DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

ASSESSING THE OPTIMALITY OF BUS STOP LOCATIONS IN URBAN AREAS USING QUANTITATIVE TECHNIQUES

by
Taha HATCHA

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İZMİR

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We have read the thesis entitled "**ASSESSING THE OPTIMALITY OF BUS STOP LOCATIONS IN URBAN AREAS USING QUANTITATIVE TECHNIQUES**" completed by **TAHA HATCHA** under supervision of **PROF.DR. K. MERT ÇUBUKÇU** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ABSTRACT

Transportation represents the city's veins. It must cover every single part of it, in order to desert different services and serve the population. However, the city shape is changing with time, which have an impact on the transportation system users, for that reason the adaptation of the transportation system is necessary.

Bus stops locations have considerable effects on the quality of the transit service, especially when it comes to functioning time, which is one of the top priorities of bus riders.

This study proposes a method of determination of the bus stops number and locations, it provides practical recommendations to aiming to minimize the total time spent on the journey of users of public transportation. In the scope of this study, the number and location of bus stops for a given bus line in the city of İzmir were increased by two different methods, iteratively the number of bus stops that minimizes the total duration was determined by the passengers as follows: arrival at the stop, boarding, dwelling and going to the destination point. The riders of the bus were located around the bus line by 500m, their origin and destination points were chosen randomly in this area. In a next step, the same method has been applied on diffrent the numbers of passengers riding the bus. On this line, the optimal stop numbers and positions are determined on the line according to different passenger numbers. Thus, the optimal stop numbers and positions are determined on the line according to different passenger numbers.

Key-words: optimization, public transportation, users time, GIS

KENTSEL ALANLARDA OTOBÜS DURAKLARININ EN UYGUNLUĞUNUN (OPTİMALİTESİNİN) NİCELİKSEL YÖNTEMLER İLE İRDELENMESİ

ÖZ

Ulaşım kentlerin yaşam kanallarıdır ve nüfusun bütününe hizmet vermek amacı ile kentlerin en uç noktalarına kadar ulaşmak zorundadırlar. Öte yandan kentler sürekli bir değişim içerisindedir ve ulaşım sistemlerinin bu değişime ayak uydurmaları gerekir.

Duraklarının yerlerinin yer seçimi, kentiçi otobüs sisteminin etkşnlği açısından son derece önemlidir. Özellikle kullanıcıların harcadıkları zaman açısından, toplu taşım durakların yer seçimi belirleyicidir.

Bu çalışma, toplu taşıma araçlarının en yaygın kullanılanlarından birisi olan otobüslerin durak sayılarının ve yerlerinin, yolculuk yapan kişilerin yolculuk için harcadıkları toplam zamanın minimize edilmesi amacı ile belirlenmesine yönelik bir yöntem önerisi niteliğindedir. Çalışma kapsamında, İzmir il merkezinde seçilen bir otobüs hattı için otobüs duraklarının sayı ve konumları, sabit aralıkta ve aralıklara eklemeli olarak iki farklı yöntem ile arttırılmış ve iteratif olarak yolcular tarafından durağa geliş, biniş, yolculuk ve duraktan varış noktasına gidiş olarak toplam süreyi minimize eden durak sayıları tespit edilmiştir. Otobüse binen ve kişilerin durağa girmek için çıkış noktaları ve duraktan indikten sonra vardıkları noktalar, otobüs hattına en fazla 500m. mesafede olmak üzere rastlantısal olarak seçilmiştir. Daha sonra bu çalışma otobüse binen kişi sayıları farklılaştırılarak tekrar edilmiştir. Bu sayede belirlenen hat üzerinde farklı yolcu sayılarına göre optimal durak sayıları ve konumları tespit edilmiştir.

Anahtar kelimeler: Optimizasyon, toplu taşıma, kullanıcı zamanı, CBS

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CHAPTER ONE

INTRODUCTION

Public transportation systems are valuable in boosting cities and urban areas, it helps to create more employment and financial opportunities. They bring numerous environmental, economic and social benefits to individuals and communities, but mostly this sector does not get enough attention as it should. It does not only offer more trades in the domain, but it comes with a tremendous refreshment for businesses at different levels. According to the American Physical Therapy Association APTA, about $32 million of increasing business can be generated from an investment of ten million dollar in public transportation. Every billion-dollar invested in public transportation bring up more than fifty thousand occupations opportunity, every ten million-dollar in invested in transit service produces $30 million of benefits from commercial trades, and for every ten million dollars invested in operating profits around $32 million. More than 71% of public backing for public transportation goes to the private sector, to create and support hundreds of thousands of jobs. Also, Hotels in urban areas with direct accessibility to airports get more advantage of 11% of revenue per room. Same thing for home values, it can achieve up to 42% higher when it is located in, or near the neighborhoods with high-frequency public transit.

When it comes to the environment, using public transit makes a considerable difference. While several countries have progressively undertook the repercussions of the global warming, data shows that transport sector is one of the main reasons of the greenhouse gas emissions. In term of air pollution generation, public transportation options move people with more efficiency, with significantly less air pollution compared to moving a person in a solo-occupant vehicle. According to DART, buses produce only 20% as many carbon monoxides per passenger compared to a car user, less than 10% hydrocarbons, around 75% nitrogen oxides and 25% nitrogen oxides. Undoubtedly, riding public transit would make a big difference with time, especially for having a better air quality and preservation of natural resources. During the summer, when detrimental ozone levels increases, the public transportation get more credits and make more difference.

Public bus fleets are a good example of progress in alternative fuels adoption. APTA reports that public bus fleets are made of diesel-hybrid by 16.9%, Liquefied Natural Gas 16.7%, 7.4% biodiesel, and 0.3% other alternative fuels, like hydrogen, propane, and electric. Other alternate fuel options are certain to make an impact. The Department of Transportation in the United States reported in 2017, more than 300 zero-emissions buses, including electric and hydrogen, operating across country.

Public transportation has a good impact of population’s well-being and the individuals the health in general, while driving as the basic alternative for daily trips is linked to several cons. The comprehension of the ways transportation and quality of life intersect widespread and has been the subject of many research, (Hisako T. 2010) indicated that people using public transportation on regular basis for their daily-trips, are less exposed to the risk of diseases such diabetes, hypertension and obesity than drivers, and even the walkers or bike users, the research argued that the distance public transportations walk to and from stations is estimated longer compared to the distance walkers or bike users travel to and from work. The study took a sample of drivers and public transportation commuters in Japan, they were adjusted for other factors such as age, gender, smoking, and others, and the results show that 44% are less risky to overweight, the risk of having blood pressure and diabetes is reduced for public transportation users by 27% 34% respectively. In addition, public transportation riders benefit from having less stress coming from the daily driving, especially in the congested areas, it helps also to reduce traffic congestion by conveying many people in a limited space compared to using cars.

The public transportation as an alternative of driving keeps the users away from the steering wheel, it gives them the opportunity to enjoy free time, and spend it in reading, studying, working, or being entertained instead. Cumulatively, this time can finish up with weighty amounts, the American Public Transportation Association claimed that those living in areas with public transportation in America, save more than 850 million hours spent on traveling per year. It has been proven that transportation alternatives such as buses, trains, railways, and trams, have higher rate of safety compared to driving, the chance of being in accident can be reduced to more than 90% when taking those transportation options, which makes it ten times safer than traveling by car. And the reason is referred to many facts: transit operators are well trained and way apt than the normal car user, they receive refresher training on a regular basis at least 120 hours of training. According to statistics, accidents due to buses and trains occur at a slighter rate, and with much lower passenger casualty rates compared to car travel option. Another reason is the high levels of security monitoring most transit centers have (Paul M, 2016).

With the countless befits and the awareness raised by the population around the world, public transportation usage frequency augmented significantly, according to Patricia A (2015), year-round transit ridership increased from 5.5% and 8.5% in 2014 and 2013 respectively in Canada, and 2.5% in the worldwide. Therefore, policy makers and researchers are paying more attention to that sector and showing more interest in making improvements in its process. By contrast, bus riders whom are clearly the backbone of transit service, have a much simpler view on things. The frog perspective of the want-to-be riders that stands in the station and peers down the road to see if the planned bus is certainly coming, is perhaps the clearest view. The biggest complaints about buses are the unreliability and the slowness of the service. Bus riders would feel under-appreciated and forgotten when they have to wait more during the transit time. The riders really want two things: That the bus shows up in time (reliability), that it takes them to their destination in a reasonable time. Based on this, the study will shield the light on the passenger’s time and aim to optimize it.

Although different methods are applied with the purpose of minimizing time, the multi-factor process optimization can take diverse shapes and be more complicated. The simplification of the operation process is the first target, in the second place, a proper method of optimization is to be fixed, understood and adapted with the task purposes. A prime example of the time/mechanism optimization is the Jamaican sprinter Usain Bolt, the world record breaker in the 100 meters, 200 meters and 4 × 100 meters relay, he could run the 100 meters with an astonishing 9.58 second. Such impressive accomplishments led scientist to seek for an explanation, Barrow (2012) has identified the way Bolt could improve his speed, through three factors: launching with a high speed off the mark; running at higher altitudes and with stronger tailwinds. These tricks may work, but they are not scientifically satisfying, the main concern here the determination of the factors that make it possible for the sprinter to reach the finish line in 9 seconds, without relying on external providence. Weyand (2016) says, “It’s tougher to get a handle on sprinting mechanics than on feats of strength or endurance,” in the approach he developed each cycle of runners’ legs is divided into two parts: the foot in the air, and when it is stepping on the ground. The study showed that, for most runners, at the highest speed, it takes around a 0.3 second to pick the foot up and put it down in every step. On the other hand, for a fast runner, speed is principally determined by the amount of force he can apply when his foot is landing. So, the proportion of the springer’s weight with the swing time or the part of a second in the air, both make the springer go faster or slower, more weight would give him more power to endure and going further fast, but the heaviness would slow him down by physics low (gravity), likewise, lightweight moves quicker but slighter since the produced force reduces with his total weight. It was concluded that for the best records, a fine adjustment on the runner weight and the force he can apply, that is what makes Bolt breaking the record, and this is the scientific explanation for such optimization of time.

The main principal in the given example is testing the performance of a process to determinate the interval or the value in which main factors coincide with the optimized time. For public transportation, the same principle can be applied in order to reduce the time, knowing that its process involves similar factors. The application of the optimization operation must follow a certain methodology, in management PDCA (Plan Do Check Act) or (Plan Do Check Adjust) is an iterative method based on four steps frequently used in managing, control and the continual enhancement of some methods. Plan is the first step when the solutions and processes are established to carry out the results in harmony with the expected purposes. The establishment of the final outcomes expectations makes the comprehensiveness and the precision of the spec a part of the targeted improvement as well. Likely it starts on a small scale to test the probable effects. The second step Do, is for the implementation of the plan, the execution of the process of collecting data for charting and analysis, graphs can make the task much easier to see trends over several PDCA cycles. The third step (Check) meant to study the measured, collected outputs and compare them with the expected results, it is aimed to look for deviation in implementation from the plan, the appropriateness and completeness of the plan to enable the execution. Finally (Act/Adjust), in this step corrective actions are requested on significant differences between actual and planned results. The analyze of the differences to determine their root causes, the determination of the changes to apply, that will include improvement of the process.

This study is aimed to highlight the optimization of transportation users' time through a practical method, knowing that every optimized second counts and means a lot in the long-term process of transportation system functioning. The remaining of the thesis is organized as follow, in the chapter two, a brief literature review is presented, showing different modalities of bus stop spacing practices, the factors to consider and the way of estimating the access to public transportation, t explains the optimization process and the functioning of simulation, it highlights the importance of time for transportation commuters. The third chapter clarifies the methods to follow, it decorticates the steps and the components of the calculation process. It combines the theorical background from the previous studies, along with the research purposes and the finalities of the process, yet no calculation or even the operational steps, but in the next chapter for data, each step of gathering or treatment of information is demonstrated, this chapter focus mostly on the operations and the way of obtaining data and its usability for reaching the requested results.

CHAPTER TWO

LITERATURE REVIEW

Urban planners, transportation engineers, and researchers have shown remarkable interest in analyzing problems related to public transportation, especially with the urban explosion that emerged more issues. Many studies have been published concerning the improvement of public transportation service. These studies were performed in different ways like social science, sustainable development, focusing on different purposes. And since the objective of this study is to highlight the optimization of transportation users' time, this chapter is aimed to review the research related to bus stop location and summarize their findings. The way that bus operates, and the allocation and distribution of bus stop are discussed. Time optimization for more efficiency for the system operating and some of the existing methods to simulate the functioning are determined.

The literature review of this study has been categorized into four parts; bus stop placing measurements in urban areas, that deals with the theatrical and practical methods that have been applied from the very first studies up to nowadays. The second part is about the access to public transportation by users, their behavior, distribution and the estimation of their travel time. Third part is about the concept of optimization, it clarifies the way a transportation system can be optimized, some examples to illustrate the process of some optimization operation over the time consumed on public transportation. The next part presents the value of time, highlight the importance and the role it plays for transportation system. The fifth and last part describes different methods of simulation, performed by several studies, the factors that have been used frequently and the way they were measured.

2.1 Bus stops locating

The subject of this study is to define the location of bus stops and the distances between stops that matches with the minimal time spent during the process of the bus service by the travel makers. Locations and distances of bus stations are treated as input data, nonetheless, they are not the focus of this study. Rather, the purpose here is to examine the total span of time for choosing bus location along a given bus line. Researchers started trying to identify the relationship between access and dwelling time on public transportation about a century ago, the main concern was the organization of the boarding and alighting stations. This research made the localization of bus stops one of the oldest issues in the field of transportation engineering. Vuchic (1968) stated that there were more than five studies on this subject -between 1913 and 1930- already published by German authors.

The focus of research at that time was about discovering a reasonable method for spacing of and locating stations for public transportation in urban area, typically with the finality of minimizing the travel time.

Later, many works have been published on the examination of stop location and spacing along with related factors, like the bus lines and networks frequency and density, bus and route size. The distinctive approach was the development of techniques and process to create optimized models that propose and analyze several functions, explicitly: Total cost minimization for operators and users. Mohring (1972), Wirasinghe (1981) with researches on the location of the stations for multiple to multiple transport demand, and Kikuchi (1985) analyzing the effect of the stations volume and the time taken by the bus for a defined bus line. User cost minimization on frequency, fleet size and budget constraints by Furth (2000) was an attempt to develop a model of optimization for bus stop placement by a dynamic programming and geospatial simulation. Van Nes (2001) and Li Bertini (2009) assessed models of transit stations spacing and allocation with optimized high-resolution maps and stopping regime data.

Another eminent approach was developed by Kikuchi and Vuchic, (1982) in which the stopping regimes were classified into 3 types: (1) All-Stop; the vehicle stoppings is equal to the number of stop locations. (2) On-Call Stopping; vehicles stop only at those locations where passenger for boarding or alighting exists (This regime is typical for trolley operations and the number of the vehicle stations is fewer than the number of the provided stations) (3) Demand Stopping, the vehicles can stop anywhere the line wherever boarding or alighting is requested, thereby user access distance and time parallel to the line operating regime is used, with some variations.

The number of stops for a given line of a bus trip, under the on-call stopping regime, depends upon passenger demand rate and trip origin/destination pattern. The probability of k passengers using a stop, assuming Poisson passenger arrival pattern, is expressed by:

$$P(k) = (\lambda h)^{k} e^{-\lambda h} / k! \qquad (2.1)$$

where λ is the passenger demand rate of using the stop for access/egress by persons per second, and *h* is the headway in units of time. The probability of vehicle bypassing the stop is obtained by substituting zero for *k* in equation (2.1)

According to Ziari (2007), there are two alternative design methods, the first is based on the determination of the distances between stations as per density of the population: where some values are suggested for the distances between the stations, The distance between stations in the city trade center: 750 to 250 m with a population density of more than 3500 P/km². The distance between stations in the city center, with an average density from 1000 to 3500 P/km², is determined from 200 to 300 m. The second design method is used in the suburb of city, with an average density of less than 1000 P/km², is determined from 250 to 3000 m.

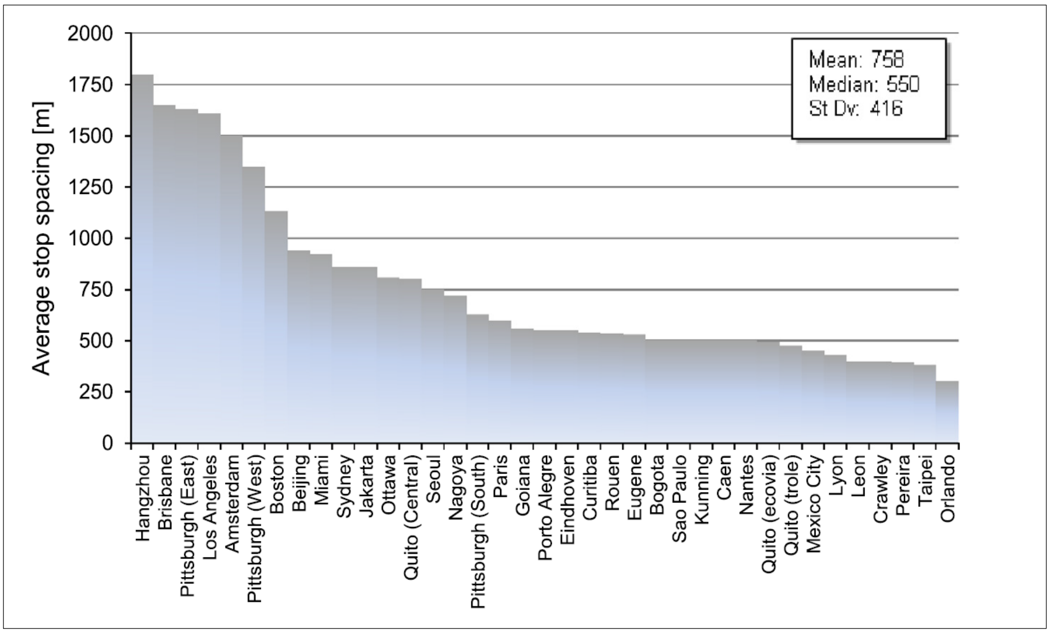

Figure 2.1 the average of bus stations distancing over 37 bus systems around the world. based on Wright (2007)

Before concluding this review of the literature on bus stop locating, we have to discuss some guidelines and current practice of bus stop

The problems related to bus stop design and spacing have been the subject of many engineering textbooks of transport, strategical reports, and guidebooks, often focusing on the conception of benches and shelters, the dimensions of the platform, the height, the station–bus crossing point, interactions with the fleeting traffic, safety and security measurements, availability and allocation. The measurements recommendations in these guidelines are location specific; the common advice for city-center zones is that bus stations must be located no more than 300 m away from each other, whilst for residential areas outside the central business district distances for 300 to 500 m are recommended in the Britain and south America with tinier detachments recommended for the United States. European cities like Rotterdam, Paris, Zurich, and London, with a typical spacing of around 300m to 450 m is common. In Australian cities the average spacing is 350–400 m in the suburbs and 300 m in the CBD.

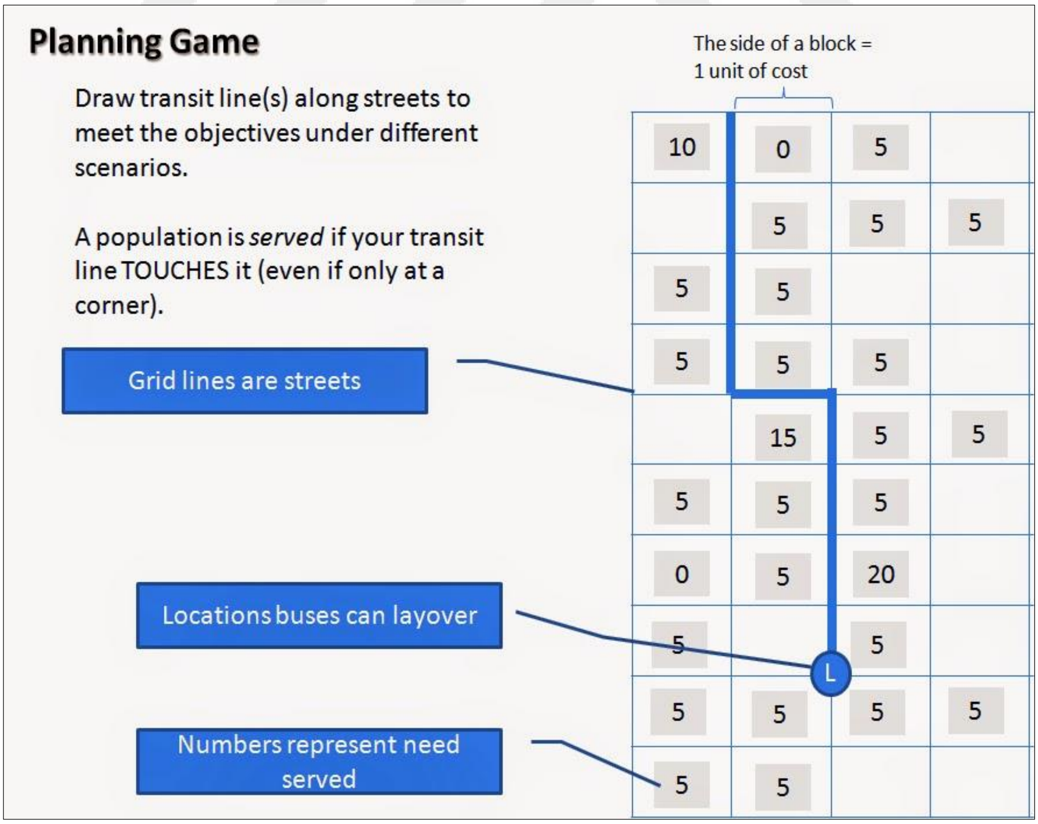

Figure 2.2 The bus route planning game includes cost, number of those serviced, layover and available streets (Michael, 2014)

To provide higher operating speeds for Bus Rapid Transit than conventional bus routes systems busways are usually characterized by larger distances between stops. A survey of 37 public transportation systems around the world reveals an average stop spacing of about 750 m over a wide range of values from 300 to 1800 m. (Figure 2.1). More methods have been invented to improve bus stop location for the users according to the surrounding area (urban area mostly), such as the planning game (figure 2.2) introduced by Michael (2014).

Determination of the distance between stations by the popular method in England includes some variables of the travel time, such as average speed, travel length, and firstly of the public transportation properties and characters. Ten factors affecting the calculations are as follow:

- The average distance covered by every travel (m): L
- The average distance between the stations (m): D
- The average distances that vehicle increases or decreases its speed (m): A
- Performing time of the process (s): B
- The constant speed of passengers' movement (m/s): F
- The constant speed of a vehicle in the distance between the stations (m/s): V
- The average distance for getting to destination or origin is almost equal (m): X
- Stopping time in every station (s): S
- Travel time is (s): T

Travel time is obtained by collection of the above-mentioned times. The relations (1) and (2) show how to calculate the time.

$$T = 2.\frac{X}{F}+\frac{L}{D}.S+\frac{L}{D}.B+\frac{L}{D}.\frac{(D-A)}{V} \qquad (2.2)$$

Or

T = (travel time for getting to the first station) × 2 + (quantity of stations × stopping time in every station) + (quantity of movements at stations × time of constant speed of movement) + (quantity of movements at stations × acceleration and deceleration time).

2.2 Access to the public transportation system

For the access to public transportation or the bus station, the most typical method is a walking. This method coverup the bus line from the origin toward the bus stops and get to the destination that the user covers. This distance is usually considered about 500 m for local buses (the passengers, in normal and safe conditions, cover this route in five minutes, since the disabled people in wheelchairs and the old need two times more). Ziari (2007) refers that the first station was reachable by 95 % of passengers by walking, 88 % of passengers cover this distance in about 6 minutes, and 12 % of passengers cover this distance in around ten minutes, due to the existence of some obstacles that covers the distance in the zone or other movement incapacities of the user.

Access to transportation studies was founded on measuring the intercity or the shortest distance, thus the distance may be ground or Euclidian distance or time factor Behbahani (2001) Hansen (2007) suggested more inclusive index of accessibility described in the form of the population related to the distance. Then T. Matis (2009) expanded this concept.

Detailed access capabilities (social, trade and occupational) of the zone were given in calculating the distance access. In the calculation of access, distance is
given to the bus station by Hansen's method as per ground distance in relation

$$d = \frac{\sum_{i=1}^{n} P^2.d_i}{\sum_{i=1}^{n} P_i^2} \tag{2.3}$$

where; *Pi:* population in the scope of the zone (person);

di: the distance of scope from the station (m);

h: quantity of scopes in the zone;

p: zone population (person);

d: access distance to the station (m).

The method of calculating access time to origin station or moving from destination station to destination has a mere logical than calculation form. Travel time could be calculated by relation.

Another approach by Salvo (2012) based on GIS network and take route obstacles into consideration, proposed a way for public transportation access assessing, with GIS databases. This aim of this approach is to define the proper locations of the new bus stops or to adjust their locations, so most users in the area would benefit from it easier and can be served. In this method, three different ways were presented, aiming to define the catchment areas around bus stops; The first one is based on creating a buffer around an entire route assuming that all locations along the route buffer are available. For the second method, the buffer is created only around the bus stops with a radius shaping the walking distance. The third one is based on a specific network distance 300 m in this study, by identifying all routes in the global network around bus stop that can be reached by walking. The option of creating layers in GIS to allow the creation and separation of databases that contains demographic data is used to intersection with the catchment areas, it can potential people and jobs can be estimated in the specified network from the bus stop.

Those experiments confirmed the benefit of developing approaches for a reasonable design for public transport systems accessibility.

2.3 Optimization

Fundamentally, buses are a local service and work best when they are tailored to meet local needs and circumstances. Some studies assume the rider would desire three elements: the reliability, so the bus should come in time and gets to the destination in a reasonable time (speed) and that the stations would be easily reachable, the wait and the ride are not too cumbersome (convenience). Nonetheless, bus stop locating isn't that simple when a long list of factors can affect it. Many studies proposed a set of parameters to improve bus functioning and provision,

Ceder (1986) developed an optimization model that considers the crowding on buses, the interactions with current traffic, operative variables like the frequency, the fleet, the budget of the operator, and the socio-demographic characteristics of each zone in the concerned area. Ibeas (2009) also proposed a method through a mathematical bi-level model to explain the issue of bus stops locating. The upper level is designed to minimize the cost function for the user and the operating company and the lower level includes a mode choice, a model that considers the influence of private traffic and congestion on the public transport vehicles.

2.4 Value of time in transportation

In transport economics, the worth of time is equal to the charge spent by the traveler on his trip, which makes it the price traveler would be willing to pay for it in order to save time or the amount he would accept as reimbursement for the lost time. Thereby, the understanding of time managing during service, get more importance. For public transportation users, several researches prove the interaction between public wellbeing -health- and public transportation. Richard (2016) studied the intersection between transportation and physical, psychological, social and economic well-being and proposed a framework for those four QOL (quality of life) dimensions and their interaction with transportation, the framework indicates that targeting improved QOL through public transportation requires the consideration of three elements of the transit system: operation time, mobility, availability, and the traffic. Generally, the operation time is the principal driver overall the pyramid.

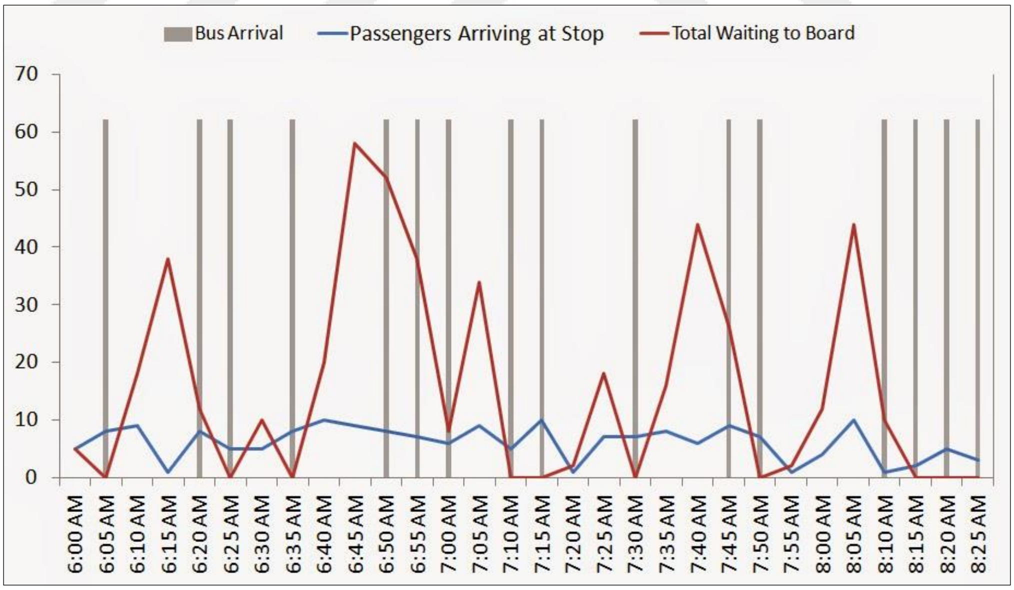

Figure 2.3 Model graph illustrating how uneven headways such as delayed and bunched buses (the vertical lines) affect boarding at bus stops (red graph) and overcrowding of buses. (Michael, 2014)

Time in bus transit service can be estimated in various ways. For dwell time, many studies based on limited sample sizes and commonly route-specific, with the focus on exploratory the reasons for bus delays (Dueker, 2004). Some dwell time studies are built on the method of Ordinary Least Squares (OLS) to establish relationships between dwell time and passenger access/egress, based on selected operating conditions that affect dwell time. Levinson (1983) developed a linear regression model for dwell time assessment with the total number of boarding and alighting passengers. Guenthner (1983) developed an ordinary logarithm model for dwell time estimation considering the sum of boarding and alighting passengers as the variable.

Another study by Kraft (1975) refers that dwelling time is influenced by 7 main factors: operating strategies and applies, users, modality, local environment, traffic, and other system variables. The study demonstrates how some bus stop characteristics could influence the time spent by a bus at the station, including right-lane volumes, vehicle classifications, path utilization, route design, traffic intensity, length of the bus space.

Although, the determination of an accurate estimation still depends on many other factors, as shown in (Figure 2.3)

Literature review on time estimation shows clearly how important time would be in the bus operating system, therefore in the following section, the methods of making accurate estimation -simulation- will be discussed.

2.5 Simulation

Simulation process and operations are well-established procedures aiming to comprehend, describe, and forecast the questioned phenomena. Modeling reports the way things work in an intrusive way. The simulation in experimental science is a way of representation, it is considered as a tool used for testing, executing and decision making.

In general, simulation models are a valuable tool in urban planning. They can be of use in the domaine of urban planning such as urban hazards, extensions conception, choice of residential locations, public transport issues. A general utility simulation system has been established by (Eldin ,1980), can be applied to a multitude of problems. In our research, simulation is not only recommended but a fundamental element for assessing the results of the inputs we suggested to improve the system of bus stop spacing. The below studies are based on different type of simulation for the same purpose.

A simulation of the hypothetical model on a specific bus line was established using a PARAMICS (Parallel Microscopic Simulator) for a study by Chandrasekar (2002), it implicated a continuous following of bus positions along the bus line, and supervisory of bus spacing by engaging signal priority when it is needed. The assessment aimed to create traffic and bus functioning conditions when the strategy performs best, and the results modernize the strategy for diminishing bus headway time.

The bus movements were estimated for the disruptions to headways, is found to get up with reduction in the headway time, increases in the length of the network, and more intensity in traffic congestion. This study on bus stops placement, demonstrated an important development in the cases of shorter headways times of five to ten min, ending up in 80% of cases having at least 10% discount in the surplus waiting time, and 60% of the cases having about 20% reduction in additional waiting time.

Another study by Fernández (2003) applied a simulation model on bus progression along a bus path. The model is made up of three elements: a simulation model of bus stops; a model that represents bus movement along the lane; and the representation of a traffic signal. Simulation experimentations were performed to evaluate the impact of the operation of these elements on a section of a bus lane. The results gave a better understanding of these interactions and help to define the improvements of bus stop spotting. those parts represent the support for the document, as references to base on, shortcuts to take toward the purpose of the study and to reach the desired results, avoiding the misleading ways, it helps to choose or shape up the formulas used in different stages of the calculation. The study is based on a deep examination of public transportation planning and practices over years and observations of the potential lacks. it aims to make an attempting of enhancement for the transit service focusing mainly on optimizing time. A set of technics, tools and skills are required to be familiar with the domain first and suggesting methods to make the operation correct and feasible, the next chapter is devoted for the explaining of the steps to take, methods to follow with details.

CHAPTER THREE

METHODOLOGY

As discussed in the previous chapter, many ways have been developed to define the bus stops along the bus's line. Frequently, the common factor is distancing, or bus stop locating. The principle of the method used in this work is based on simulation, to minimize time for the bus users, by making iterations a single factor: number of bus stops and number of passengers. In this chapter the setting of parameters is explained, and the way each parameter is adjusted to calculate and optimize the best settings of the bus stop location system.

To find out the best setting -numbers and locations- of bus stops, that matches with the shortest time for bus and passengers trip, we established a set of equations, in a certain order for both, the bus and the passengers, considering factors and changes in their times, the purpose is to arrange the time taken by each factor during the headway time of the bus and the travel time of the passengers, to end up with the total time to compare in each scenario.

3.1 The bus headway time

In this study, the trip maker's travel time estimation is based on certain factors involved in the process of bus operation. For Kikuchi (1982) the bus trip is composed of three components: (1) trip time, T_c, at a constant velocity V, on the entire length between terminals, (2) supplementary time, T_i, incurred by decelerations and accelerations due to stopping at all stations cumulatively, and (3) total standing time at stops, T_s. the bus headway time at a constant velocity over the entire line length.

In this study, the travel time is composed of the parts explained below, the order of factors is managed in way that facilitate the insertion of data easily on the rows later in the main table of time calculation and assemble it and get the outputs easily. Vehicle travel time table contains:

- In the first column (Table 4.2) the bus stations are cited by name or number in a row, the following columns will specify the concerned factors for each part.

- Distance between two stops: this row specifies the distance between stops by meter, in the next section we will present the way these distances are defined - bus stop locating -.
- Dwelling time between two stops: is based on the distance between two stops and the velocity of the bus throughout, as showed in the previous chapter, the velocity changes over different stages, therefore the time of going over that distance must be calculated systematically.

In real life, when the bus is rolling, it starts with a velocity of 0 m/s, which coincide with the departure point, the velocity keeps increasing to reach the limited speed, this part is defined as the acceleration distance. The next stage is the maximum but the constant value of the bus speed, equal to the current traffic speed of the route. In this stage the acceleration goes to a null value. In the last stage, the acceleration goes for negative value and the velocity reduces, so before arriving to the next station the bus takes a certain distance to reduce the speed, the so-called distance of deceleration. Yet to stop at 0 m/s at the exact bus stop, it also takes some distance and time -the stopping distances-.

To calculate the previous stages (as displayed in the Figure 01), the distance must be split into three main parts – increasing speed or acceleration to A1, constant velocity or null acceleration value to B, decreasing the speed or deceleration to C.

Part 1: Acceleration span from 0 to A, when the original speed V_0 = 0 m/s, acceleration a = 2 m/s^2 and the time: t = 10 s, the final velocity is calculated as follow: considering that: $V_1=V_0+at$; (V_1: initial speed, V_2: final speed, t: time, a: acceleration), So:

$$V_1 = 0 + 2 \times 10 = 20 \text{ m/s}$$

Part 2: Zero acceleration period from A to B is simply: the initial speed V_0 = 20 m/s, Final speed V_1 = 20 m/s and the time t = 30 s. No equation necessary!

Part 3: Deceleration span in this case, using the same equation: original speed V_0= 20 m/s, the final speed V_1 =0 m/s, and the acceleration: a= -4 m/s^2

Therefore, the time: $V_1=V_0+at$ (3.4)

So: $t = (V_1 - V_0)/a$

$t = (0 - 20) / -4 = 5$ s

The graph below (Figure 3.1) is drawn based on the example given of the principal of bus acceleration and its stages, the acceleration and deceleration are assumed to be linear.

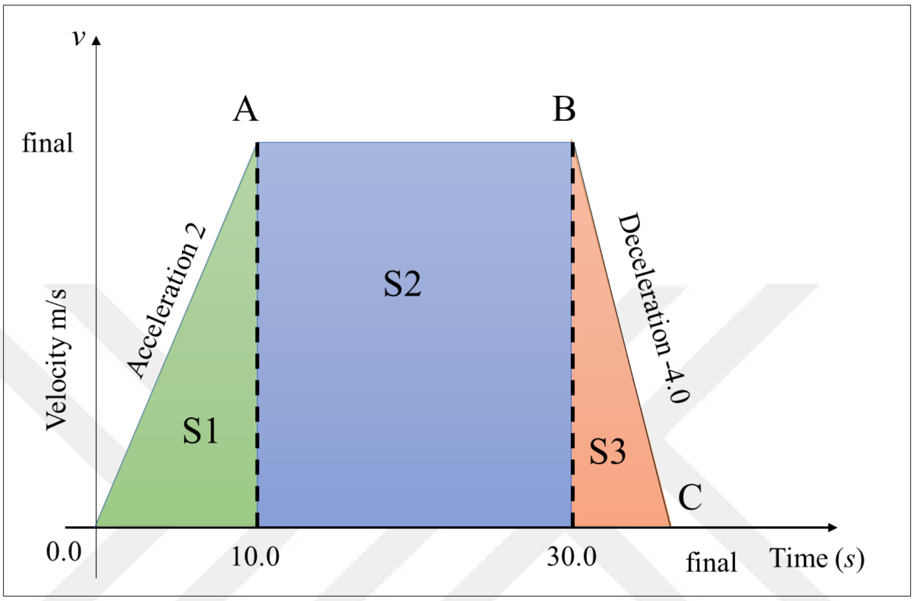

Figure 3.4 The stages of bus acceleration (acceleration, constant velocity, deceleration)

Traffic speed calculation consists basically on the maximum velocity allowed in urban area, which vary from a city to another, even from a district to another according to drivers, vehicles, and the roadway environment (George 1995). In real life, the congestion reduces it even less than the value it is supposed to be, therefore it cannot be considered constant by default. For that reason, using real-time velocity is the way this study goes for. Many websites, API and applications provide instant average speed of routes 7/24, like “HERE Traffic”[1], “we Go Here”[2] and “Yandex”[3].

It’s also noted that for the calculation of bus acceleration (and vehicles in general), there are more factors to consider –vehicles movements physics, route conditions, size and weight of the vehicle- to make the estimation accurate, some of the highly

[1] https://www.adci.com/here/here-traffic/
[2] https://wego.here.com/
[3] https://yandex.com/maps/traffic

recommended online calculators are “Engineer toolbox”[4], “Spicer parts”[5], “Boost town”[6].

The calculations of the distances defined previously (acceleration, constant, deceleration and stopping distance) define the exact time spent between stops excluding the passengers getting in and out times. The sum of them gives the net time spent by bus moving from the first to the last station. Upon the bus arrival to bus stop, the bus spend time to load/unload passengers, the time throughout the operation is estimated by two seconds for each passenger. At each station, the time for open and close the doors is counted, by 3 seconds. In the end, all the previous elements are aggregated to sum up the total time between each station, and the vertical total of time spent on each station gives the time of the bus trip.

3.2 Passengers time

The passenger trip time involves four elements: access/egress time from stops, waiting time, riding time on the bus and egress times to/from stops (Kikuchi, 1982). The time spent by the passenger from the origin point to the destination is based mainly on the distance he gets through, which is -in this study- composed of four main parts: walking from the origin point to the bus stop, estimated time for waiting the bus, taking the bus from departure to the arrival stop -dwelling time-, then walking distance to the destination point.

Passenger time= Origin to departure bus stop (walking) + waiting time + dwelling time (in the bus) + arrival bus stop to Destination (walking).

[4] https://www.engineeringtoolbox.com/
[5] http://spicerparts.com/calc/transratio/
[6] http://www.boosttown.com/gearbox_differential/speed_calculator.php

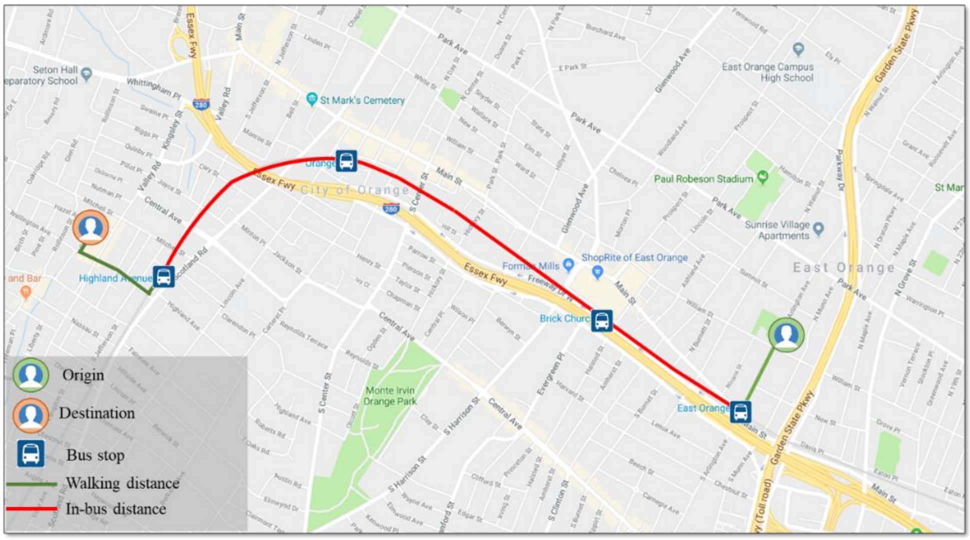

Figure 3.5 Illustration of a passenger's trip from the origin to the destination -the map background from New York city (Googlemaps, 2018)

The time of walking the is estimated by multiplying the distance by the average of walking speed, estimated by 4.5 kilometer by hours, 1.25 meter per second Browning, (2006), which is applied for Google maps walking time estimation standards as well. The time spent on the bus is calculated based on the estimation of the net distance between two stops explained previously in bus time calculation, so the span between the bus stop from which the passenger gets in to the one the passenger gets out is calculated by aggregating the time spent between two stops over all the stops the passenger gets over during his boarding time on the bus. Yet the time of passenger must be more specified considering the same features as the bus time, the open/close doors is counted, plus the time of getting in/out of passengers in each bus stop with the same way bus stops is calculated. Another factor to consider is the waiting time, the average user waiting time is assumed to be a half of the vehicle headway for a reasonably short headway operation, as discussed by Seddon, P. A (1974),

$$T_W = h/2 \tag{3.5}$$

T_W: waiting time; h: headway time

The headway is the sum of the time the bus takes from the first to the last station, which is taken from the table of bus time.

3.3 Bus stop locating

Previous studies on bus locating took different factors to shape up a policy for stopping locations. Brouwer (1983) assumed that the factors to be considered when locating and designing bus stops are smooth operation, operating costs, energy consumption, working conditions of the bus staff, safety, attractiveness, traffic flow and environment. As explained before, the variables in this study are the number of bus stops and their locations. The number of buses is altered for each iteration on regular basis, and the way they are located follows two different approaches:

3.3.1 Shifted stations

With an equal distance between stations, in which the bus stops coordination change for each iteration along the bus line as displayed on the Figure 3.6

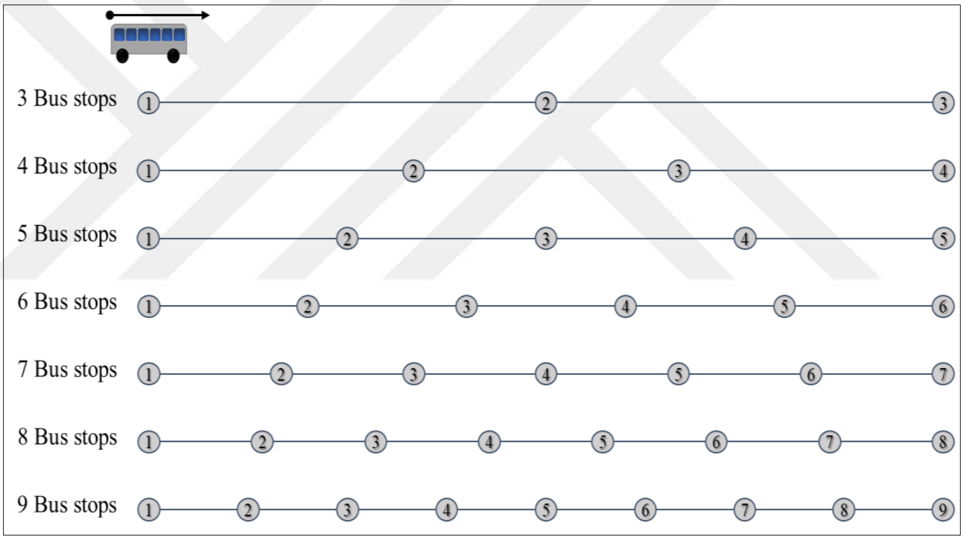

Figure 3.6 Positioning of bus stops by equal distances (shifted stations)

3.3.2 Fixed stations

Division of distances with constant locations, by having persistent locations of bus stops, and increasing their number do not change the existed bus stops location (Figure 3.7) in both settings, the number is fixed, the difference is the way of distribution. In the first setting, the bus stop’s coordination changes in each iteration whether by adding or removing. The idea is making equal distances between bus stops (Figure 3.6). For the second setting, the bus stops coordination does not change, adding or removing other bus stops does not affect the location of the remained bus stops (Figure 3.7)

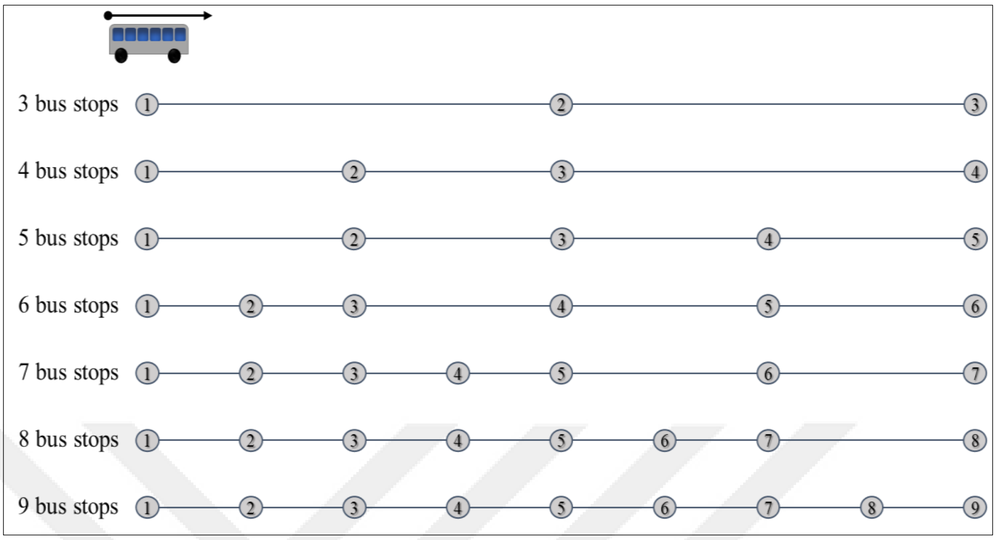

Figure 3.7 positioning of new bus stops between the existed with equal distance (fixed stations)

3.4 the number of Bus stops

In general, the number of stops for a one-way vehicle trip depends on stopping regime (all stops, on call stopping or demand stopping), under this stopping regime, it depends upon passenger demand rate and destination pattern (Kikuchi, 1974). In this study, the number of bus stops is considered as variable for the experiment process, the proper number is decided upon the final result derived from the passengers' time, headway time and number of passengers.

3.5 The relationship between the volume of stations and the user travel time

For Vuchic (1982) the number of stations that minimize the average user travel time, a proposed equation is derived through to expresses the passenger trip time as a function of the following factors: the volume of stops, passenger volume, trip time, access speed and vehicle dynamic characteristics. (Figure 3.8) illustrates this relationship,

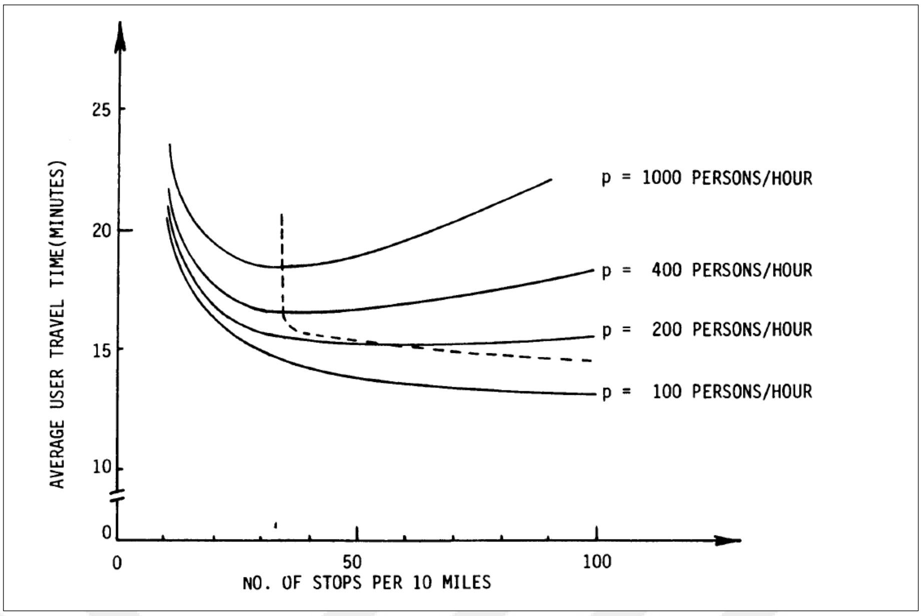

Figure 3.8 Relationship between number of stops and average user travel time (Vuchic, 1982)

The graph has been developed with the following set of values: Route length: L = 11,817 Km; bus' constant dwelling speed: V = 40 mph (64 km/h); Acceleration rate: a = 3 ft/sec2 (0.9 m/sec2); Deceleration rate: b = 4 ft/sec2 (1.2 m/sec2); Average passenger trip distance: l = 3 miles (4.8 km); Boarding and alighting rate: x = 30 persons/minute; Headway: h = 10 minutes; Average user access velocity: V_a = 3 mph (4.8 km/h); Load factor: $a = 0.9$. (Vuchic, 1982).

In this study, the relationship between bus stops volume and users time is based on the iteration on different number of bus stops, that affect the bus time and the users time directly, so it will show the optimum bus stop number coincide with the minimum aggregate user time.

3.6 The number of passengers

In real life, there are many factors affect the number of passengers, like peak hours, crowdedness of the area the bus line gets through, the capacity of the vehicle, the quality of the service. As for this study, the number of passengers play a main role in bus functioning process; at the bus time level, the more passengers get in the bus, the longer it takes to arrive to the destination (time taken to load/unload passengers). At the simulation level, the more involved passengers in the experiment, the more it gives disparity in cases and more accurate results. The number of passengers is considered here as the third level of the optimization, given that the volume of passenger can affect the bus headway and passengers trip time.

3.7 The simulation

The simulation performed in this study is based on iterations over a given bus route settings with different number of bus stops. The passengers' origins and destinations are located randomly around the bus line on a specific area, each one of them has a trajectory, starts from the origin point to the destination. Since the bus stops numbers will be changed in each iteration according to the settings (by numbers and locations or just number with constant locations), the passengers itineraries will change accordingly.

The simulation of this study assumed that:

- Origins and destinations of Passengers are fixed.
- For the walking distance from the origin to the bus stop, the choice goes for the closest itinerary in the direction of the passenger, forward.
- The choice of the itinerary from the arrival bus stop to the destination is based on the distance as well (shortest) and the closest previous bus stop before the destination.
- In case the trajectory of the passenger does not get over at least two bus stops, the simulation opts for excluding the use of the bus, the passenger's itinerary is counted, and the time is calculated based on walking.

The final purpose of the simulation is to gather the total time estimated in each iteration and compare it to end up with the most optimized setting -number and location of bus stops- for the bus line.

CHAPTER FOUR

DATA

In the previous chapter, the way of proceeding this work was explained. This chapter presents a detailed description about the obtained data on bus system process, the established tables, maps and calculations on the study case and different scenarios.

4.1 Data collection

The study case is chosen from the city of Izmir, Turkey. The public transportation system of the city is covered by different modes: buses, metro, tramway, ferry and teleferic (aerial tramway). The dominated mode so far is the bus.

The very first step in this study started by checking the operating system in real life, in the city of Izmir, the study case; bus line 304 from the University of Dokuz Eylul campus Tınaztepe to the city center of Izmir Konak, the length of the path is 11.817 Km, with 19 bus stops, this bus line was chosen randomly out of more than hundred bus lines in the city of Izmir (figure 4.9). On 18.07.2017, 11:55 AM, we checked the operation process; the number of passengers getting in/out the bus in each station, departure time, the time of moving from/to each station, open/close doors time, access/egress time for passengers. The collected data showed in Table 4.1.

Table 4.1 Headway timing for the bus line 304

Bus stop code	Bus stop	Access	Egress	Time	Duration
40121	Tınaz Tepe	5	0	11:55	
40088	Begos	18	0	11:57:30	0:02:30
40086	Fabrika	1	0	11:58:30	0:01:00
40070	Eski Mezarlık	6	0	11:58:55	0:00:25
41200	Hasan Ağa Bahçesi	3	0	12:00:15	0:01:20
40742	Buca Üçkuyular Meydan	6	3	12:01:32	0:01:17
40738	Buca Sağlık Ocağı	3	1	12:03:02	0:01:30
40038	Buca Devlet Hastanesi	2	0	12:04:05	0:01:03
40036	Dokuz Eylül Eğitim Fakültesi	7	7	12:05:09	0:01:04
40022	Sağlık Meslek Lisesi	5	1	12:07:20	0:02:11
40018	Öğretmen Evleri	8	0	12:09:15	0:01:55
40016	Buca Belediye Sarayı	5	4	12:10:40	0:01:25

Table 4.2 continues

40103	Fabrika	2	1	12:17:00	0:00:36
40105	Yeniyol	5	3	12:18:30	0:01:30
10032	Konak	0	57	12:23:15	0:04:45
40014	Ceza Evi	1	0	12:11:30	0:00:50
40012	Yeni Mahalle	1	2	12:12:55	0:01:25
40010	Şirinyer PTT	3	1	12:15:30	0:02:35
40101	Banka	4	5	12:16:24	0:00:54

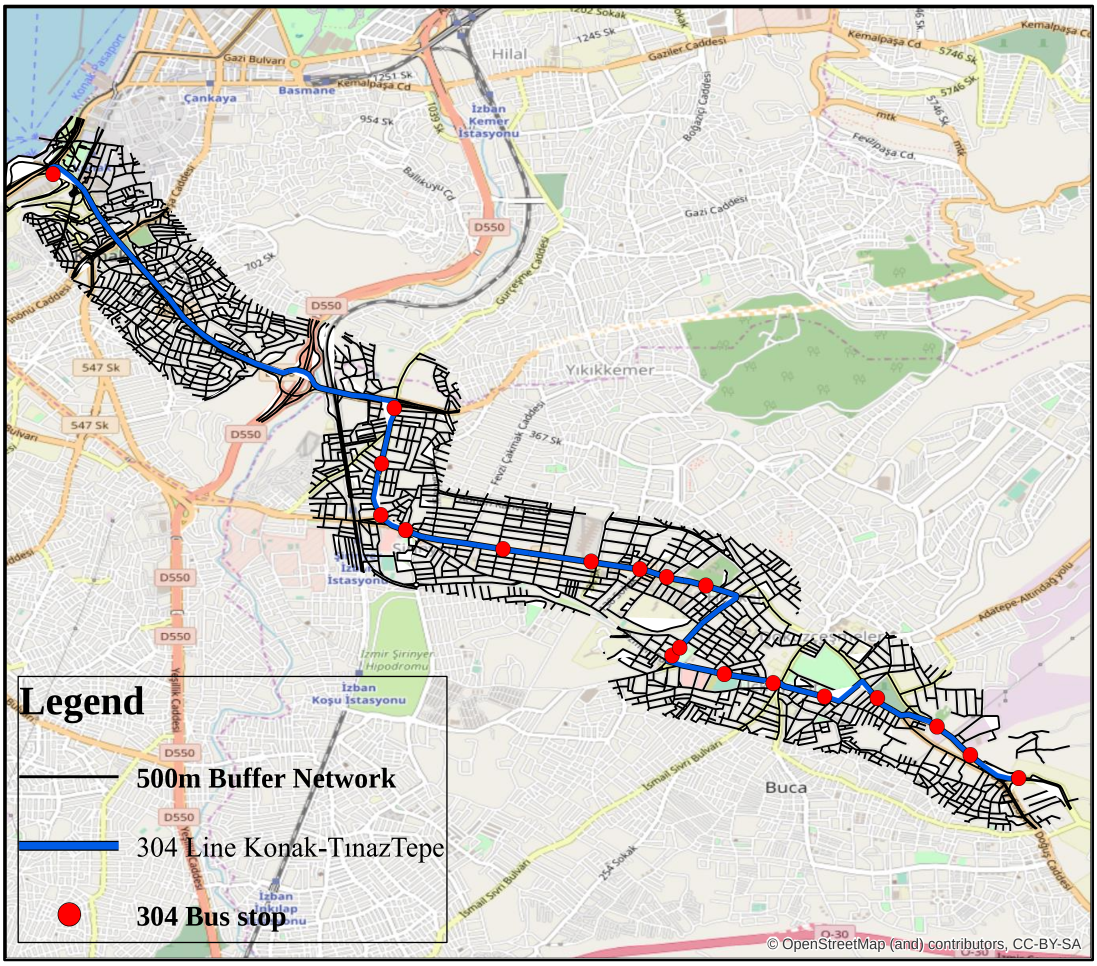

Figure 4.9 Bus line 304 and the original bus stops, (ArcMap, 2018)

4.2 Passengers coordination

For each passenger, the coordination of origin and destination has been generated randomly by ArcGIS - Generating Random Points tool- after preparing the map document in ArcMap, and adding the layers we need, including a polygon layer -in which random points would be generated (figure 4.10).

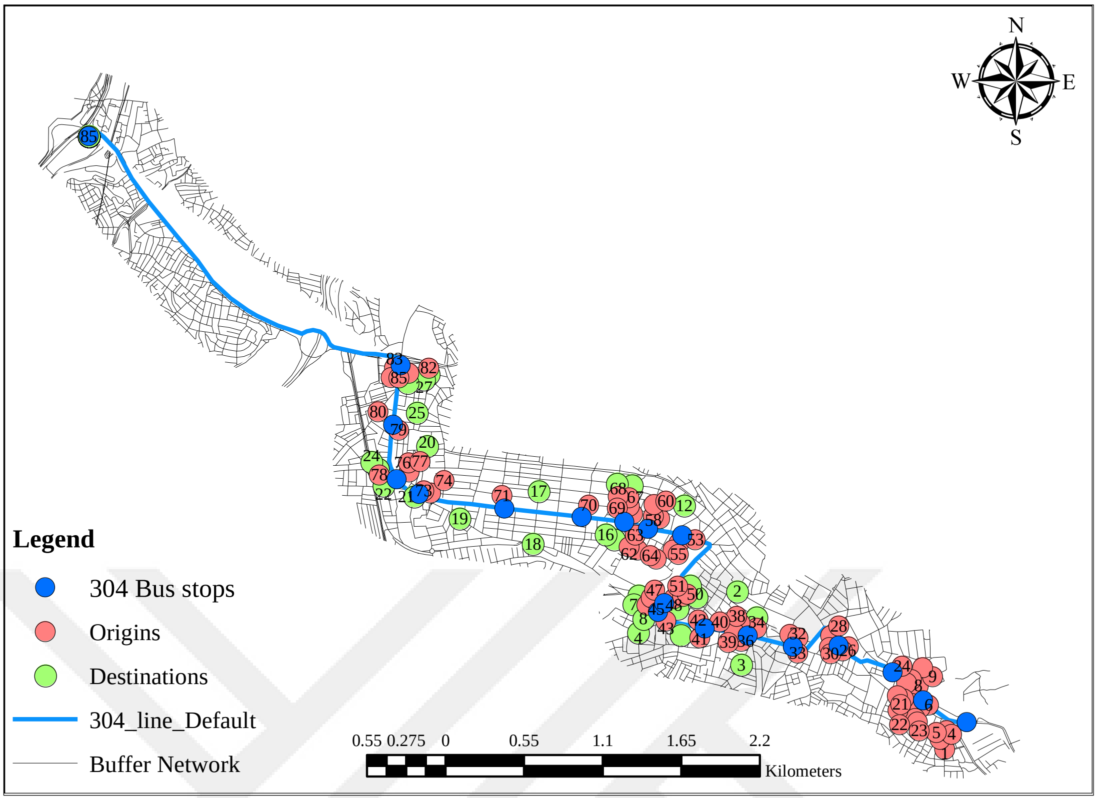

Figure 4.10 Origins and destinations of the passengers

The generated points origins/destinations for the 85 passengers are distributed in the area of the polygon – a buffer of 500 m - around the bus line along the way over the network (Figure 4.10).

The destination is oriented forward from the right to the left of the line, with no passenger going backward, and since the bus direction is on one way, from the east to the west, the origins are located in the east part, in the half right part of the line of the bus, passengers are taking the same direction to the west part.

For the observed case in the survey, the number of passengers was 85. Hence to generalize the study, this number may change (increase or decrease) depend on many factors, like the traffic, the time of departure (hours in a day and days in the week), which is a later step in our study to change the number of passengers and testing the process of the bus operation and its effects on the passengers' time and the bus headway time.

The passengers' itineraries are generated then from the origin point to the ascending bus stop and from the descending bus stop to the destination. Based on the network created around the bus line -buffer network-, using route analysis in ArcGIS 10.5, the quickest and the shortest route is defined to link each passenger to the closest bus stop (figure 4.11).

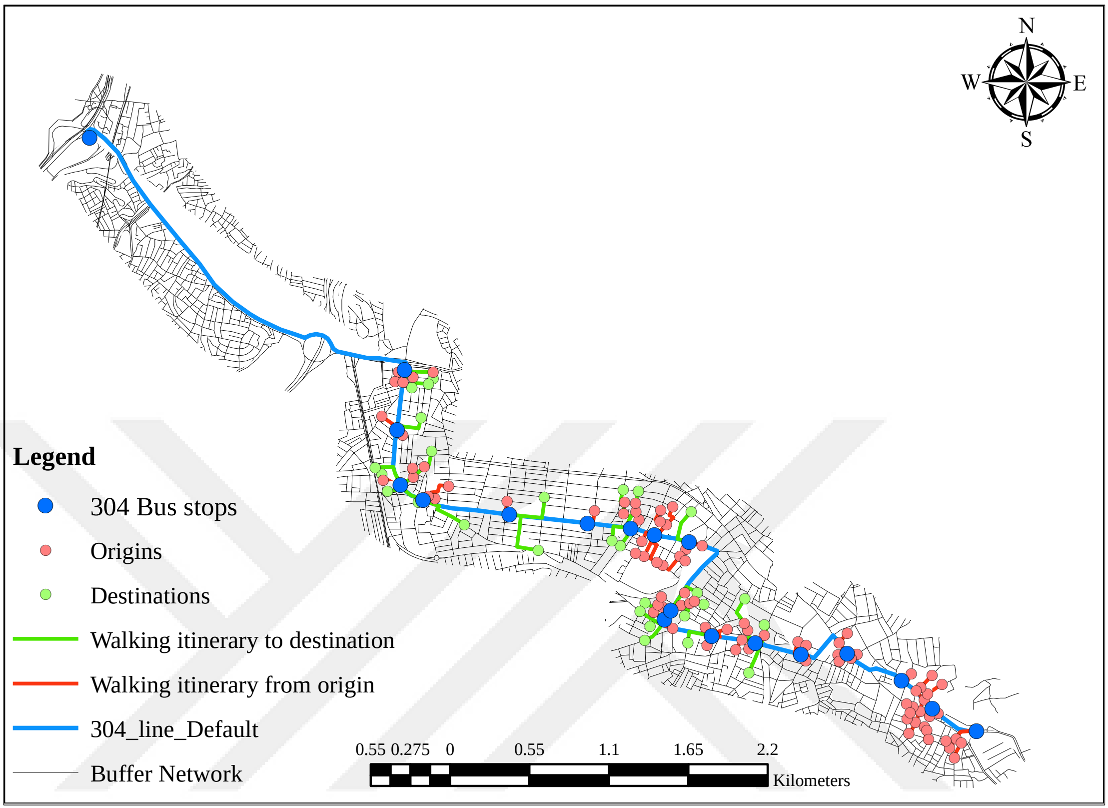

Figure 4.11 Itineraries of passengers walking to/from the bus stations

4.3 Bus headway time estimation

As explained in the previous chapter, the elements that influence the bus time from the first to the last station are mentioned in the Table 4.2.

The different stages of the velocity of the bus (acceleration, constant speed, deceleration, and stopping) distance and time are based on the online calculator of Johannes Strommer. The velocity of routes was taken from (Yandex.tr) at the exact time of the survey, it is filled in tables and represented in the map above (figure 4.12)

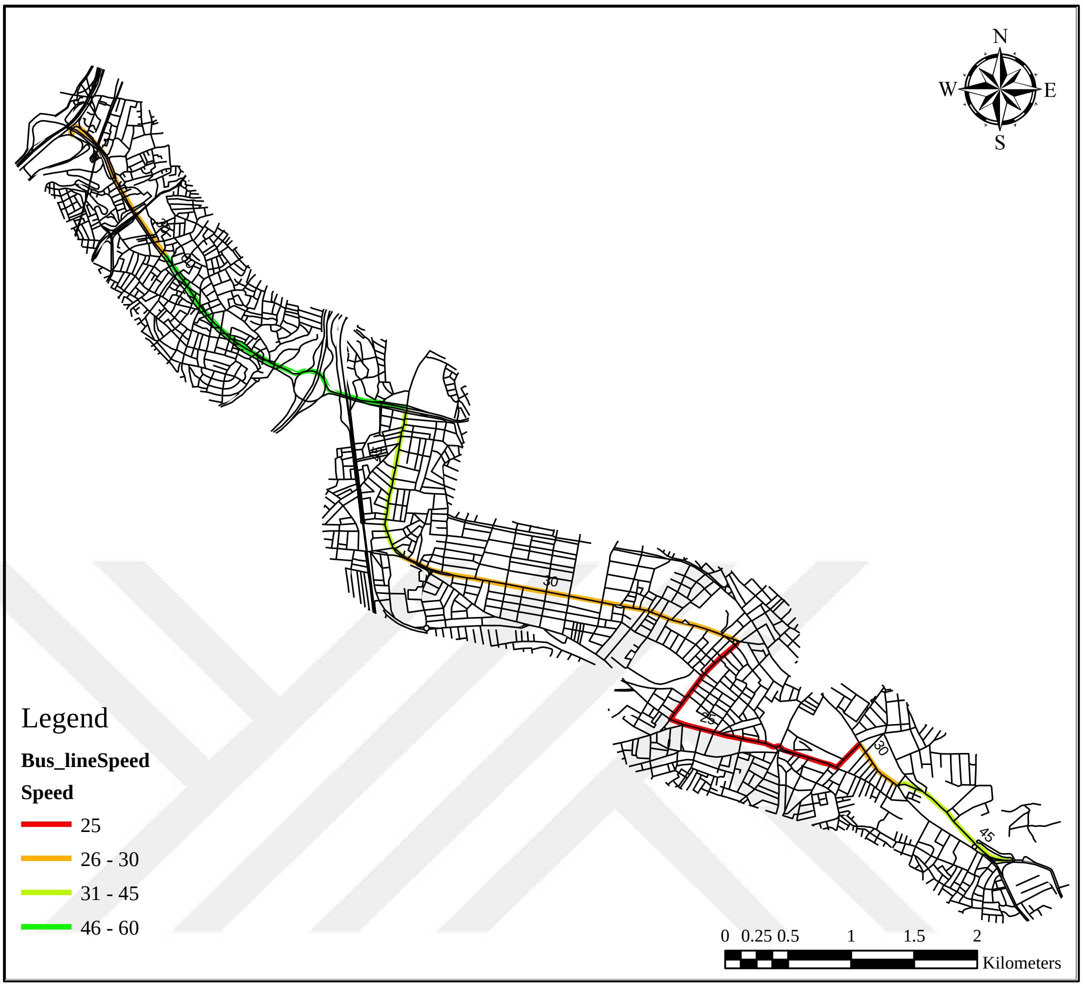

Figure 4.12 velocity of traffic along the way of the bus line treatment of data on ArcGIS 10.5 (Yandex, 2018)

Johannes-Strommer is an online distance calculator (figure 4.13) designed for a wide range of applications, used to calculate the different elements like braking distance & overall stopping distance, (braking) time, starting velocity, final velocity, and acceleration/deceleration, also considering the road or track condition.

Considering the traffic velocity (as the maximum value on each route) and by having the distances between bus stops, we can calculate the distance and the time taken by bus -of each acceleration stage- from a station to another with more accuracy.

The table (Table 4.2) shows the way different stages of bus moving speed are calculated;

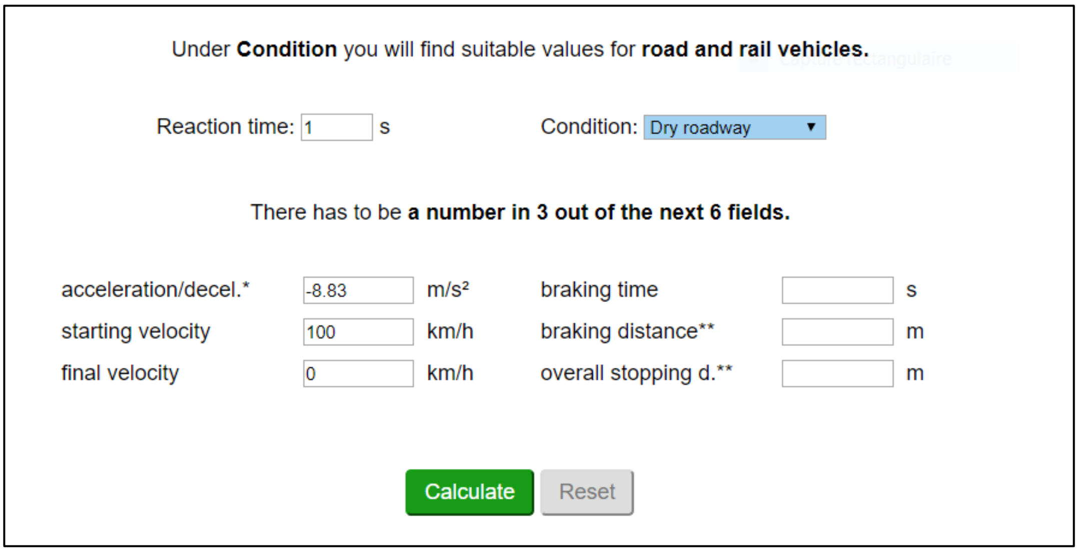

Figure 4.13 the interface of velocity stages and braking distance Calculator

First, we have the distance between 2 stops, as explained in the previous chapter, the distances are equals all the way along -setting 01-, and it does change from iteration to another on some points according to the added/removed bus stop -setting 02-, it can also be a variety of distances as for the case of the bus line 304 original bus stops.

The second and the third column (Table 4.2) are about the acceleration distance and time, by having the maximum speed, considering the $V_0 = 0$ the distance and the time taken by bus for that stage can be calculated from "Johannes-Strommer" calculator.

The next column (Table 4.2) defines the time taken by the vehicle to decelerate from the constant velocity, by having the constant velocity value and considering the finale velocity value as $V_f = 0$, we can get the time it takes by this stage and the distance as well.

The column for the stopping distance (Table 4.2) is filled from the same source -Johannes-Strommer calculator- generated automatically after getting the deceleration distance. The distance of deceleration, this column is used to define the remaining distance -constant speed-:

The distance between two stops= acceleration distance + constant velocity + deceleration and stopping distance (4.6)

Constant velocity = distance between two stops – (acceleration distance + deceleration and stopping distance)

After getting the distance the bus moved over with a constant velocity, we can calculate the time spent on it, the constant velocity is taken from the traffic velocity of each route (Figure 4.12).

The next column displays the dwelling time between two stops, by summing up the time of the previous acceleration stages, we can get the brute time taken by bus moving from a station to another. Access/egress: represents the number of passengers getting in/out the bus at each bus station. Access/egress time: assuming that the time of getting in/out the bus by a passenger is in average 1.5 second, to calculate access/egress time the biggest value is to be considered (if we have 10 passengers getting in and 12 passengers getting out at the same time, the major value would be taken: 12 passengers). Open/close doors time is by default 3 seconds for all the stations.

Time trip: for each row the time trip represents the estimated net time from a station to another, the total gives us the dwelling time from the departure to the arrival station, which is the bus time that to be optimized.

To illustrate, the way of calculation of the pan of time from the second to the third station on the table 02, is explained as follow;

The distance between stops is: 1477.21 m

Considering that the maximum speed is 40 km/h or 11.11 m/s, the calculator gives us the following information:

Time to reach the constant (traffic) speed from 0, acceleration time= 50s

And the distance taken in acceleration: acceleration distance= 277.77 m

The time taken to reduce the vehicle speed from 11.11m/s to 0, and the stopping time, that the vehicle takes to get in stable standing and positioning next the bus stop to start leading passengers, deceleration and stopping time= 9.25s

Deceleration/stopping distance= 51.44 m

So according to the equation (4.6), the constant speed distance can be derived from the acceleration and deceleration distance:

Constant velocity = distance between two stops – (acceleration distance + deceleration and stopping distance)

Constant velocity = 1477.21 – (277.77 + 51.44) = 1147.99 m

Now to get the time taken on constant speed, the distance is simply divided on the traffic velocity, which gives:

Constant Velocity Time= Constant Velocity Distance (m) X Traffic velocity (m/s)

Constant Velocity Time= 1147.99 / 11.111= 103.319 s

The dwelling time between two stops is accordingly calculated by summing the three stages of movement:

Dwelling Time between two Stops= acceleration time + constant movement time + deceleration and stopping time (4.7)

Dwelling Time between two Stops= 277.77+103.319+ 9.25= 162.578 s

For passengers loading time, at the second station there are 4 passengers ascending (4 x 1.5s = 6seconds), with no passengers descending.

Open and close doors time is fixed by default on 3 seconds,

Which make the total time from those stations:

Trip time= 162.578+ 6+4= 172.578s

Table 4.3 estimation of the bus headway time (an example of 9 stops, 10 passengers from setting 01)

Bus Stops	Distance'2Spss	Acceleration distance	Acceleration time	Stopping distance	Deceleration time	Constant Velocity' Distance	Traffic velocity (m/s)	Constant Velocity' Time	Dwelling Time '2Sps	Access	Egress	Access/Egress time	Open/Close d- time	Trip Time
1										7	0	10.5	3	13.50
2	1477.21	277.77	50	51.44	9.25	1147.99	11.111	103.319	162.578	4	0	6	3	172.58
3	1477.21	277.77	50	51.44	9.25	1147.99	11.111	103.319	162.578	4	0	6	3	172.58

Table 4.4 continues

4	1477.21	277.77	50	51.44	9.25	1147.99	11.111	103.319	162.578	5	4	7.5	3	173.07
5	1477.21	277.77	50	51.44	9.25	1147.99	11.111	103.319	162.578	11	5	16.5	3	182.07
6	1477.21	277.77	50	51.44	9.25	1147.99	11.111	103.319	162.578	8	8	12	4	178.57
7	1477.21	277.77	50	51.44	9.25	1147.99	11.111	103.319	162.578	1	6	9	5	176.57
8	1477.21	277.77	50	51.44	9.25	1147.99	11.111	103.319	162.578	0	12	18	6	186.57
9	1477.21	277.77	50	51.44	9.25	1147.99	11.111	103.319	162.578	0	4	6	7	175.57
														1429.12

4.4 Bus stop Location settings

4.4.1 Setting 01 (Shifted Stations)

For this case, we reinitialized the location of all the bus stops, by locating them in equal distances along the bus line, so we changed the number of bus stops (from 10 to 20) making the distance equal between two stations according to the number of the bus stops we locate, which means changing the location of bus stop in each iteration. Figure 4.14 illustrates the distribution on 05, 10, 15 and 20 bus stops.

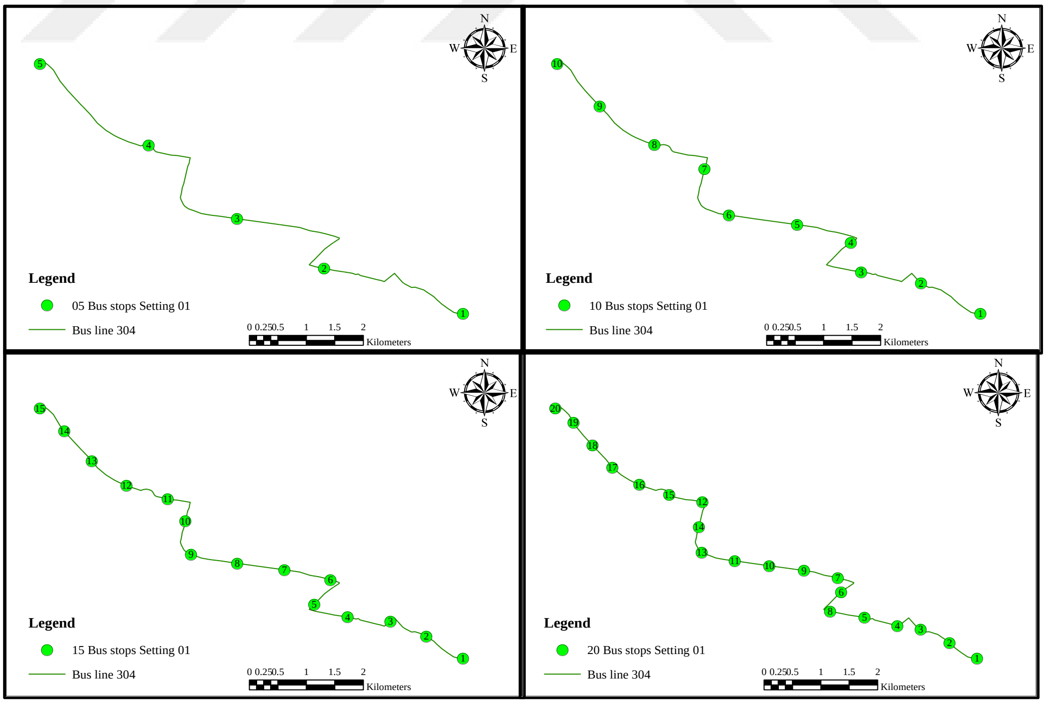

Figure 4.14 illustration of bus stops distribution over the bus line with (5, 10, 15 and 20 bus stops) on setting 01

4.4.2 Setting 02 (fixed stations)

For this setting the bus line is divided equally first to get 3 stations (figure 4.15), the next added bus stop is located in the middle of the station 1 and 2, the fourth station as well is placed in the middle of the stations 2 and 3, continuously, each time a station is added to the bus line, it takes place between two bus stops. in the end, we get equal division without changing the coordination of the existed bus stops, consequences, if there is no new bus stop around the passenger the itinerary does not change as well. Figure 4.15 illustrates the way bus stops are distributed over the bus line with the setting 02, by the examples of 5, 6, 7 and 8 bus stops. For this setting, 22 iterations are performed, from 3 to 25 bus stops.

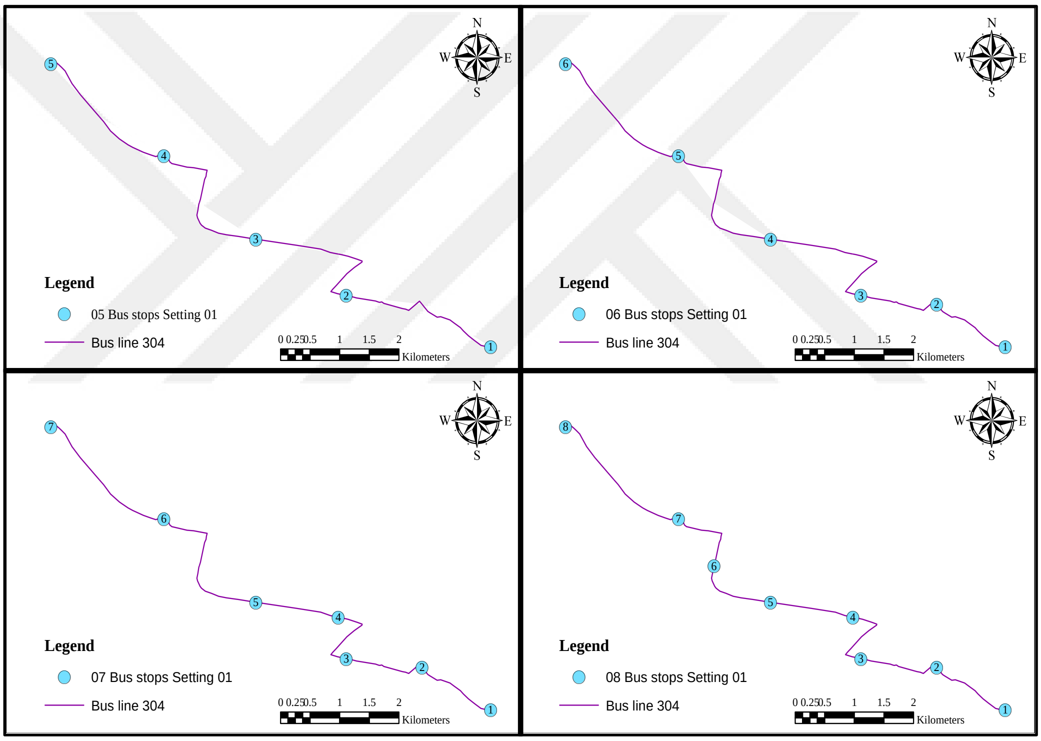

Figure 4.15 Illustration of bus stops distribution over the bus line with (5, 6, 7 and 8 bus stops) on setting 02

4.5 Passenger time estimation

The table of the estimation of the user's travel time is established based on the travel time elements from the origin to the destination (O-D) as follows; (1) Walking time from (O) up to the bus stop, (2) waiting for the bus at the stop (3) Time of getting on the public transportation vehicle, (3) Reputation time of an alternative movement of a vehicle for arriving to the next station consists of: a. enough time for the vehicle to develop the acceleration, constant speed; b. the time in which a vehicle moves between two stations; c. enough time for a vehicle to get to the deceleration station. (5) Stopping time in the stations along the route (6) Time of getting off the vehicle (8) Time of walking to the destination (D).

Since the purpose of this study is to minimize the time of passengers, the priority for the chosen itinerary was fixed on the closest bus stop for departure and the closest bus stop for arrival. The time of taking the bus (spent in the bus) is based on the estimations explained below (bus headway time), but it differs from the calculations made with the setting 01 and 02;

For the setting 01: distances between stations are equal, so the time taken by the bus to move from a station to the next one is constant as well, that’s why all that it needs for that case is multiplying the number of distances between departure station to the arrival of each passenger by the constant time between two stations. For the other factors (access/egress time for passengers, open/close doors time) they were calculated according to each case, and mostly it was changing for each iteration.

For the setting 02, the change occurs only at the added/removed stop level, so we reconsider the distance and the other parameters accordingly to calculate the time spent for each case separately.

The waiting time is derived by dividing the headway time by the fleet size (number of vehicles required for the line) Day P, (1974)

Table 4.5 Estimation of the user travel time (an example of 11 stops, 40 passengers with shifted stations)

Passengers	Origin to Bus stop	Bus stop to destination	Moving speed	Walking Time	Departure	Arrival stop	Number of distances	Dwelling Time '2Sps	Dwelling time	Waiting Time	access	egress	Access/Egress time	Open/Close doors time	Total time
1	95.278	234.99	1.2517	413.409	1	4	3	162.57	487.735	714.563	7	4	10.5	3	1629.208
2	127.340	314.30	1.25171	552.816	1	4	3	162.578	487.735	714.563	7	4	10.5	3	1768.615
3	281.731	385.42	1.25171	835.089	1	4	3	162.578	487.735	714.563	7	4	10.5	3	2050.888
4	501.064	675.80	1.25171	1473.101	1	4	3	162.578	487.735	714.563	7	4	10.5	3	2688.900
5	569.067	285.39	1.25171	1069.539	1	5	4	162.578	650.313	714.563	7	5	10.5	3	2447.917
6	493.412	184.14	1.25171	848.103	1	5	4	162.578	650.313	714.563	7	5	10.5	3	2226.481
7	589.507	425.61	1.25171	1270.633	1	5	4	162.578	650.313	714.563	7	5	10.5	3	2649.011

Table 4.6 continues

8	492.730	626.48	1.25171	1400.933	2	5	3	162.578	487.735	714.563	4	5	7.5	3	2613.733
9	564.306	645.74	1.25171	1514.626	2	5	3	162.578	487.735	714.563	4	5	7.5	3	2727.426
10	18.684	406.453	1.25171	532.1484	2	6	4	162.578	650.313	714.563	4	7	10.5	3	1910.526
11	271.789	229.20	1.25171	627.100	2	6	4	162.578	650.313	714.563	4	7	10.5	3	2005.478
12	259.829	124.62	1.25171	481.228	3	6	3	162.578	487.735	714.563	4	7	10.5	3	1697.027
13	378.306	199.25	1.25171	722.9438	3	6	3	162.578	487.735	714.563	4	7	10.5	3	1938.743
14	453.242	455.18	1.25171	1137.087	3	6	3	162.578	487.735	714.563	4	7	10.5	3	2352.886
15	484.094	576.62	1.25171	1327.715	3	6	3	162.578	487.735	714.563	4	7	10.5	3	2543.514
16	279.447	514.30	1.25171	993.541	4	6	2	162.578	325.156	714.563	5	7	10.5	3	2046.761
17	212.413	436.89	1.25171	812.741	4	7	3	162.578	487.735	714.563	5	4	7.5	3	2025.540
18	554.728	168.71	1.25171	905.535	4	7	3	162.578	487.735	714.563	5	4	7.5	3	2118.335
19	787.189	398.44	1.25171	1484.072	4	7	3	162.578	487.73	714.563	5	4	7.5	3	2696.871
20	539.309	593.23	1.25171	1417.610	4	7	3	162.578	487.735	714.563	5	4	7.5	3	2630.409
21	552.509	410.62	1.25171	1205.558	5	8	3	162.578	487.735	714.563	11	11	16.5	3	2427.357
22	518.956	465.71	1.25171	1232.520	5	8	3	162.578	487.735	714.563	11	11	16.5	3	2454.319
23	267.472	400.06	1.25171	835.567	5	8	3	162.578	487.735	714.563	11	11	16.5	3	2057.367
24	200.646	177.70	1.25171	473.580	5	8	3	162.578	487.735	714.563	11	11	16.5	3	1695.380
25	183.800	114.64	1.25171	373.564	5	8	3	162.578	487.735	714.563	11	11	16.5	3	1595.363
26	190.549	285.22	1.25171	595.536	5	8	3	162.578	487.735	714.563	11	11	16.5	3	1817.335
27	392.799	260.00	1.25171	817.117	5	8	3	162.578	487.735	714.563	11	11	16.5	3	2038.916
28	615.663	261.07	1.25171	1097.425	5	8	3	162.578	487.735	714.563	11	11	16.5	3	2319.224
29	697.607	297.18	1.25171	1245.192	5	8	3	162.578	487.735	714.563	11	11	16.5	3	2466.991
30	629.925	188.35	1.25171	1024.249	6	8	2	162.578	325.156	714.563	8	11	16.5	3	2083.470
31	813.176	244.23	1.25171	1323.576	6	8	2	162.578	325.156	714.563	8	11	16.5	3	2382.797
32	597.914	385.69	1.25171	1231.194	6	9	3	162.578	487.735	714.563	8	4	12	3	2448.493
33	306.609	370.03	1.25171	846.965	6	9	3	162.578	487.735	714.563	8	4	12	3	2064.265
34	252.291	140.84	1.25171	492.093	6	9	3	162.578	487.735	714.563	8	4	12	3	1709.392
35	154.744	62.559	1.25171	272.000	6	9	3	162.578	487.735	714.563	8	4	12	3	1489.299
36	370.814	191.37	1.25171	703.697	6	8	2	162.578	325.156	714.563	8	2	12	3	1758.418
37	185.989	288.28	1.25171	593.651	6	8	2	162.578	325.156	714.563	8	2	12	3	1648.371
38	532.225	532.22	1.25171	1332.382	7	7	0	0.000	0	0	0	0	0	0	1332.383
39	533.053	693.42	1.25171	1535.198	5	7	2	162.578	325.156	714.563	2	2	3	3	2580.919
40	525.677	481.09	1.25171	1260.186	5	6	1	162.578	162.578	714.563	2	2	3	3	2143.329
															85281.657

To illustrate the way passengers time is calculated, the example of passenger number 16 is detailed as follow;

For the walking distance from the origin to the bus stop as shown on the Figure 4.14, the passenger 16 takes the closest bus stop forward. Same thing for the walking distance from the bus stop to the destination, the GIS based network analysis serve for the calculation of the shortest path, and the calculation of the distances, (Figure 4.15) shows the interface of the GIS with the table of waling distances calculation. It is noted that the calculations are performed by the Geometry calculation function, using (WGS 1984 UTM Zone 34S) as geo-reference system for the map in ArcMap, ESRI 10.5.

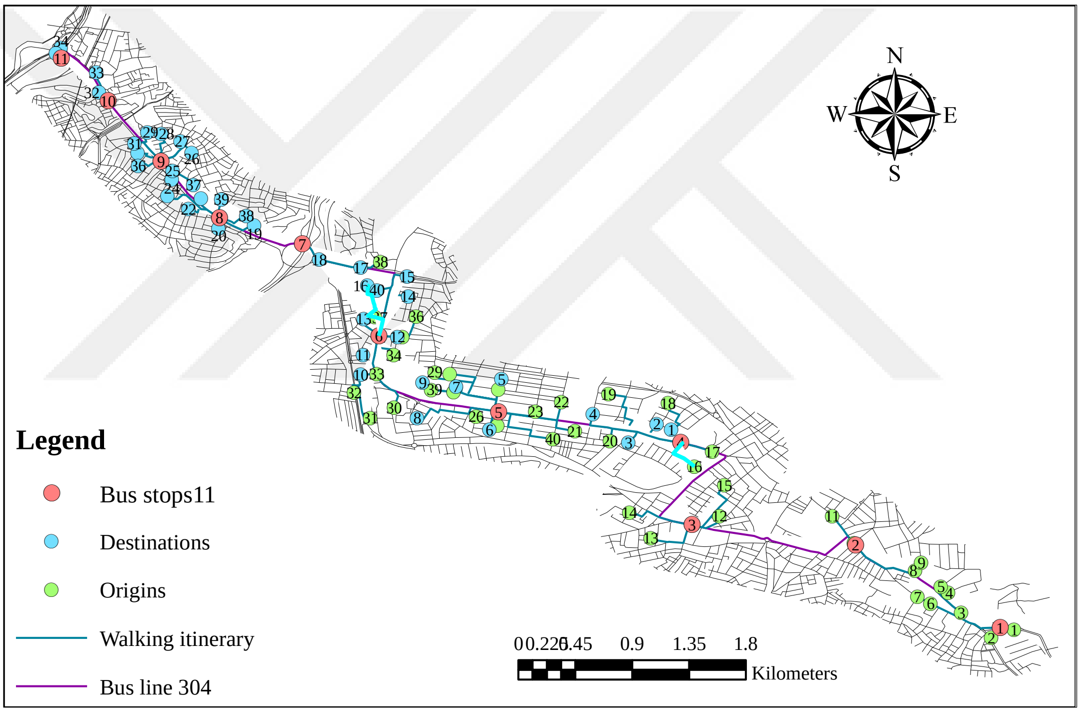

Figure 4.16 Itinerary of passengers on bus line of 11 stations with shifted stations

The data resulted from the walking distances are exported to the table, under the column of “Origin to bus stop” and “Bus stop to destination” respectively, then the walking time is derived by the multiplication of the walking distance by the walking (or moving) average speed (1.251 m/s) (Table 4.3)

Walking time= (walking from the origin to the bus stop + walking from the bus stop to the destination) x walking speed (4.8)

For the passenger 16: Walking time= (279.447+514.300) x 1.251= 993.541s

The calculate the dwelling time is based on the number of stations passenger get through and the distances between them, the table of bus heading time provides prepared results to use for this calculation,

Dwelling time= number of distances x dwelling time between two stops (4.9)

The number of distances is calculated from the stations numbers (ascending and descending),

The passenger gets in the station number 4, and descend in the station number 6, so the number of distances is 6-4= 2

Dwelling time= 2 x 162.578 = 325.156 s

The waiting time is derived for the headway time of the bus divided by 2,

From the previous table (Table 4.2), the headway time is 1429.12 S, which make the waiting time 714.563 s

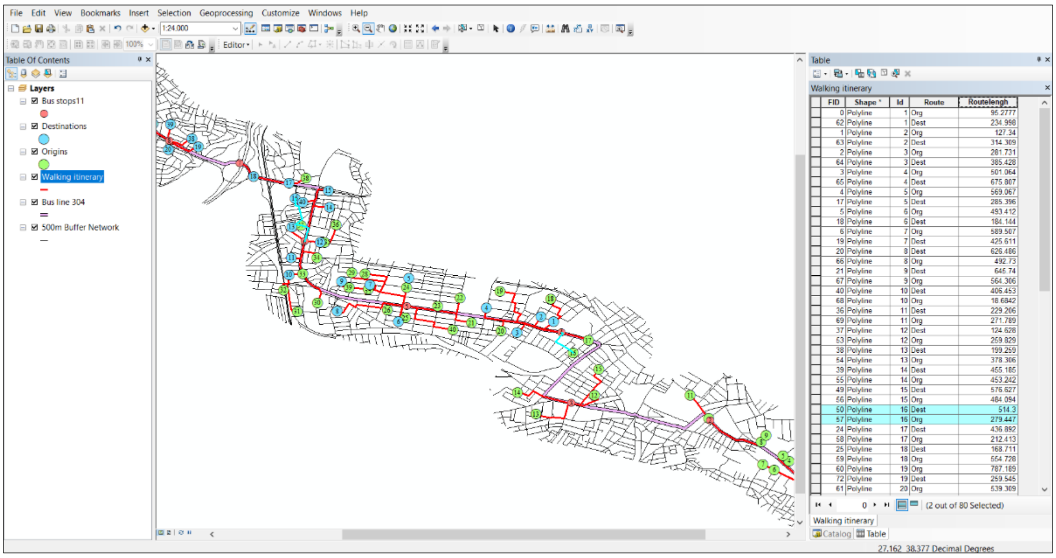

Figure 4.17 Interface of the GIS with the geographical window and the data table board, ArcMap, ESRI 10.5

Passengers getting in/out of the bus on each bus stop are counted as well, it can be seen from the Figure 11, the number of passengers linked to stations: 5 passengers getting in and 7 getting out the vehicle at the same time, the higher value is taken, so 7 X 1.5= 10.5s. Passengers loading time counts for the passenger's total time along the station he gets over, plus the open/closing doors time.

Passenger's trip time is the sum of all the previous elements;

Total time= walking time+ dwelling time+ waiting time+ access/egress time+ open/close doors

Total time= 993.541+ 325.156+ 714.563+ 10.5+ 3 = 2046.761 s

4.6 The effect of changing passenger number

Ten passengers are the minimum number of passengers generalized for both settings in the beginning, upon getting the image of the graph of the relationship between number of stops and users time and choosing the setting that demonstrate feasibility, the 3rd level of simulation will be applied - passengers volume- with an interval of 30 range of passengers from 10 to 40.

The number of bus stops to add is related to the order of the graph, the best setting is meant to give passengers the shortest time possible, although, at the other directions of the graph, the time value should testify a regular increasing.

The way data has been collected is applied on the defined cases to test the parameters of passengers' trip time, the calculations will end up with showing the variation testified in each change of setting (shifted and fixed) and the number of stations in each iteration. Overall the data presented in this chapter is voluminous: 30 tables for shifted stations with 10 passengers, 50 tables on fixed stations with 40 passengers, and 660 tables of passengers' volume iterations from 10 to 40, summarized in 30 tables for the total bus time and passengers' total time, although data collection is semi-automatic.

The analyze of those iterations' results will demonstrate the effect of each variable statistically, the findings can lead us to discover how to optimize passengers' time the best. The next chapter is aimed to analyze and interpret the resulted data.

CHAPTER FIVE

ANALYSIS AND RESULTS

From the collected data explained in the previous chapter, we got the information we need to compare results of the different scenarios and iterations. The main factors to minimize as empathized at the beginning is the time for the bus and its users, which are the result of the two typical tables in the experiments. In this chapter, the final data will be represented in a different way to make observations and analysis over it.

5.1 Bus time analysis

For the setting of shifted stations, with bus stops distributed on equal distances along the bus line, from 10 to 20 stations 10 iterations, the results are presented in the Table 04. The heading time increases with more bus stops, but the passengers' time testify many variations over the tested cases, a graphical representation of data should make the interpretation of results easier (Figure 5.18)

Table 5.7 Bus and passengers time for the setting with shifted stations over the bus lines with 10 to 25 stations

Number of Bus Stops	Passengers' time	Headway time
10Stops	22978.582	13815.038
11Stops	21868.479	14153.834
12Stops	21803.640	14450.107
13Stops	21771.557	14738.918
14Stops	19815.836	15090.213
15Stops	20489.016	15404.007
16Stops	19948.227	15687.796
17Stops	19599.198	16044.093
18Stops	19240.897	16370.390
19Stops	19437.082	16721.680
20Stops	19130.520	17035.477
21Stops	19302.583	16837.946
22Stops	19435.316	17160.613
23Stops	19877.690	17792.860
24Stops	20172.557	17930.567
25Stops	20650.735	18109.431

As displayed in the graph (Figure 5.18) based on the data from the Table 04, the heading time keep increasing steadily with the number of buses stops, from almost 1350 second with 10 bus stops up to 1703 second with 20 stops, the reasons of the increase in time are the factors explained in the previous chapter, the more the bus line contains bus stops, the slow the bus moves and its velocity reduces, plus more passengers in/out in several stations instead of ascending/descending from less station, and finally the open/close doors time in each station.

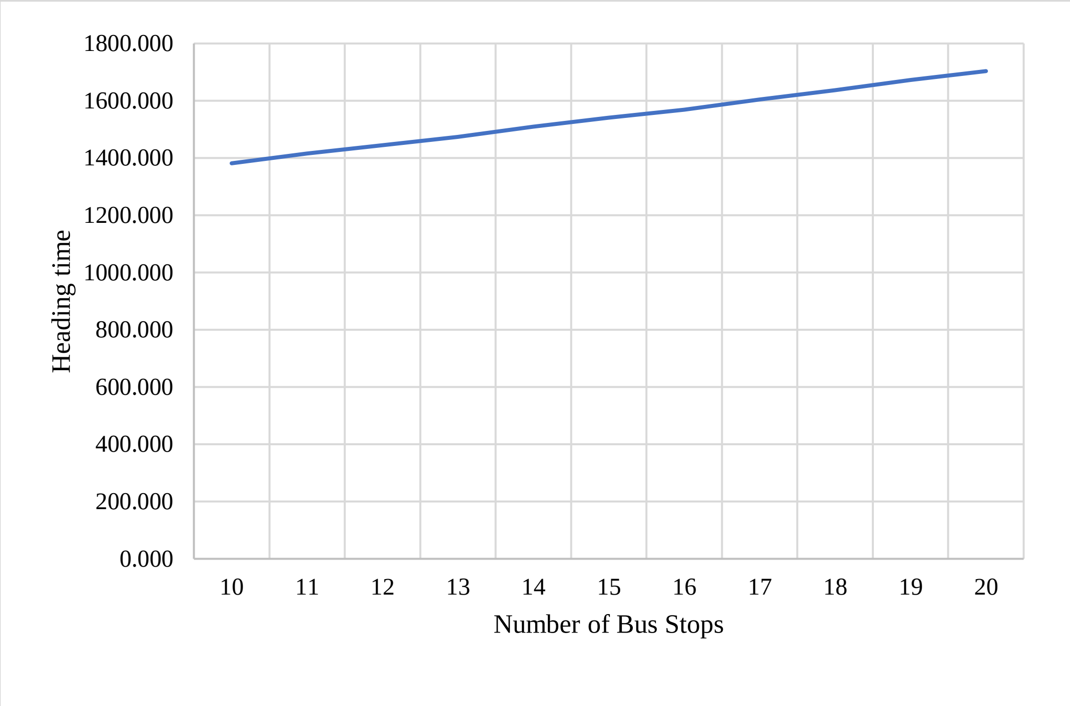

Figure 5.18 Buses heading time for the setting of shifted stations

Setting with fixed stations: for this setting, more bus stops are needed to clarify the effect of adding a station between equal distanced bus stops for each iteration, the total number of bus stops is 23 (from 3 to 25), the experiment starts with 3 stations: in the beginning, the middle and the end of the bus line, and then in each iteration a station is added in between two stations till 25 stations.

Table 8.5 Bus and passengers time for the setting of fixed stations

Number of Bus Stops	Heading time	Passengers' time
03 Bus Stops	1208.349	137371.485
04 Bus Stops	1264.977	124617.070
05 Bus Stops	1293.106	117734.590
06 Bus Stops	1338.736	116310.282
07 Bus Stops	1367.366	93519.463
08 Bus Stops	1393.996	94616.021

Table 9.5 continues

09 Bus Stops	1429.127	85281.656
10 Bus Stops	1468.755	86084.239
11 Bus Stops	1493.384	84532.348
12 Bus Stops	1533.013	84332.477
13 Bus Stops	1559.142	82452.150
14 Bus Stops	1594.271	81614.863
15 Bus Stops	1638.400	77840.679
16 Bus Stops	1637.029	78020.664
17 Bus Stops	1669.659	80486.620
18 Bus Stops	1702.246	81423.015
19 Bus Stops	1734.834	81671.482
20 Bus Stops	1767.422	81682.717
21 Bus Stops	1800.009	82176.134
22 Bus Stops	1837.097	82917.889
23 Bus Stops	1868.185	83107.216
24 Bus Stops	1902.273	83636.104
25 Bus Stops	1936.360	84317.858

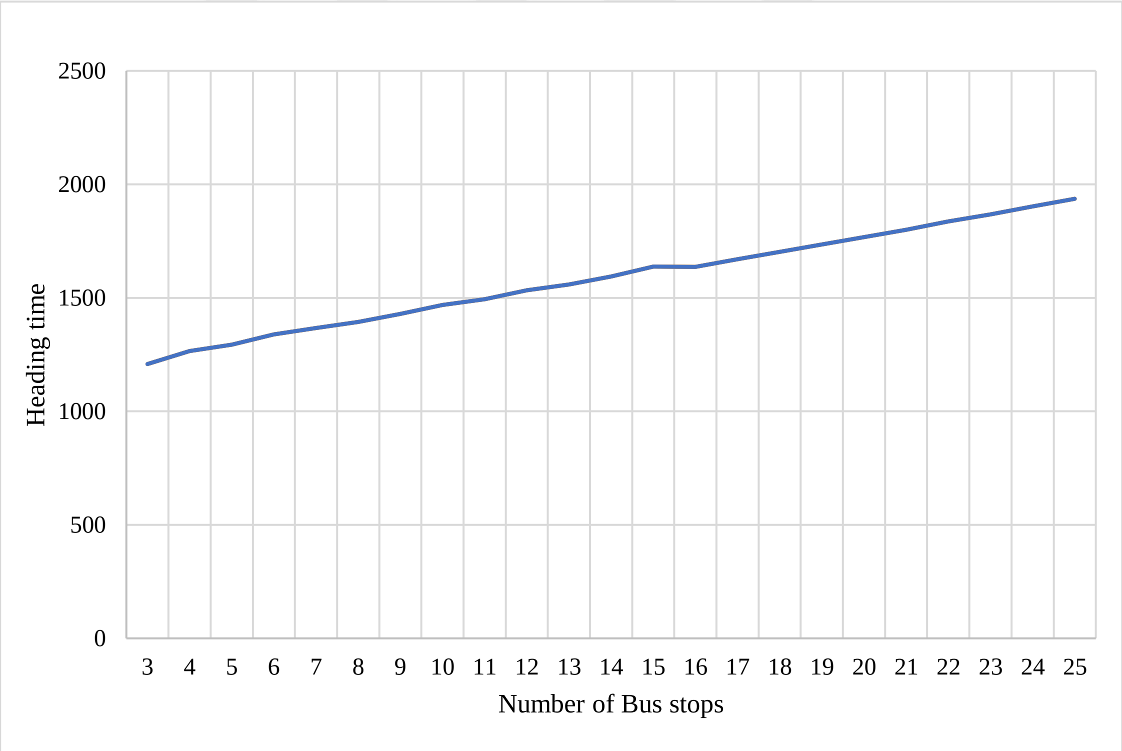

Figure 5.19 Heading time for the setting 02

For the setting of fixed stations, the table shows a larger set of bus stops than the previous. Although the main difference is the way bus stops are distributed along the bus line, the graph shows the same attitude (positive increasing of time with the number of bus stops) since the factors affecting headway time are the same.

5.2 Passenger time analysis

Setting 01: Nevertheless, the graph of the headway time is showing a constant increase, the passengers time is showing a diminution but not in a regular way, we can spot some distortion in the graph, on the bus lines with 11, 12 and 13 stops, the passengers' time is 21868.480, 21803.641, 21771.558 respectively, which shows a very slight difference compared to the change occurred over the bus line. Also, the line of 15 bus stops displays a prompt increase after a decrease in passengers' time with 14 bus stops, same thing can be seen on the bus line with 19 bus stops, an increasing in time passengers followed by decreasing harmonically with the general order of the graph. With the bus line of 20 stations bus users time goes down slightly again, almost equal to the time of the line with 18 stations, 19240.897 s and 19130.520 s respectively. The bus user's time take a slight but steady increasing after the implementation of 20 stations, and this increasing is applied up to 25 stations.

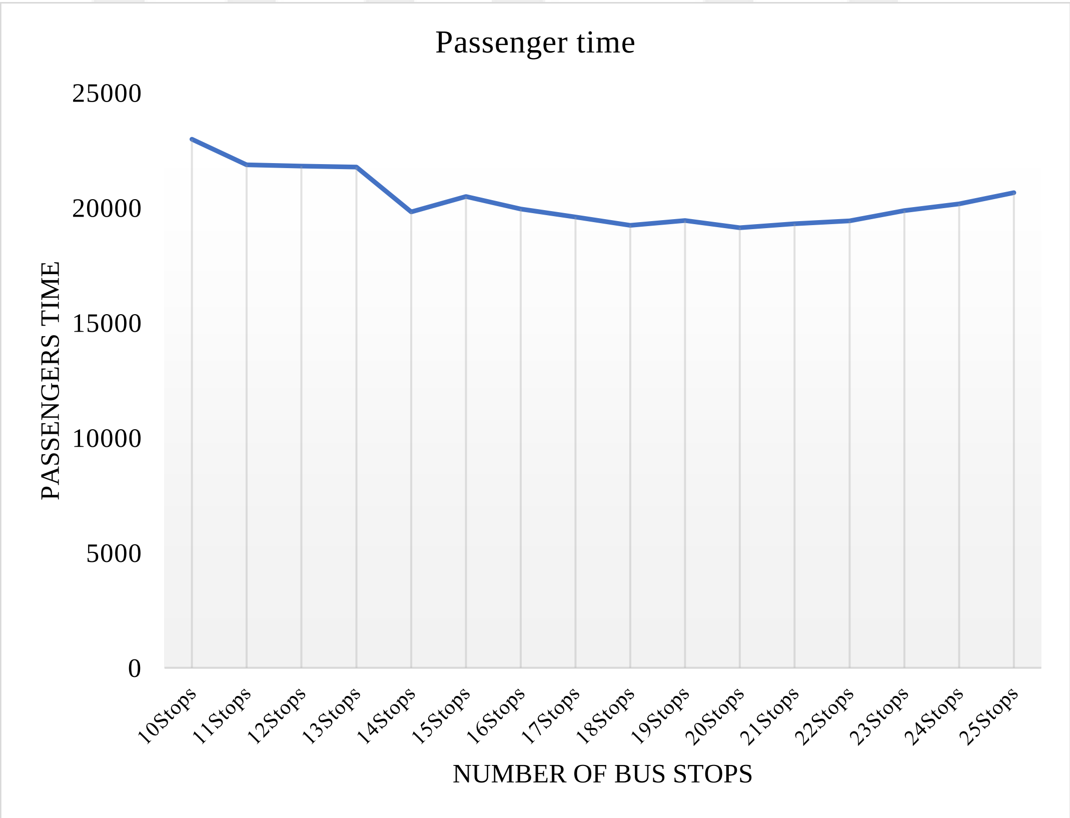

Figure 5.20 Total passengers time for setting of shifted stations

According to the expected results, the bus users would get less time with more bus stops, since the bus velocity is higher than walking.

To analyze the reason of that distortion, resorting to using more detailed graphs on the passengers' time is needed, by checking the walking time from the origin to the bus stop, waiting time and dwelling time, then the walking time from the bus stop to the destination (Table 5.6).

Table 5.10 Detailed passengers' time for setting of shifted stations

Number of bus stops	Total walking time origin to bus stop	Total waiting time	Total Dwelling time	Total walking time bus stop to destination
10Stops	4661.964	6907.519	4877.597	4215.664
11Stops	4338.147	7076.917	4487.615	3791.889
12Stops	4441.424	7225.053	4168.532	3784.167
13Stops	4245.885	7369.459	3902.640	4046.338
14Stops	3650.788	7545.106	3677.650	3121.411
15Stops	3594.313	7702.003	3484.801	3794.148
16Stops	3559.858	7843.898	3317.665	3365.998
17Stops	3392.123	8022.046	3171.422	3226.406
18Stops	3316.514	8185.195	3042.384	2996.504
19Stops	3226.375	8360.840	2927.683	3183.703
20Stops	3639.967	8517.738	2825.056	2481.838
21Stops	3010.095	8418.973	2820.178	2825.057
22Stops	3266.604	8580.307	3177.610	2825.057
23Stops	3115.365	8896.430	3245.813	2825.057
24Stops	3392.716	8965.284	3511.594	2825.057
25Stops	3245.950	9054.716	3172.293	3595.527

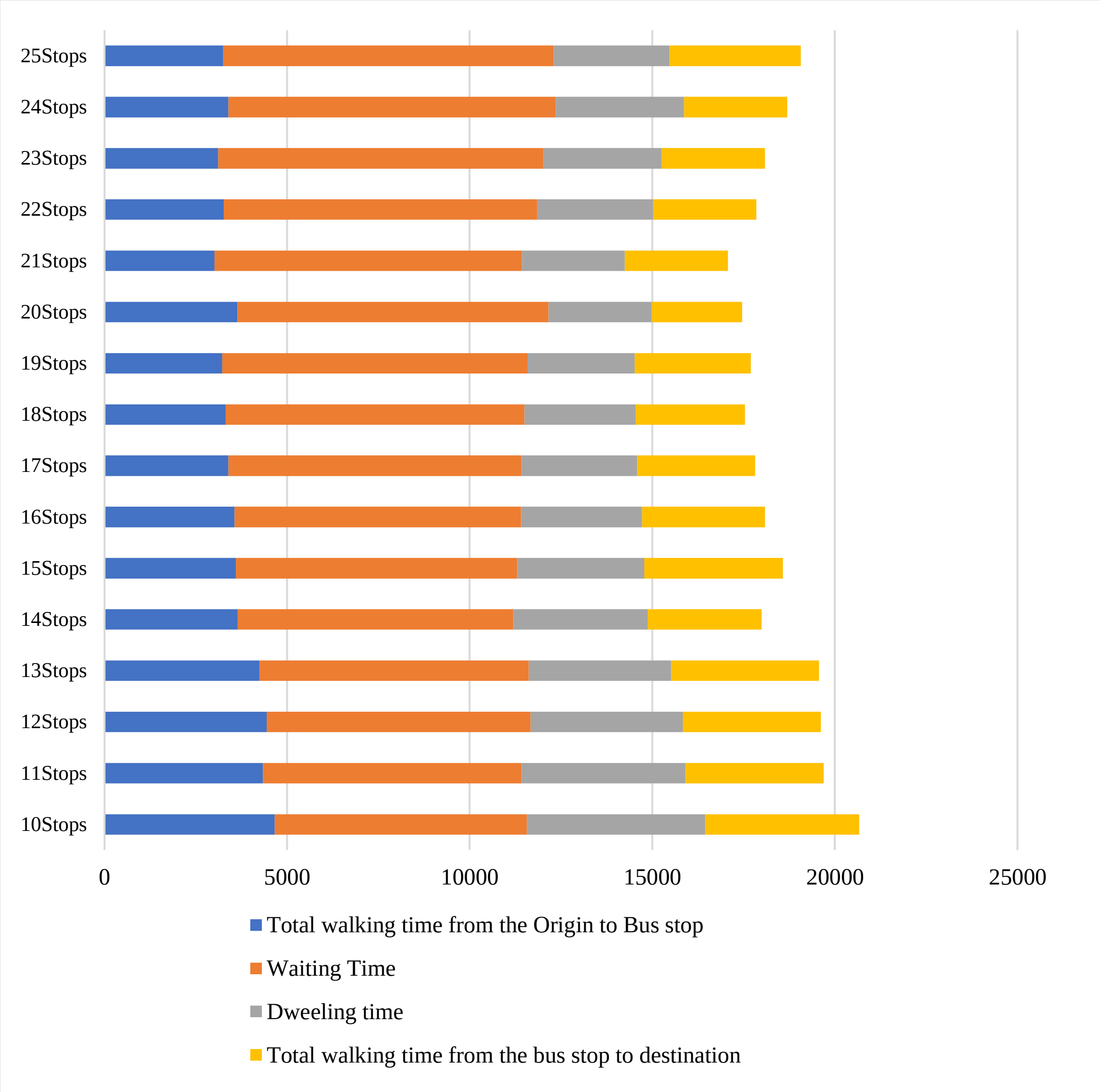

Figure 5. 21 Detailed passengers' time for setting 01

According to the graph, for the bus lines with 12, 13 and 14 bus stops, the distance was not enough to make difference, in other words, the number of bus stops -at that point- is negligible compared to the bus line length, so the difference cannot be seen yet.

In the other hand (The figure 5.21) demonstrate the unexpected increase in the parts pointed out previously (bus line with 15 and 19 bus stops), for the bus line containing 15 stops, whereas the waiting and dwelling time is quite similar, the walking time of the passengers -from bus stop to destination- is greater than the previous (14 bus stops) and the next one (16 bus stops), the same thing for 19, that is showing longer time for line with 18 and 20 bus stops.

The difference is due to the dislocation of the bus stops, the stops took other locations far enough to make the passengers take another direction (forward) or getting out of the bus in a previous stop (backward) to continue walking to their destination, hence the walking distance and simultaneity the walking time increases,

the figure 17, displaying the maps of the bus line of 13, 14 and 15 respectively with a highlight on the itinerary of the passenger number 4.

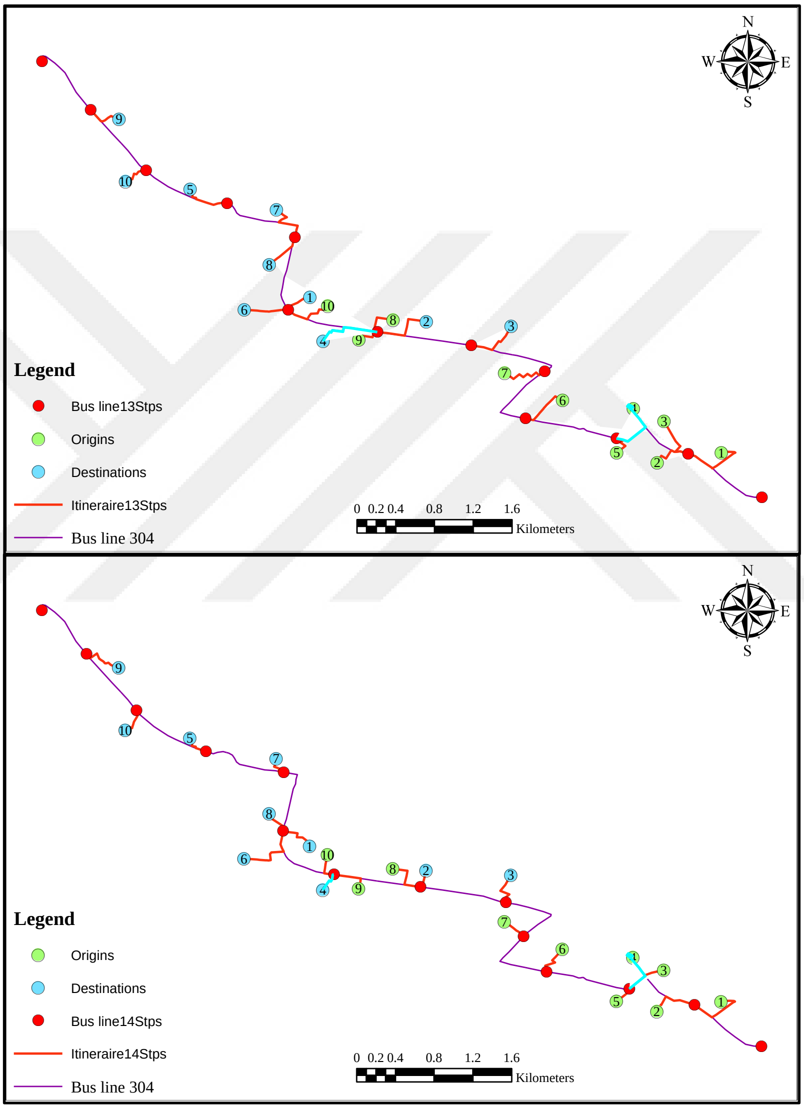

Figure 5.22 Itinerary of passengers on bus lines with 13, 14 and 15 bus stops

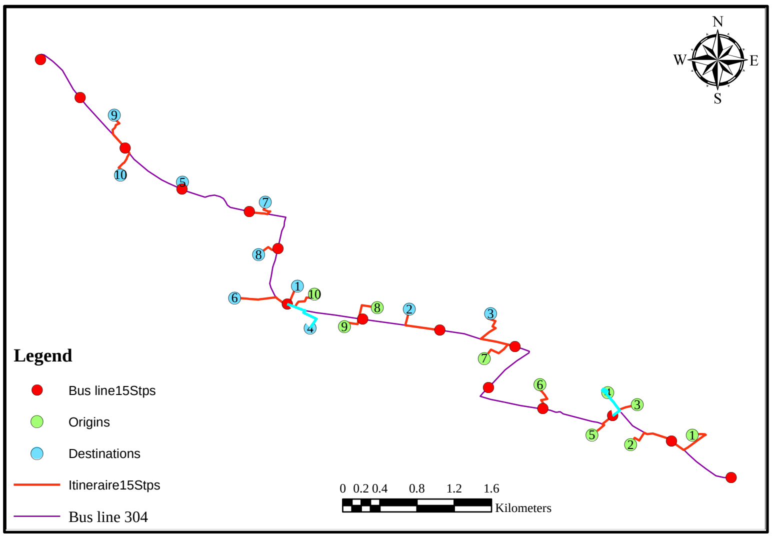

Figure 5.23 continues

It can be observed from the maps (Figure 5.22) the dislocation of bus stop by adding more bus stops, which make the passenger walk more. In the figure 5.21, the highlighted passenger number 4 represent the case of having more walking distance with more stations, idem for the passengers 2 and 3. The next graphs show the analyze of time spent by each of the 10 passengers, and it clearly displays the differences (ups and downs) from the bus line of 13 to 15 bus stops.

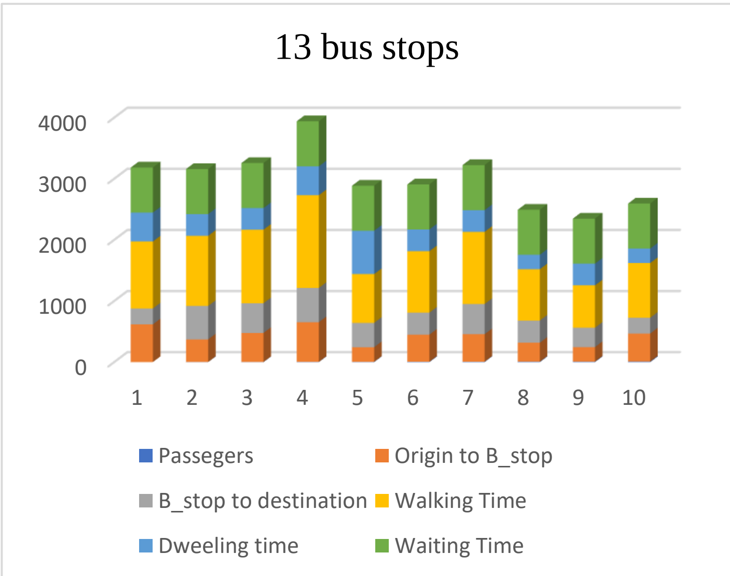

Figure 5.24 Detailed spent time by passengers on bus lines with 13, 14 and 15 bus stops

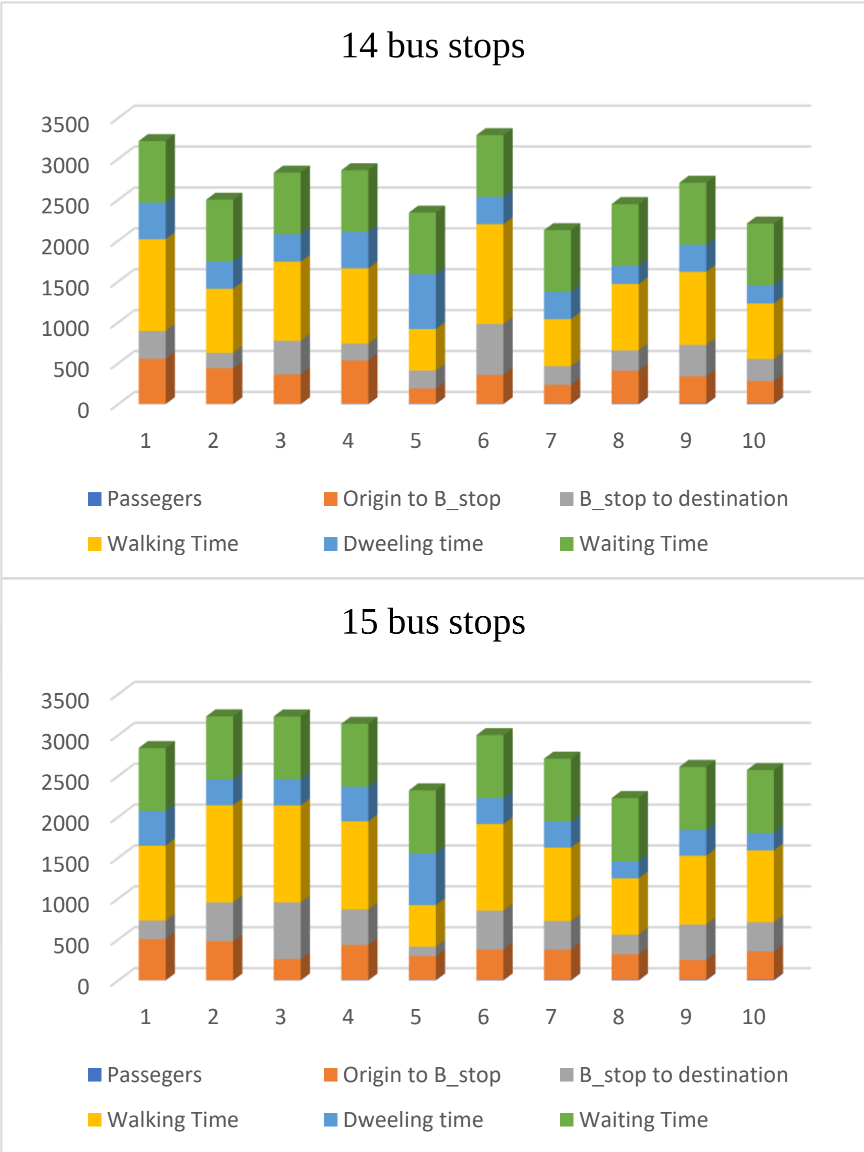

Figure 5.25 continues

As the example shows, the setting of distribution of bus stops with equal distances may cause a disturbance instead of optimization, due to the dislocation of bus stops. The more stations added do not mean less time for passengers, either for the bus headway of course. Furthermore, the advanced methods of generating passengers are not practical with variable locating of bus stops.

For the setting 02 (fixed stations), The wide range of bus lines allows us to analyze the effect of adding/removing bus stops over a bus line, from the line of 3 stops to 9, the passengers time decreases significantly from 137371.4855 for 3 stops to 85281.6567 for bus line of 9 stoops (figure 5.24). Over the pane from 9 to 25 the increase/decrease is slightly visible, the minimum value is marked on bus line of 15 the bus stops by 77840.679 seconds, after that the passengers' time goes for a steady increase up to the last bus line tested 25 stops by 83636.10402 seconds.

Although abnormal increases are remarkable over some bus lines in this setting, a detailed passengers' timetable and graph would be of great use to explain them.

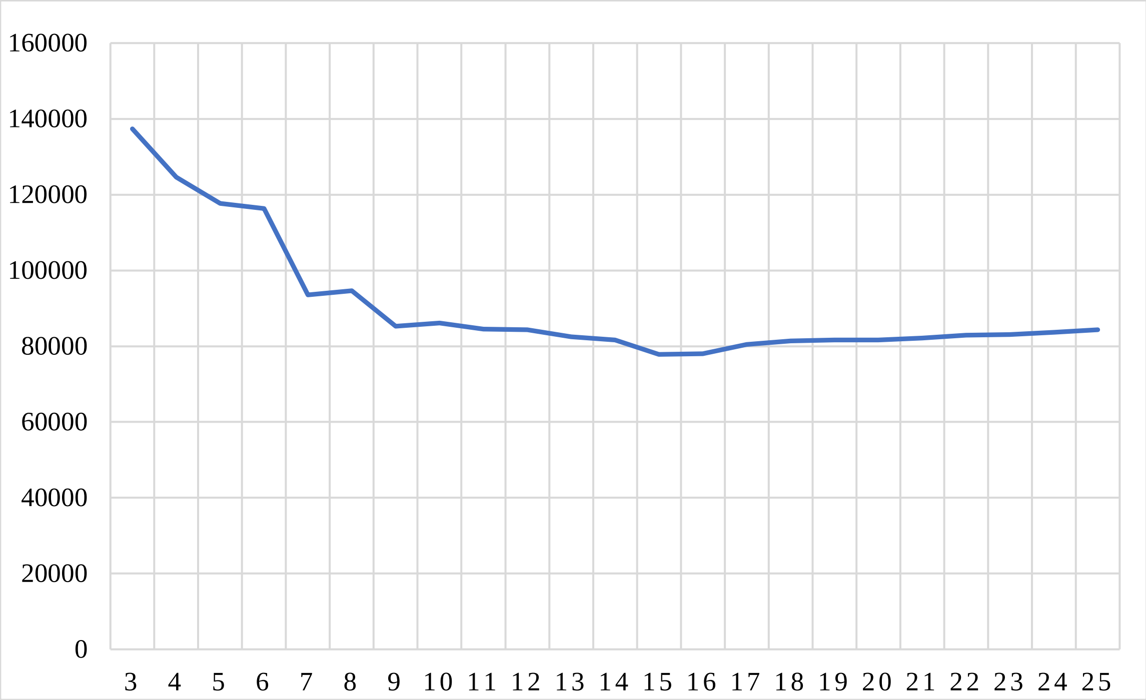

Figure 5.26 Total passengers' time for the setting of fixed stations

Table 5.11 Detailed passengers' time for the setting of fixed stations

Number of stations	Origin to Bus stop	Bus stop to destination	Dwelling time	Waiting Time
3	34774.139	45406.902	17404.162	18729.412
4	36443.249	29658.764	17581.933	23402.086
5	27346.581	31327.874	18618.171	24569.016
6	27346.581	31327.874	16326.889	25435.992
7	21650.358	16974.235	18088.708	25979.967
8	21650.358	16974.235	18562.792	27182.941
9	16475.883	14131.237	18533.937	27867.980
10	17008.108	13681.718	18460.246	28640.731
11	16518.587	11838.828	19347.589	29120.999
12	16117.771	10659.644	19586.146	30660.273
13	14250.256	9791.730	20607.201	31182.854
14	13095.914	9206.163	21245.194	31885.436

Table 5.12 continues

15	12783.445	9206.163	16979.548	32768.018
16	12783.445	9206.163	17186.952	32740.599
17	10566.619	9206.164	21911.650	33393.181
18	10566.619	9206.164	22196.290	34044.935
19	10566.619	8372.259	22196.290	35348.443
20	10566.619	8372.259	22196.290	35348.443
21	10566.619	8245.763	22196.290	36000.198
22	10566.619	8245.763	22196.290	36741.952
23	10566.619	7900.294	22196.290	37363.706
24	10444.493	7900.294	22196.290	38045.460
25	10444.493	7900.294	22196.290	38727.214

The graph (Figure 5.25) displays the time spent by passengers on each stage of their itinerary (Origin to bus stop, bus stop to destination, dwelling time and waiting time).

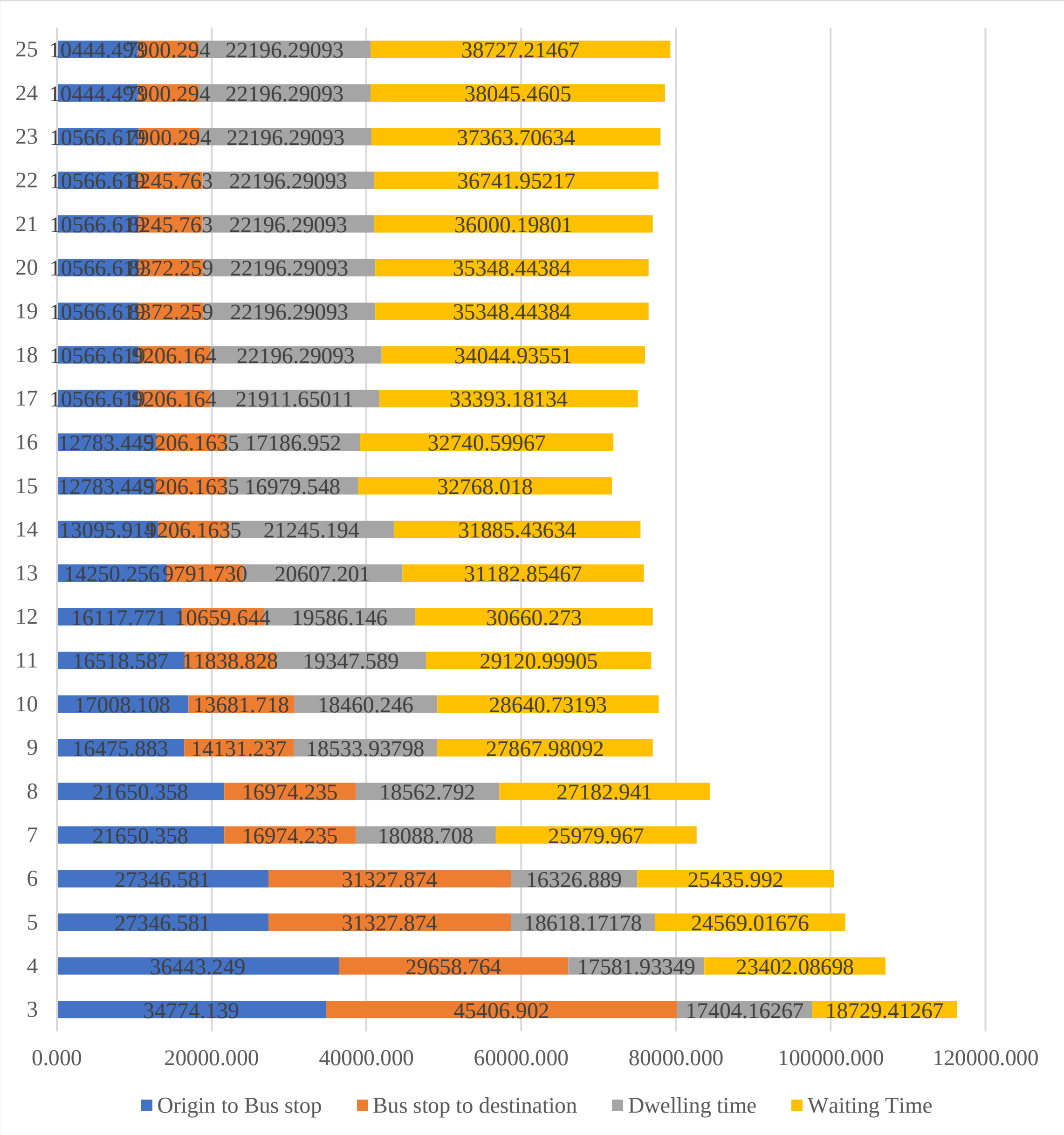

Figure 5.27 Detailed passengers' time for setting 02 (fixed stations)

The shortest time bus line contains less dwelling and waiting time, but same walking time as the next iteration, for all the next iterations, the factor that makes the trip linger is the dwelling and waiting time. At some point adding more bus stops will not help passengers to have a closer bus stops bus rather reduce the velocity of the bus and add more time for stopping in each station.

As the figure 5.25 shows, the first iterations, with few buses stops, demonstrates way longer time than lines with more bus stops, mainly the majority of time is referred to walking (origin to the bus stop- bus stops to destination).

As mentioned in the previous chapter, if the walking time from origin to destination with no taking bus (dwelling time) and waiting time for the bus is estimated less than the time passengers take using the bus, then the optimization opts for excluding the use of the bus. Accordingly, if the increase in time remarked on the bus line with 8 bus stops is referred to waiting time, it may due to the automatic choice of the nearest bus stop without considering the total time and comparing it with time taken by only walking, the following graphs on the detailed time of each passenger will allow us to find out about that.

The figure 5.26 shows how the itinerary of some passengers is completely walking, since there are no bus stations or only one, so they opt for walking the whole itinerary.

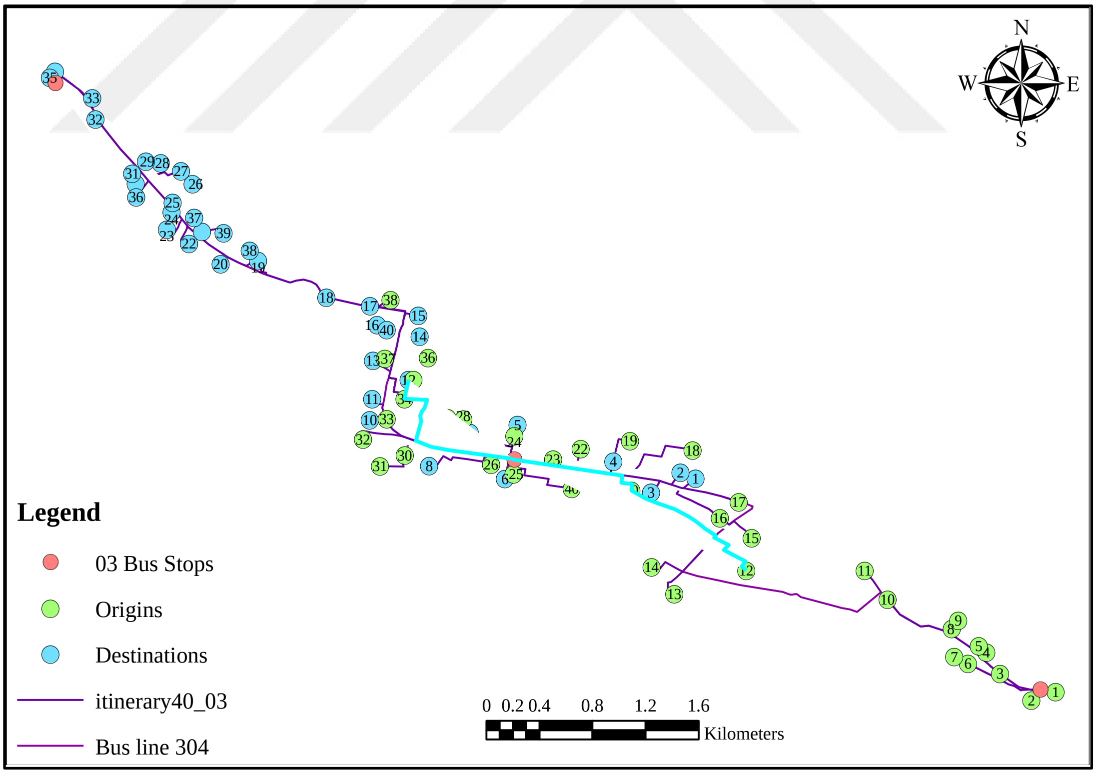

Figure 5.28 Itinerary of passengers with 3 bus stops in setting 02

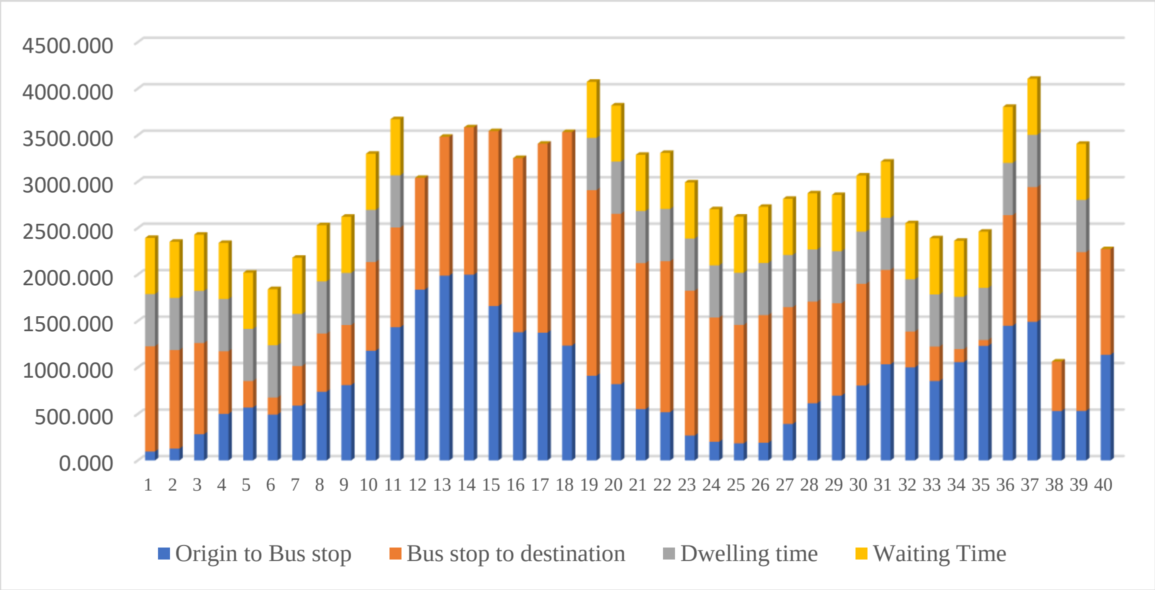

Figure 5.29 Detailed spent time by passengers on bus lines with 3 bus stops

According to the graph (figure 5.27), for many passengers 11 to 18, 38 and 40, there is no waiting and dwelling only walking, yet the graph (figure 18) registers them as lines that took longer time compared to the lines with more bus stops.

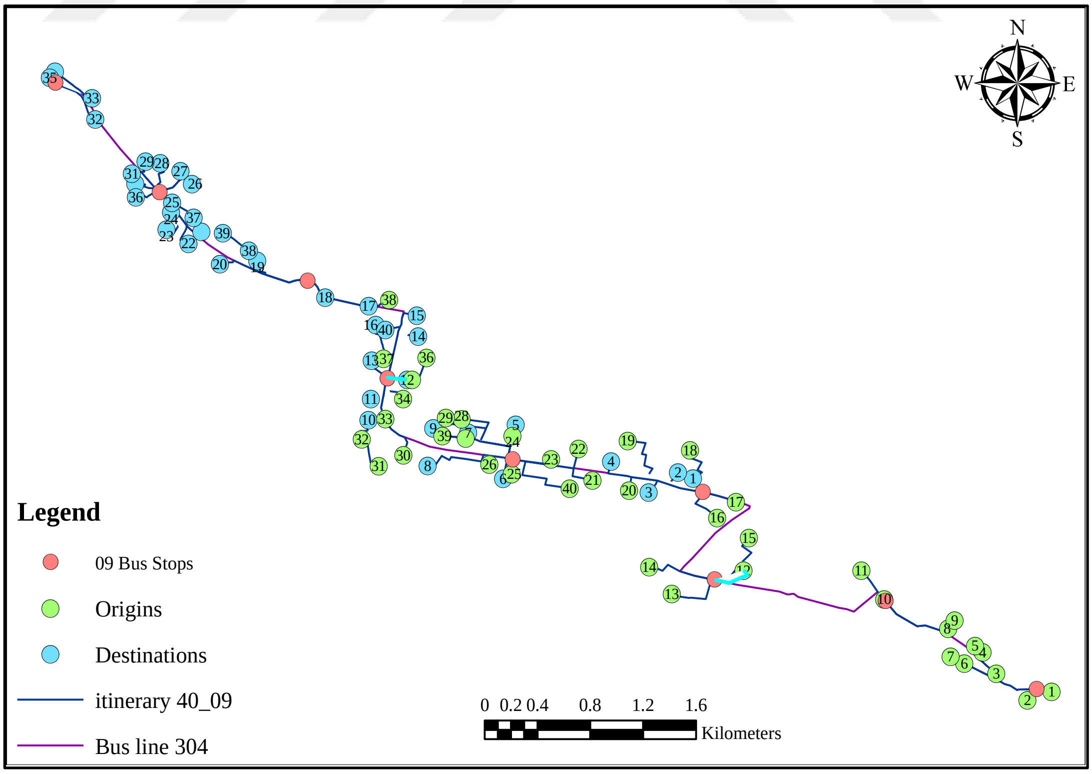

Figure 5.28 Itinerary of passengers with 3 bus stops in setting 02 (Fixed stations)

A good example of the difference of the distance of walking and simultaneously the time taken by a passenger is the highlighted passenger number 12, in bus line of 3 stops (walking all the way over the itinerary) and on the line with 9 stops (walking for a very short distance). Now, for the bus line of 8 stops, although the walking time seems to be the same, dwelling and waiting time are longer, the following graphs express the reason for the difference.

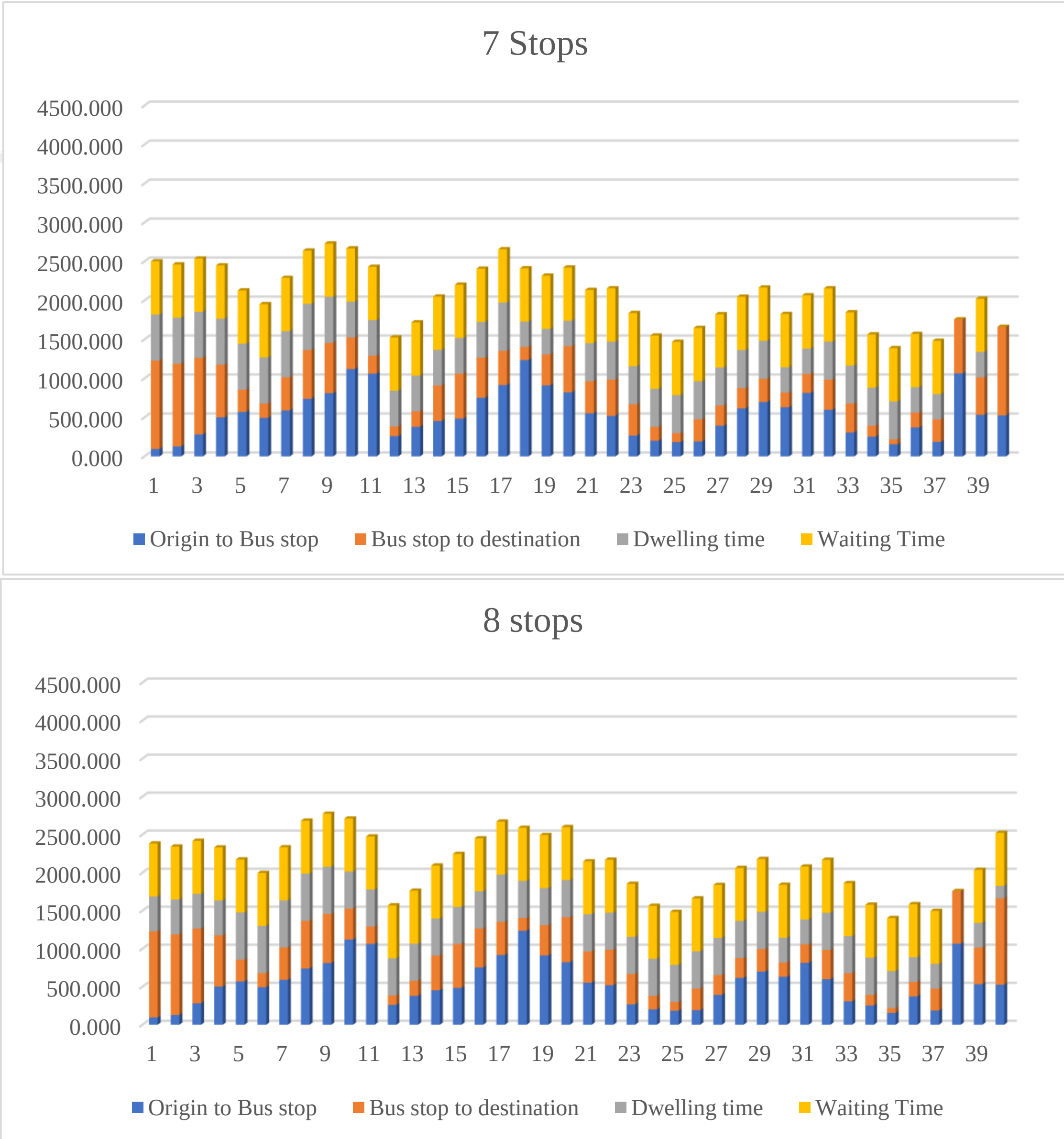

Figure 5.29 Detailed spent time by passengers on bus lines with 7 and 8 bus stops.

As shown on the graphs (figure 5.29), the slight difference is referred to the bus stop added at some point of the line, in which only one passenger (number 40) switch from walking to taking bus, despite the dwelling time is quite short, most of the time does for waiting, and since the dwelling time is changed by adding that station, the waiting time for all passengers increases. So that is the explanation of the increase observed on that line, just after, the next lines show a continuous decrease in time.

5.3 Passenger volume graph

The analysis aims to examine the determined number of stops as optimal for a certain number of passenger than others. The graph (figure 5.30) considers three dimensions, the number of bus stops, the passengers time, and the number of passengers.

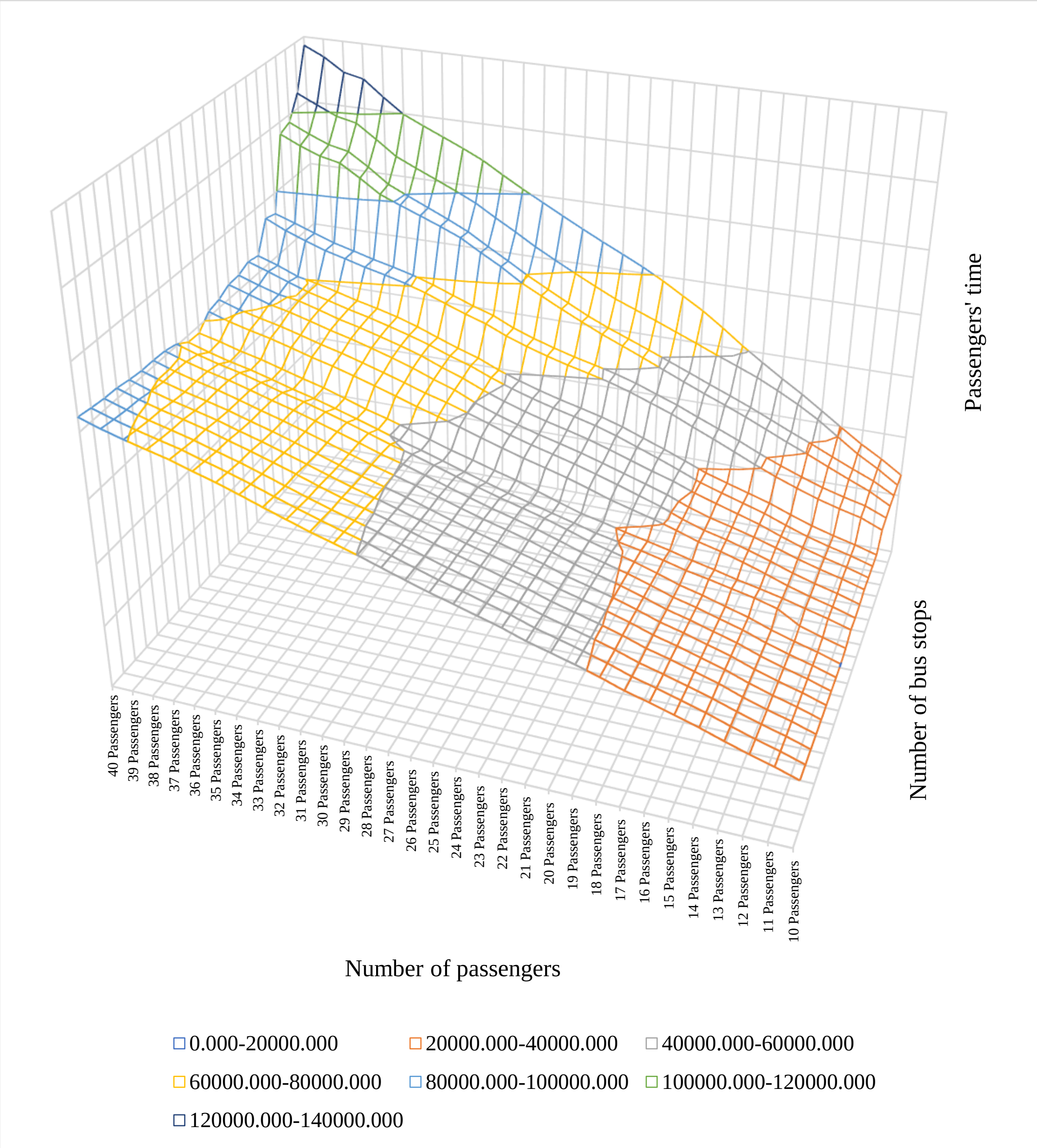

Figure 5.30 users time change over the change of bus stop and passengers’ number

Overall, the time spent on the bus increases with the increasing of the number of passengers, hence for the number of bus stops it testify many changes ups and downs, and the relationship (passenger time-number of bus stops) is changing according to the number of passengers. The graph (figure 5.32) shows how the time spent on bus may change at the same number of bus stops with higher and lower values over the iterations, but it keeps only getting higher when it comes to more passengers.

5.4 Results

Basically, the more bus stops distributed along the line, the linger bus time gets and passengers waiting time increase. Inversely, the less bus stops available, the more passengers walking distance and time increase.

Whatever the setting, the more bus stops meant more time for the bus, since it takes more time for stopping with more station, and with shorter distances between stops, the bus get to more with lowed speed, which result with further time.

With shifted stations, more bus stops does not mean necessarily less time for passengers, nor less bus stops could mean to more time for passengers, the odd thing about it is that the station location feature (shifting) would make it in the closest place to the passenger with some stations number, in other iteration, even with more stops (that are supposed to dispose more stops, and less walking for passengers) the station can get far, simply because the reference is the division of the whole line to equal distances.

For fixed bus stops setting, adding more stops leads to shorter walking distance for passengers, or at least keep the same distance, but never make it further far. It is also observed that in case the added station is located where no passengers are around, the process goes inversely, it makes the dwelling time linger for the time taken to decelerate and stop and accelerate again, and consequence the passengers will be having longer time, without any improvement on their itinerary.

CHAPTER SIX

CONCLUSION

The objective of this study is to develop a simple approach based on an optimization that minimizes the time of passengers by changing the number of bus stop on a given bus line. The method uses scientific analyses utilizing GIS tools to generate data and export it in a sequence on well-established tables. With the explained steps, the method is facile to follow, the adjustments and the editions over the GIS part can be handled with ease, even for the tables, it can be performed smoothly to get the desired results. The calculations are handy, once the model table is established, the outputs can be obtained by just inserting the data from the network analysis. It is admitted that the tools used are well recognized and widely used by engineers over the worldwide, which make foolproof way for time optimization.

The study shows that passengers travel time can differ based on the number of bus stops along the line and of the bus stop location. The model can be adequately used, to predict users' time with different scenarios. This method can provide bus operators, urban planners, transport engineers and decision-makers an additional useful tool to enable the improvement overall functioning time, reliability and planning of bus stop location for each line separately. In order to make the idea of this study practical and of use for real life public transportation optimization, it has to deal with some further struggles, Although the study emphasis the time spent on movement, either by walking or riding, still more factors have to be considered in order to get closer to an operational simulation. For the bus acceleration time, the route shape over the bus line has to be considered. The existence of curves, intersections, light traffic but also the schedule of the educational establishments and public equipment such as school and kindergartens. Also, the change in the traffic velocity that vary from time to time, implicate the updating of the traffic data accordingly. A more specification in the bus line element would give the developer more accurate results. In the same vain, for passengers' movement time, the average proposed in the study was a generalization of cases, while in many applications for distance/time estimation, the estimation has to be more sophisticated. For example, walking over a hill up or down, the estimated time differs. To check, Edinburgh's famous Royal Mile was chosen, which slopes from Edinburgh Castle down to the Palace of Holyroodhouse. And Google Maps turns out to show that it should take 17 minutes to walk down the Mile – but 21 to walk up. The involvement of such applications would give the results more credibility, even if the algorithms and the establishments of it on a program could be difficult, the use of online open sources, user-friendly programs and the API Application programming interface would have great benefits for the method improvements.

Another drawback of the method is that the time taken through the process of obtaining results, a blind follow of the steps with an offline GIS tool, by drawing itineraries (or even with automatic drawing) and the geometrical calculating of distances in real-time, the operation would take long time at least to set up each iteration, perform the commands, talking about Graphical User Interfaces (GUIs) not even command-driven systems. The time it takes to get outputs is way long for an operational practice. In the same context, data volume in real life with an average bus transit system would generate much bigger amount of data. Its treatment and getting the results out of it through the steps of the proposed method requires a hard work and would become a difficult task to handle with a huge amount of inputs. The analysis of big-data is conducted with some different ways, differs with the explained in this study, although the final purpose is the same, the use of intensive calculations software is mostly the solution, but the automatization of the operation needs either a compatibility between the GIS, the generator of data or the exporter with the data analyst tool or the importer, or using a dynamic programming tool with and create an application or a program coded for that purpose.

Although the mentioned drawbacks, the approach presented in this study is based on an inventive principle, its application is straightforward, easily operated, manageable and it reveal reasonably effective outputs. At the theorical level it represents a new platform to develop more models for public transportation users' time. The simplicity of it makes it adaptable, easy to adjust according to the targeted elements in the process of time optimization. It will essentially enable decision makers and policy makers to evaluate suitable strategies for the best practices to be executed for serving passengers time, so that efficient and optimum transportation facilities can be implemented.

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