Integration of Personnel Services with Public Transportation Modes: A Case Study of Bogazici University

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ABSTRACT

Personnel service is a common application that is offered by employers to provide comfortable transportation for the employees. It is mostly applied in developing countries and even though it brings some convenience for both sides, it also has downsides. Especially, the extra cost of the system for institutions and additional congestion created during peak hours due to the wrong optimization of the service routes are huge problems that can be fixed by proper applications. Moreover, such an optimization would create huge benefits in general because of the extensiveness of the application. Besides some of the employees have complaints about the arrangement of the services which results in private car usage in the long term. The purpose of this study is to optimize the personnel service system in a systematic way and additionally, to combine the system with public transportation to be able to obtain a new approach. Therefore, the first method optimizes the routes whereas the second method gives a new suggestion for the system. The data of the study is obtained from the current personnel services of Boğaziçi University. During the process, the Geographic Information System (GIS) is utilized to investigate all possibilities. The study showed that both of the offered methods results better than the conventional approach by improving personnel welfare, congestion during peak hours and transportation habits.

1. Introduction

Nowadays, increasing population affects every part of the society including daily traffic consequently the quality of life negatively [1]. Therefore, transportation systems are one of the most important dynamics of a city and having a proper public transportation system has massive importance with their economic and environmental benefits that reduce congestion by decreasing the number of vehicles [2,3]. 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 [4]. As an effective solution, public transportation is especially important for the crowded metropolis’s city center [5].

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Even though the main aim of every city administration is to provide well-organized connections throughout the city, the task is not easy to obtain especially for large cities with high demand. In this study, Istanbul is taken as an example with its population over 15 million [6] and 6th place congestion around the world [7]. The data is obtained from personnel services of Boğaziçi University to introduce a new approach as a prototype for future improvements in related areas.

In most of the developed countries, cities provide multiple transportation solutions for trips of their residents, however, independent from their availability, during the rush hours they serve in full capacity which motivates private car usage as a more comfortable option that results in congestion. According to the Bureau of Transportation Statistics [8], 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. Especially, individuals with high-income level tend to use private car whereas lower incomes are willing to use public transportation more [9]. So, income level and public transportation demand have an inverse correlation [10]. To solve this dilemma, both private sector and state institutions offer a free of charge option called personnel services that act as a mean of public transportation and provide comfort for employees of a given workspace that meets the transportation need of the personnel and carries them from their residence to their workplaces. 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 judgments can have important and various equity impacts: Available transportation facilities affect people’s social and economic opportunities [11-13]. Improving transport accessibility is important to cope with social inequality. One focus of transportation equity issues is surely job accessibility [14-16]. In this case, it is significant that the personnel services are equally offered to all without separating anyone.

Nowadays, the route planning of personnel services is being conducted manually. Any usage of systematic knowledge or computer-based technology is beside the point. The study aims to prove that a systematic approach can optimize the traditional methods feasibly and the integration of the system with public transportation might give outstanding results while reducing fuel consumption, congestion, and expenditures of the institution. In that sense, the contribution of the study will affect the city in a wider perspective by offering an adaptable system solution that covers all institutions.

1.1 Background

Even though the personnel service system has many advantages for a developing country, a study, made with the subject group of this research, showed that 25.3% of the registered users did not use the system and who did not prefer to use personnel services, stated that shuttle routes were not favorable, because of the availability of faster alternatives, long service routes and early pick up time. So, the current route planning has a lack of efficiency which decreases its utilization [17]. However, if it is arranged according to the demand, users might show increasing interest in the system. The analyze of San Francisco Bay Area for Personalized demand-responsive Transit (PDRT) systems, that allows the passenger to schedule according to themselves, shows that approximately 60% of the participants are willing to consider PDRT as an option [18].

In the literature, there are two types of routing problems related to their pattern namely changing route and stable route. Cargo companies can be an example for the first one that has a changing route every day [19]. Contrary, a personnel service is an example of static routing that follows the same route every day. Therefore, it must be planned efficiently at the first stage since the concept is widely used and accepted. However, it also creates an economic burden on the limited budget of the institutions, in this case, universities that must lower their external expenditures to spend more on academic purposes. Rising costs, especially for the transportation of personnel, might lower the
academic purpose of the university [20]. Moreover, the service system adds extra load to the traffic during peak hours. To find a solution for all those problems, many universities are searching for new approaches for the personnel transportation optimization to university [21].

Over time, innovative solutions are investigated to find a solution without worsening the problem. With this concern, a research conducted in Seattle observed that using bus stops as hubs to collect the personnel, as suggested in this study, doesn’t affect bus schedules negatively [22]. In Utah, a shuttle route is proposed to connect to the railway system to prevent private vehicle usage. In another study, routes are offered for shuttles to metro stations to minimize the costs for users and providers [23]. In consideration of all the examples, a combination of shuttle services and public transport is essential and might bring benefits for an efficient transportation system.

2. Methodology

The methodology of the study is divided as data and analysis parts. In the data part, the current situation of personnel services will be explained and in the analysis part, two methods will be analyzed separately. Firstly, a method of optimization will be explained that sets some conditions for optimization. Secondly, a new approach, namely hubs, will be introduced as an alternative.

2.1 Data

The data of this study is obtained from the personnel services of Bogazici University and during the evaluation process of the current situation and each method, GIS (Geographic Information System) will be used as a geographical tool for analysis and visualization.

GIS is a database management system capable of storing, retrieving, analyzing and displaying locational data. Containing geographic and spatial data in addition to attribute data separates it from traditional databases [24]. It is widely used in city and transportation planning [25] with powerful visual support [26]. GIS is used in many areas such as accessibility analysis [27-29], route/site selection for new transportation facilities [30], route optimization [31] fuel consumption optimization [32]. The comprehensive usage of GIS enables to conduct studies from various backgrounds as literature showed.

2.1.1 Current Status

The data of this study is obtained from the personnel services of Bogazici University and during the evaluation process of the current situation and each method, GIS (Geographic Information System) will be used as a geographical tool for analysis and visualization.

According to the current data of the system, there are 62 services for 961 personnel in the system that refers 60% of all personnel. The total travel distance for all of the services equals 3460 km per day in both directions. The services are always between the campus and personnel houses and more importantly, they are not operating with full capacity. Only 961 seats are occupied out of 1284 available seats with an occupancy ratio of 0.748.

Information about the route, personnel addresses and passenger number of the current services are obtained and it is understood that there is plenty of room for further optimization due to high percentage of vacancies in the current services. Some of the services are given as an example on Table 1. Kurtkoy, Esenler, Ziverbey, Kucukcekmece, and Kandilli are some of the districts in Istanbul where there are 39 districts in total.
Currently, the system works depending on the service company that defines the routes according to the location of personnel. The process is conducted by personal experience and knowledge, without any systematic approach. Even though the price policy for the bidding process might change, at the end the fee depends on the fuel consumption of all services in total. So, total distance traveled is the key to pricing. Since the profit margin of the service company doesn’t affect from the road length, spending time to optimize routes isn’t logical in their point of view. Moreover, the services take the personnel from their houses that means that they must extend their roads for each person separately resulting in more expenditure for the university. The current locations of personnel houses and service routes are shown in Figure 1.

<table>
<thead>
<tr>
<th>Service Name</th>
<th>Number of passengers</th>
<th>Service capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kurikoy - Guney</td>
<td>8</td>
<td>16+1</td>
</tr>
<tr>
<td>Esenler - Guney</td>
<td>8</td>
<td>16+1</td>
</tr>
<tr>
<td>Ziverbey - Guney</td>
<td>8</td>
<td>16+1</td>
</tr>
<tr>
<td>Kucukcekmece - Kandilli</td>
<td>3</td>
<td>16+1</td>
</tr>
</tbody>
</table>

Currently, the system works depending on the service company that defines the routes according to the location of personnel. The process is conducted by personal experience and knowledge, without any systematic approach. Even though the price policy for the bidding process might change, at the end the fee depends on the fuel consumption of all services in total. So, total distance traveled is the key to pricing. Since the profit margin of the service company doesn’t affect from the road length, spending time to optimize routes isn’t logical in their point of view. Moreover, the services take the personnel from their houses that means that they must extend their roads for each person separately resulting in more expenditure for the university. The current locations of personnel houses and service routes are shown in Figure 1.

**2.2 Analysis**

During this study, the main objective is to optimize personnel services by using GIS. Due to the pricing system that suggests payments depends on total travel distance personnel service optimization should be based on to reduce the total distance. To this end, two methods are offered. The first one aims to reduce the number of services by optimizing routes whereas the second one suggests combining services with the public transportation system.

**2.2.1 1st Method**

The idea behind the method is to limit the service routes with only primary, secondary and collector roads so that individuals have to reach a predefined area to take the service. The critical part is the location of those meeting points that must be accessible within a certain influence area that is defined by the American Public Transport Association [33]. Previously, walking distance is used in some researches as 400m, 500m, 800 m. and so on [34-39]. By considering the size of Istanbul, the maximum walking distance is decided to be placed in less than 1 km away from the house of each employee. The route of the service serves as a station throughout the way. The two exceptions for
the limitation are that if there is no other feasible option or for the ones with disabilities, then residential roads might be used.

![Diagram of Bosphorus crossings and university campuses]

**Fig. 2.** Location of Bosphorus crossings and university campuses

The location of İstanbul covers two continents where employees spread two different part of the city. There are different crossing options and one campus on each side as in Figure 2. The campus on the European side is called Guney campus and the one on the Asian side is Kandilli campus that needs only 3 services currently. Therefore, it must be noted that the main focus during optimization will be on Guney campus. Since both campuses are closer to Fatih Sultan Mehmet Bridge (FSM), it will be used as the main crossing. Only the ones who live closer to 15 July Martyrs Bridge will use it due to its feasibility. The other options are not suitable in distance as well as in price.

Considering the set of conditions (1km, FSM and main roads) mentioned, the new roads are created for each part by projecting all roads and personnel to the map. The routes are drawn from the first passenger house until the campus in a systematic way that is explained in Figure 3 in detail. The process of creating the route will continue for each employee and after each change to make sure that it fits everybody. If service has to leave primary, secondary and collector roads necessarily, the route is designed to turn back to the main road immediately to prevent time and fuel consumption.
Service capacity was another consideration that varies between 15 and 45 passengers, therefore they must be arranged according to the density of the region. However, the service time should be considered as well to prevent successive stop-and-go motion which increases travel time significantly. While deciding the routes, the traffic conditions of the road at peak hours are considered as a time-related aspect and the improvement are made accordingly.

Fig. 3. Flowchart of the 1st Method

Fig. 4. Example of the initial version of two routes and the routes after optimization

2.2.1.1 Manuel Application for Kandilli Campus
Kandilli Campus locates isolated from the majority of the university. It is for graduate students specialized in the fields of earthquake engineering, geodesy, and geophysics. Herein, the population of the campus is quite low including employees. However, it is still a necessity to provide equal conditions for every employee, therefore a solution must be prepared for Kandilli as well.

Currently, there is 17 personnel who live on the European side and work at Kandilli campus. They are transferred with 3 separate district services (Kucukcekmece, Sarıyer, Yedikule) that equal approximately 200 km in total which gives a relatively high amount per employee. That is why the system optimized in a way that they will come to Guney campus with existing services and then they will be carried by only one service to Kandilli. Such an arrangement will save approximately 175 km.

<table>
<thead>
<tr>
<th>Service 1</th>
<th>Service 2</th>
<th>Service 3</th>
<th>Guney Campus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Küçükçekmece - Kandilli</td>
<td>Sarıyer - Kandilli</td>
<td>Yedikule - Kandilli</td>
<td>Guney Campus - Kandilli</td>
</tr>
<tr>
<td>90</td>
<td>56</td>
<td>52</td>
<td>25</td>
</tr>
</tbody>
</table>

The same logic is applied to the personnel services coming from the Asian side to Kandilli campus. There are also three of them, however, their route is longer, and therefore, integrating them with existing services resulted with a better solution. The only difference is the transfer point of the employees that is chosen as the intersection of all three services namely Kavacık because bringing them to Guney campus and transferring to Kandilli would take extra time and wouldn't be feasible as well.

<table>
<thead>
<tr>
<th>Service 1</th>
<th>Service 2</th>
<th>Service 3</th>
<th>Kavacık - Kandilli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sultanbeyli - Kandilli</td>
<td>Tuzla – Kandilli</td>
<td>Göztepe – Kandilli</td>
<td>Kavacık – Kandilli</td>
</tr>
<tr>
<td>72</td>
<td>96</td>
<td>60</td>
<td>12</td>
</tr>
</tbody>
</table>

The optimization at the Asian side resulted in saving more than 200 km. as indicated in Table 3. As a result of both Asian and European sides, almost 400 km more are reduced with a manual implementation for Kandilli campus.

2.2.2 2nd Method

As mentioned before, the main idea for the 2nd method is to combine personnel services with public transportation systems based on a transportation hub logic. The hub will be a central point where there are public transportation options such as metro or Metrobus that is a form of BRT (Bus Rapid Transit) or intersection of each. A large number of employee will be collected from those hub points through hub services to the campus. To be able to connect employees who can’t reach to a hub by themselves, the local services will pick up the employees from their houses and transfers them to the nearest hub. If the system of hub and local service doesn’t work feasibly for some employees then they will be transferred through campus services directly to the campus. Transfer
services will be used to obtain the connection between two campuses. The design of the routes will follow the same logic as the first method meaning that employees may walk up to 1 km.

The lines that are connected to the campus directly without the need of any other transportation mode are called type-A lines (43R, 59R, 59RH, 59 RS, 559C and M2 Metro line via M6). To detect and eliminate the employees who can reach to the university by using type-A lines, a zone of 1km away from each stop of those lines are created on the map as Zone 1. Then, the employees who stay inside Zone 1 are marked to be removed from the personnel service system.

The lines that directly connect an employee to a hub without the need for transfer are called type-B lines (M1A, M1B, M3, M4, M5, Marmaray, and Metrobus). Zone 2 is created on the map by drawing buffers of 1km circles to detect the employees who can reach to a hub with public transportation. Each stop of every metro and Metrobus lines are marked on the map and the employees nearby are represented with green dots in Figure 6. The black points are personnel who can’t feasibly reach the campus with public transportation. The area that covers black dots will be stated as Zone 3.
To sum up, there exist three travel alternatives depending on the zoning system;

The employees in Zone 1 will travel with only public transportation unless one of the hub points is not closer to them.

The employees in Zone 2 will use public transportation to arrive in a hub from which they will take a hub service to the campus.

The employees in Zone 3 have two options; either they will use campus services that will carry them directly to the campus or they use local services to reach to a hub point and then take a hub service to the campus.

The flowchart of the method is represented in Figure 7 as explained below. Moreover, employees will use transfer service from Guney campus to Kandilli campus, if needed. The only exception is for the ones who work in Kandilli campus and live on the Asian side. They will transfer from Kavacık as mentioned in the first method.
2.2.2.1 Hub Locations

The selection of hub points was made by considering different priorities for different zones. They are mostly chosen in central locations and intersections of primary roads to maneuver easily for the large vehicles and preferably close to public transportation transfer centers for reachability. The exceptions of these concerns were only for the employees in Zone 3. The hubs in Zone 3 were selected according to the houses of personnel or transfer service point (Kavacik).
2.2.2.2 Personnel categorization

The personnel can be categorized in two ways according to their hub usage; personnel who uses hubs and personnel who don’t. The ones in Zone 2 will reach hub services via public transportation nearby, whereas some of the personnel in Zone 3 will take local services to reach the hub service point. However, there are the ones who live far from any hub point meaning that it is not feasible to carry them to a hub, therefore, they will use campus services to go to the campus directly. For example, Gokturk is a district which is far from any hub or public transport option, therefore a direct campus shuttle will be attained for the area. Zone 1 can be categorized as the group that doesn’t use hubs, however, they will be excluded from the categorization because they don’t need to be a part of the service system.
3. Results and Discussion

In the first method, the situation is tried to be fixed by optimizing the routes and picking points of personnel. As a result, 38 personnel services are decided to be enough to carry every employee and the traveled distance reduced to 2626 km from 3460 km. The most significant difference compared to the current version is that the personnel will be picked up from a location at most 1 km away from their houses instead of in front of their houses. In total, 961 employees occupy 965 seats with 0.9958 occupancy rate. The services are tried to be kept small incapacity to prevent dissipation of time by continuous stop-and-go motion as in Table 4.

Table 4
Fleet size and capacity for the 1st method

<table>
<thead>
<tr>
<th>Service capacities</th>
<th>Number of service vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>15+1</td>
<td>7</td>
</tr>
<tr>
<td>17+1</td>
<td>4</td>
</tr>
<tr>
<td>20+1</td>
<td>1</td>
</tr>
<tr>
<td>21+1</td>
<td>1</td>
</tr>
<tr>
<td>23+1</td>
<td>3</td>
</tr>
<tr>
<td>27+1</td>
<td>15</td>
</tr>
<tr>
<td>30+1</td>
<td>2</td>
</tr>
<tr>
<td>35+1</td>
<td>1</td>
</tr>
<tr>
<td>45+1</td>
<td>3</td>
</tr>
<tr>
<td>47+1</td>
<td>1</td>
</tr>
</tbody>
</table>

In the second method, a completely new approach is suggested with different purposes such as including public transport to the system. So, the concern was not only to carry personnel most sufficiently but also encourage them to use public transportation. Again smaller services are preferred due to time and movement concerns as mentioned in the 1st method.

Table 5
Fleet size and capacity for the 2nd method

<table>
<thead>
<tr>
<th>Hub Services</th>
<th>Local Services</th>
<th>Campus Services</th>
<th>Transfer Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Capacities</td>
<td>Number of service vehicles</td>
<td>Service Capacities</td>
<td>Number of service vehicles</td>
</tr>
<tr>
<td>15+1</td>
<td>1</td>
<td>15+1</td>
<td>2</td>
</tr>
<tr>
<td>17+1</td>
<td>1</td>
<td>17+1</td>
<td>2</td>
</tr>
<tr>
<td>27+1</td>
<td>1</td>
<td>19+1</td>
<td>1</td>
</tr>
<tr>
<td>30+1</td>
<td>1</td>
<td>20+1</td>
<td>3</td>
</tr>
<tr>
<td>35+1</td>
<td>2</td>
<td>27+1</td>
<td>4</td>
</tr>
<tr>
<td>45+1</td>
<td>12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The 2nd method allows further developments, however, it must be investigated in detail due to high complexity and unfamiliarity. The number of personnel in Zone 1 equals 106 that is % 11 of the number of all personnel (961). So, Zone 1 serves as a reduction of unnecessary service charge. The majority of employees are using hub services that are 442 employee from Zone 2 and 237 employees from Zone 3. Remaining 176 employee will use campus services due to their location. The negative
outcome of the method may be the transfer between vehicles, however, % 96.1 of employees will transfer only ones and the rest contains the personnel who goes to another campus.

### Table 6
Personnel distribution for each service

<table>
<thead>
<tr>
<th>Service</th>
<th>Number of Personnel</th>
<th>Number of Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hub Services</td>
<td>679</td>
<td>18</td>
</tr>
<tr>
<td>Local Services</td>
<td>237</td>
<td>12</td>
</tr>
<tr>
<td>Campus Services</td>
<td>176</td>
<td>9</td>
</tr>
<tr>
<td>Transfer Services</td>
<td>62</td>
<td>3</td>
</tr>
</tbody>
</table>

High levels of car dependence can have harmful effects on both people’s health and the environment [40,41]. Besides, traffic accidents [42], traffic congestion [40] and physical inactivity related disorders [43] have all been related with increasing levels of private car use. Therefore, the increase in the number of public transport users is important. In the 2nd method, the integration of the system with public transportation is aimed and achieved successfully. 40 percent of employees (383 personnel) will use public transport either to reach the campus directly or to hub service. In general, this method is open to new adjustments according to the master transportation plan of government that is foreseen new railway systems all around Istanbul as in Figure 10. In the long term, the integration will improve and spread more efficiently as the railway system grows. The key to this method is the hub system that encourages people to use public transport and introduce it as an option in their life. Moreover, active usage of public transport daily might create a habit for the employees. Since personnel service is a very common concept in Turkey for both public and private sector as mentioned earlier, this change and course of habit will reach many people which should be the aim of a metropolitan like Istanbul.

During peak hours, most of the congestion occurs at the main arterials in Istanbul. Therefore, the idea was to reduce congestion by avoiding some of the arterials if they are not necessary. So that the congestion won’t be affected by personnel services whereas services will save time. In the 2nd method, this objective is satisfied and the travel distance in arterials is less than half for the hub system, partly due to less distance traveled in total. If such a system spreads among private and public institutions that offer personnel services, traffic may relief. Whereas, the 1st method tries to use main roads mostly where there is congestion during peak hours to obtain a satisfying time optimization and encourage employees to avoid using private car. Therefore, it is not suitable for avoiding main roads. On the contrary, it has other priorities such as reachability to the walking distance for every employee in the most efficient way.
The application of the second method consumes less time than the first one because it includes less manual intervention instead it directly follows the existing form of the city transport plan. Also, there is less personnel to carry on to the campus directly. The only manual part of the method is Zone 3 since it requires more interpretation with its similarity of the 1st method. That must be kept in mind that there is the reality that manual intervention means more possibility of human error. So, keeping it in the minimum would be a more time-saving and efficient option.

From an economic perspective, the payment is based on the total travel distance of the services as mentioned before. The results are given in Table 7 to compare each method. In the 2nd method, % 54.7 decreases are obtained with 1570 km total distance. Even though the service number become 42 that is higher than the 1st method, the ones that go to campus are only 30 which results in an enormous decrease kilometer wise. Both methods resulted in better outcomes than the current version of the system. The 0.748 occupancy ratio of the current system increased to 0.9958 by the implementation of the 1st method.

Table 7
Comparison of the current state, 1st method and 2nd method

<table>
<thead>
<tr>
<th></th>
<th>Current Status</th>
<th>First Method (Optimization)</th>
<th>Second Method (Introducing Hub System)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KM</td>
<td>3460</td>
<td>2626</td>
<td>1570</td>
</tr>
<tr>
<td>Total Number of Vehicles</td>
<td>62</td>
<td>38</td>
<td>42</td>
</tr>
<tr>
<td>Total Number of Vehicles Destined to Campus</td>
<td>62</td>
<td>38</td>
<td>30</td>
</tr>
</tbody>
</table>

As can be observed the second method contains less connection, therefore, it occupies less space on the traffic which is a very positive feature in terms of congestion.

Fig. 11. Visual representations of the 1st and the 2nd method
4. Conclusion and Recommendation

The study has aimed to offer a new approach for personnel service system that is integrated into the system by using GIS technology. The personnel data for the study is taken from Bogazici University and two different methods are compared with the existing system.

In both of the methods, vehicle number and total distances reduced, whereas the second method resulted better in terms of distances while improving the congestion and public transportation usage. The main contribution of the study lays more than meets one example, it creates the opportunity to spread such an optimization among multiple institutions which results in economic improvements and a decrease in congestion.

The benefits of the second method go beyond the company and reach the city and society itself. In a scenario that the method spreads, the reduction of the traffic will have a huge economic effect on the city.

Public transport integration is another important benefit of the second method.

Implementation of the proposed method to most of the services for the public and private sector would result with great economic benefits for institutions and government while relieving congestion. In parallel with this purpose, some recommendations for future studies are as follows;

- The same method must be conducted again for different data to check its feasibility in all cases.
- Different conditions and restrictions must be specified on GIS for similar studies to compare.
- The extra load on public transportation must be studied to understand the necessary capacity required.
- The outcome of the methods of congestion must be studied to justify local load usage.

References


