step, zones were created via ArcGIS, a leading GIS software. The personnel who are in the *Zone 1* were determined by analyzing tools of the software. A list of the related personnel was created, and they were removed from the map to avoid any confusion.

Secondly, for the rest of the personnel, hub locations were determined. While determining the hub locations several conditions were considered as it is mentioned above. In addition, besides basic rules, it can be said that it is a manual process and every hub location has its own reasons to be selected.

After zones and hub locations were created, personnel that are in *Zone 2* were listed and assigned to the closest hub. The related personnel will be using a metro or a metrobus line to reach to hub. Like the personnel that are in *Zone 1*, personnel from *Zone 2* were also removed from the map to avoid any confusion.

Rest of the personnel who are outside of the first two zones, were automatically assigned to third travel option which is combination of both; direct transportation to campus via *campus services* and transfer to the nearest hub via *local services*. Implementation for the personnel who are in the third zone includes more interpretation as there are no restrict rule. Third zone was examined district wise and it was decided to add a hub for some of those districts.

After all assignments and options were determined, according to number of personnel for each line, service capacities were determined, and results were listed.

5.9. Importance of Railway Systems in the Second Method

As well-organized and comprehensive railway systems have massive importance in a city, administrators of developing cities such as Istanbul are planning new lines to improve cities' current rail system. At the time this study is conducted, Istanbul Metropolitan Municipality has a master plan for its railway system which aims to have adding new lines in the coming years and increasing the total kilometers of metro lines from 233 km to 1100 km.

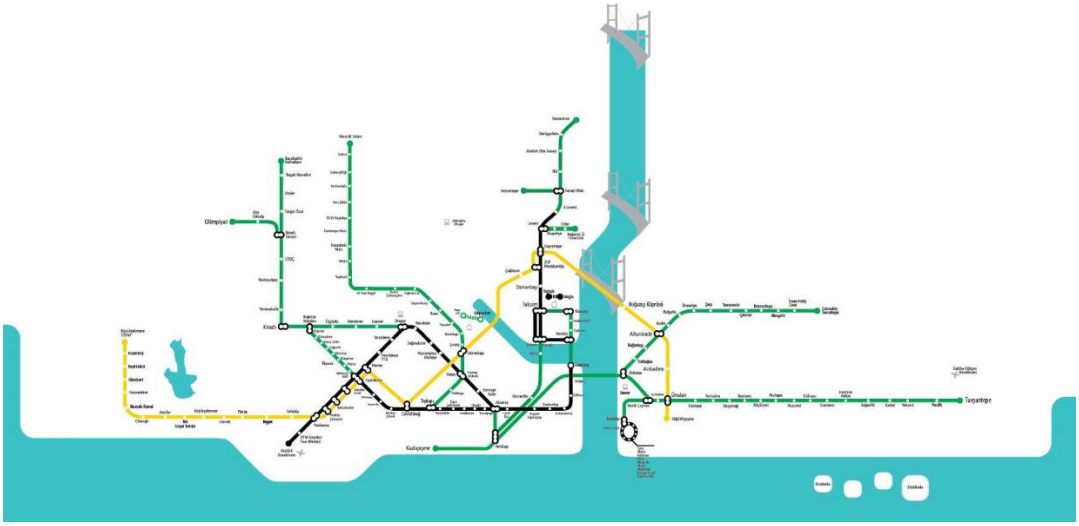

Figure 5.16 Current railway lines in Istanbul.

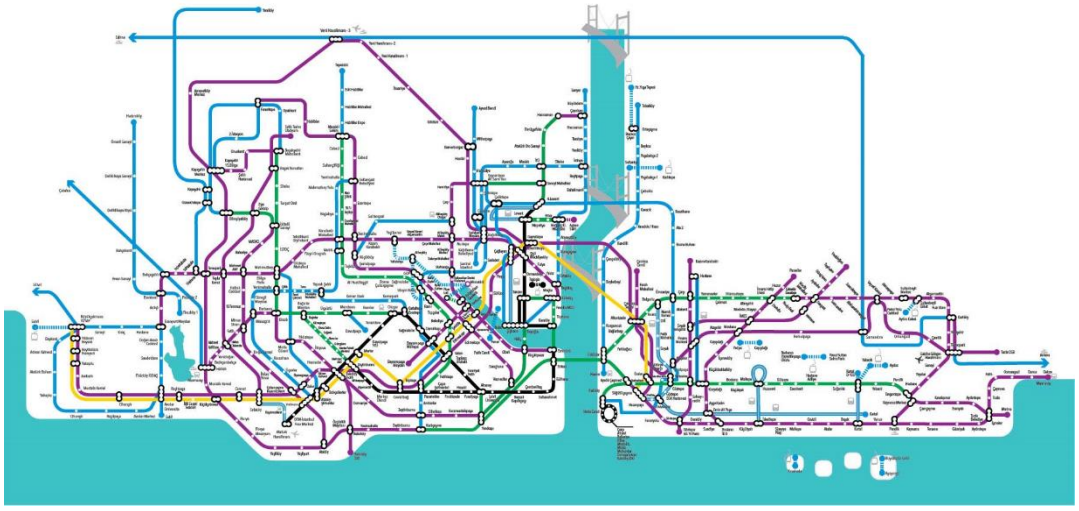

Figure 5.17 Planned railway lines after year of 2023.

As the rail system improves, hub method will become more efficient since it combines personnel services with public transportation via rail systems. This makes the hub method a more sustainable mode, as the need for service vehicles will decrease by additions of new rail lines.

6. ANALYSIS AND COMPARISONS

In this section, results of both methods represented in this study and current status will be analyzed in various aspects.

6.1. Analysis of Current System

In the current system, there are 62 personnel vehicles for 961 personnel. In daily basis, total distance that is traveled by those vehicles is 3460 km, in both directions. Each services' final destinations are campuses and they pick up personnel from their houses. One issue with the current status is that most of the services had been serving with low capacities, this made the optimization possible. There were 1284 seats available in the current system and only 961 of them were occupied. In some cases, there were service vehicles carrying only two personnel every day. In the first method, this issue tried to be fixed by optimization of service routes. However, in the second method, taking it even further, combination of public transportation with the current system is aimed, by using hub system.

Table 6.1 Occupancy ratio.

Seat Occupancy
0.748

6.2. Analysis of the First Method

In the first method, current system was tried to be optimized by some rules, which are mentioned in the previous sections. By checking the numbers after the optimization, it can be said that there are improvements. Number of personnel services are reduced to 38 and total traveled distance is also reduced to 2626 km. Compared to current system, main difference is that the personnel will be picked up from a road section, which is, mostly, 1 km away from personnel.

Information about the service fleet after the optimization is given in the following table. 961 out of 965 seats are assigned for personnel.

Table 6.2 Occupancy ratio.

Seat Occupancy
0.9958

Table 6.3 Service fleet in the First Method.

Service capacities	Number of service vehicles
15+1	7
17+1	4
20+1	1
21+1	1
23+1	3
27+1	15
30+1	2
35+1	1
45+1	3
47+1	1

6.3. Analysis of the Second Method

In the second method, numbers are reduced even further. Especially, total distance that is covered by service vehicles is decreased significantly. Decreasing by 54.7 percent, new distance became 1570 km. The main reason for a such decrease is that all services does not destined to campus, as it is mentioned in the previous sections. Number of personnel services is equal to 42 in this method, however, number of vehicles which are destined to campus are 30.

As the second method has more complex structure, more detailed analysis is necessary to understand the insights of the method. Method will be analyzed in terms of zones, service types, transfer numbers and service capacities.

Table 6.4 Comparisons of three options.

	Current Status	**First Method (Optimization)**	**Second Method (Introducing Hub System)**
KM	3460	2626	1570
Total Number of Vehicles	62	38	42
Total Number of Vehicles Destined to Campus	62	38	30

6.4. Zonal Analysis

Number of personnel in *Zone 1*, who are not assigned to any services, is 106. This number is equal to 11 percent of all personnel registered in the current system. As it is mentioned in the previous sections, personnel in this zone will use metro or bus lines, which are listed in the previous sections. In other words, these personnel will be integrated into public transportation. They will reach to campus via these lines, without any transfer.

Table 6.5 Personnel distribution according to zones.

Total Number of personnel	**Number of personnel in Zone 1**	**Ratio (%)**
961	106	11

In *Zone 2*, personnel use metro and metrobus lines to reach to hub location, where they are assigned to. There are 442 personnel within *Zone 2*. After reaching the hub, these personnel will be transported to campus via *hub services* with addition of 237 personnel from *Zone 3*, who are transported to the nearest hub via *local services*.

Remaining 176 personnel will be using *campus services* for a direct access to campus.

Table 6.6 Distribution of personnel according to service types.

	Hub Services	**Local Services**	**Campus Services**	**Transfer Services**
Number of Personnel	679	237	176	62
Number of Services	18	12	9	3

Service capacities were determined according to number of personnel in each service line. List of vehicles and capacities for each service type are given below.

Table 6.7 Service fleet in the Second Method.

Hub Services		**Local Services**		**Campus Services**		**Transfer Services**	
Service Capacities	Number of service vehicles	Service Capacities	Number of service vehicles	Service Capacities	Number of service vehicles	Service Capacities	Number of service vehicles
15+1	1	15+1	2	15+1	2	15+1	3
17+1	1	17+1	2	17+1	2	27+1	1
27+1	1	19+1	1	23+1	1		
30+1	1	20+1	3	27+1	2		
35+1	2	27+1	4	30+1	1		
45+1	12						

Table 6.8 Occupancy ratio.

Seat Occupancy
0.9832

6.5. Transfer Analysis

Transferring between vehicles may be seen as negative outcome of this method, however, number of transfers is limited to one for 96.1 percent of the personnel. Only 38 Kandilli and Sarıtepe campus personnel will be transferred twice before reaching to their campus.

Table 6.9 Transfer distribution of personnel.

	Number of Personnel			
Transfer Numbers	Zone 1	Hub Service	Local Service	Campus Service
0	106	127		176
1		277	237	
2		38		

Table 6.10 Percentages of transfers.

Transfer Numbers	**Percentages (%)**
0	42.5
1	53.6
2	3.9

6.6. Integration with Public Transportation

In current system and the first method, there is no integration with public transportation, transportation of personnel is provided via direct services to campus. However, in the second method, 40 percent of personnel (383 personnel) will be integrated with public transportation. Compared to current system and the first method, this can be counted as a huge increase.

These personnel can be divided into two groups, according to way of using public transportation. First group is representing the ones in *Zone 1*, who are using *Type-1 lines*

(M2, 43R, 59R, 59RH, 59RS, 559C) to reach to campus without any transfer. There are 106 personnel in this group.

Second group use public transportation to reach hub locations, these personnel use *Type-2 lines* (metro and metrobus lines). 277 personnel are forming this group.

Achieving such numbers by only metro lines and couple of bus lines is important in a metropolitan. As the rail system web grows, integration with public transportation will reach to higher amounts.

6.7. Visual Comparison

To have more clear insights about two methods, all routes in both scenarios are combined in two different maps.

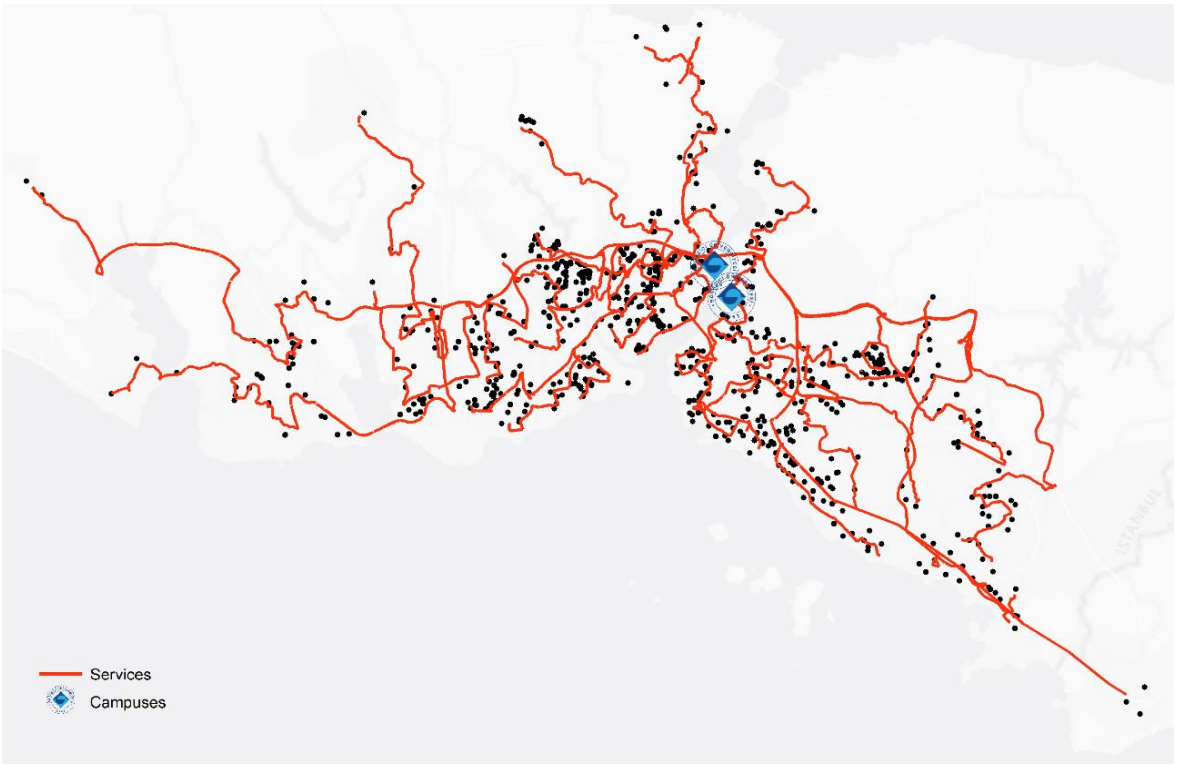

Figure 6.1 Visual representation of the First Method.

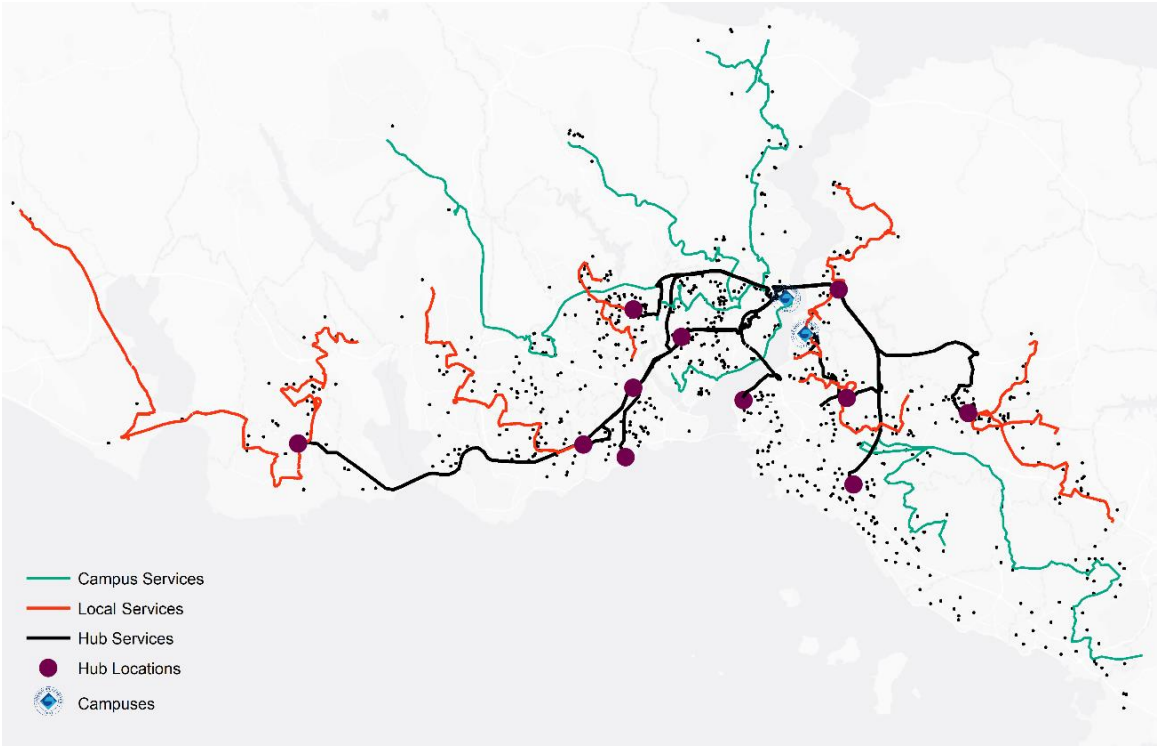

Figure 6.2 Visual representation of the Second Method.

At first sight, even though total travelled distance has been reduced by 24 percent in the first method, compared to the second method, it can be observed that the first method has tighter route web as it is expected because total distance has been reduced even more in the second method with the help of public transportation and hub system (55 percent). By checking the numbers and visual representations, it is observed that the second method is more beneficial in terms of vehicular traffic.

6.8. Economic Comparison

For 2018 education year, 2 different companies made offers for service system of Bogazici University. Details of their offers for 3 routes are given in the following table.

Table 6.11 Comparison of two offers.

	Distance (Km)	Vehicle Capacity	**Company A**		**Company B**	
			Fee	Unit Price (TL per km)	Fee	Unit Price (TL per km)
Route A	68	16	250.00 TL	3.68	392.00 TL	5.76
Route B	56	19	230.00 TL	4.11	305.00 TL	5.45
Route C	70	45	525.00 TL	7.5	653.00 TL	9.33

From the given table, economic comparison between hub and non-hub scenarios has been made to see which method is more feasible. For such comparison, Cekmekoy Hub is selected.

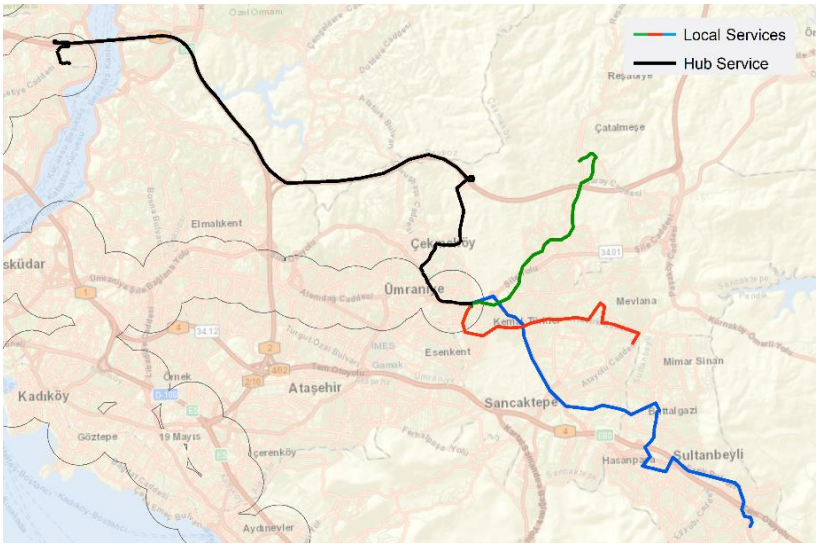

Figure 6.3 Cekmekoy Hub Routes.

Cekmekoy hub consists of *3 local* and *2 hub services* for 90 personnel. If hub system hasn't been used in given district, there would be 4 direct services to campus. Details of these services are given below.

Table 6.12 Economic comparison of two methods.

Hub Scenario			**Non-Hub Scenario**		
Service Vehicles	Traveled Distance (Km)	Fee (TL)	Service Vehicles	Traveled Distance (Km)	Fee (TL)
15+1 (Local)	15.5	57.04	15+1 (Direct)	32.4	119.23
17+1 (Local)	7.8	28.704	17+1 (Direct)	32.3	118.86
19+1 (Local)	7.9	32.469	19+1 (Direct)	41	168.51
45+1 (Hub)	24.5	183.75	45+1 (Direct)	24.5	183.75
45+1 (Hub)	24.5	183.75			
	∑ =	485.713		∑ =	590.35

As the total fee is less in hub scenario, comparison shows that hub system is also a better solution in terms of economy.

6.9. Travelled Distances in Arterials

Another idea that is effective in the development of the system is that keeping service vehicles in local roads and avoiding their negative effect to arterial traffic, as much as possible. By checking the numbers in the given table, it is observed that hub system also serves to such idea.

Table 6.13 Distance comparison.

	Total Distance (Km)	**Distance in Arterials (Km)**
First Method	2626	1299
Second Method (Hub system)	1570	646

As traffic problem is one of the major issues in Istanbul and most of this traffic occurs at main arterials of the city, spreading hub system idea among private and state institutions may help to avoid adding extra burden to traffic in arterials.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

The study has mainly aimed to bring a new model for transportation of personnel in private or public sector, by using GIS technology. Two methods have been introduced to serve such purpose, and comparisons between these methods with the current system has been made to have an insight about each method. The study has been conducted by using currently registered personnel's data in Bogazici University.

Methods of the study can be briefly summarized as follows, the first method is optimization of the current system by some restricting rules, while with the second method a new approach, hub system, has been introduced. By the analysis have been made, results have shown that new methods may improve the current system. In both methods, number of service vehicles and total distances that is travelled by these vehicles have been reduced. Such improvements would help companies economically, as lower numbers of vehicles cost them less, however, a greater benefit may be achieved if methods of this study spreads among multiple businesses. Since service vehicles serve in rush hours, and these vehicles somehow one of the reasons of traffic in these periods, lowering the number of service vehicles would help to improve society's conditions in both economically and environmentally.

Compared to optimization that has been made in the first method, hub system that is introduced in the second method promises even better results. Total distance that is travelled by service vehicles are less in the hub scenario compared to non-hub scenario, and by the analysis that has been made in previous sections, hub system is a better method economically. This already favors hub system, however, hub system offers more. First, hub system keeps more of its movement in local roads to keep its effect less on arterial traffic as much as possible. This wouldn't make a difference for employer firm, but it would for city. In a scenario where the system spread among firms, reducing the vehicular traffic on arterials during rush hours may help city's economic condition massively, as previous studies showed that a 10 percent worsening in Central Business District accessibility would decrease regional productivity by about 1 percent (Reason Foundation, August 2009).

Integration with public transportation is another benefit of hub system. Current system and the first method do not consist any integration with public transportation, whereas hub system integrates personnel with rail systems.

In overall, after analyzing three options, conclusion can be made as following; hub system is even more efficient compared to the optimal solution of conventional systems.

7.2. Recommendations

Implementation of proposed methodology may be helpful for decision makers and researchers. Methods of the study can be used to have optimum solutions for personnel transportation. Improving the idea beneath the study may be aimed by new researches.
For future studies, some recommendations are given below;

- Conducting similar studies by the help of GIS with different conditions and restrictions, to compare results.
- Conducting studies on decision makers' behaviors and their openness to new ideas, and how to convince them.
- If one of the methods of study is applied, a follow up research can be conducted to determine effects of the applied improvements.

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