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Evaluation of Waiting Time and Transport Costs with Simulation in Urban Bus Transport

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Abstract: It is important for both the bus owner and the passengers to determine the bus and minibus routes that are frequently used in urban passenger transport. Because, it affects the waiting and transport time; the distance between the stops, the streets where the vehicle passes, the distance of the passengers to the bus stop, and the number of minutes the bus will remain. Bus routes surround the entire residential area of the city as a network in various ways. The use of buses as a means of public transportation is preferred because it requires fewer infrastructure investments. The distance between stops, the population of settlements, the size/capacity of the bus and how many minutes the bus will move, determines the waiting time of passengers at the stop and duration of the tour. In this study, it is aimed to reduce bus operating costs and waiting times of passengers. Bus stops between Isparta center and Suleyman Demirel University West Campus, number and density of passengers, bus departure times and bus capacities were analyzed and modeled in the simulation software. As an alternative improvement scenario, buses with little and big passenger capacity were used and departure times were arranged. The effect of alternative scenarios on operating costs and waiting time was evaluated with the results obtained from simulation software.

Keywords: *Urban transportation, operating cost, waiting time, simulation, bus.*

1. Introduction

Today, the use of public transport is becoming increasingly important for both environmental and economic reasons. The majority of public transport journeys are city bus systems. The increase in waiting and transportation time in public transportation affects the passengers negatively due to the number of populations concentrated in cities, the number of private vehicles and the density of vehicles in traffic. To make public transport more attractive, ways to reduce waiting and transport times should be sought.

In urban transport, the number of passengers increases at some times (for example, at the start and end of work) and decreases at some times. In such cases, reducing the number of buses or choosing smaller buses will reduce costs.

There are several components of the journey time. The journey time for a passenger is the sum of the time expended in the vehicle and the time expended outside the vehicle [1].

Time expended in the vehicle is the period that begins when the passenger boarded the vehicle and ends at the moment the passenger leaves the vehicle. The time expended outside the vehicle consists of the time it takes for the passenger to walk to the station, the waiting time at the station and the transfer time. In the literature in TCGASM (Transit Capacity and Quality of Service Manual), it is stated that five factors affect the waiting times of buses [9].

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Passenger Landing - Boarding Request: The number of passengers receiving boarding and landing gates is the main factor influencing the length of service for all passengers. The rate of boarding and landing in heavily used gates is related to the movements of all passengers and is related to how long the boarding/landing will take.

Bus stop area: At small stops, passengers move away from the boarding point, which increases the passenger walking distance and consequently increases the waiting time of the bus at the stop.

Payment: The average time to pay is the main factor for each passenger. Some payment types/ methods allow passengers to receive fast service.

Bus type: Raising or lowering of the steps affects the total service time of passengers on boarding and landing.

Bus inside: If there are standing passengers, new passengers spend more time.

The increase in the rate of urbanization in Turkey has increased the city's population to migration from small settlements in the city. As a result, unplanned urbanization, unfinished urban units, and new neighbourhoods emerged. Rapidly built housing, unplanned roads directly affect city transport. This reduces the quality of public transport, increases the waiting time of the bus, causes too many passengers to board at the same stop, prolongs bus arrival times and thus extends the time to reach the destination.

In this study, bus stops between Isparta - Center and Suleyman Demirel University West Campus (approximately 8 km) were investigated. Work-study was done on this route. The number of passengers in and out of the stops was observed at different days and at different times for a week (rush and normal times). At the end of the study, existing and alternative scenarios were simulated by creating models from the obtained data. In the scenarios, bus departure times and bus types (using large or small

buses) have been changed, analysed and interpreted for specific times.

2. Literature Review

The studies on urban transportation and public transportation are given below. The aim of urban transportation is to provide transportation needs of a certain volume and quality for the social, economic and cultural demands of the city people under appropriate conditions such as time and wages.

Gökdağ [8] states that it is obligatory to provide alternative transportation systems since the inhabitants of cities need faster, safer, more comfortable and environmentally clean transportation systems. In this study, urban transportation systems have been examined, brief information has been given about these systems, and the comparisons between Road and Rail transport systems have been made in terms of the number of passengers, air pollution and noise pollution area usage.

In another study, the system was redesigned for a specific region for Istanbul. Focusing on urban bus transportation for the transportation problem that has become an increasingly complex problem in big cities, he proposed a new solution for the reorganization of the system with the help of Axiom Design (AD) principles [3].

The most important performance indicators in public transportation systems are the travel times of the vehicles. The travel times of the vehicles vary according to changing conditions such as the number of passengers, stop intervals, type of payment and the duration of payment, speed of the vehicle, boarding and landing time of the passengers. A simulation model has been developed in order to see the factors that change the performance of public transportation systems. The results obtained with this simulation model were adapted to the analytical hierarchy method used to choose between public transport types. Other criteria for public transport type selection have been determined. The weights of the criteria for each other and for the two modes of public transport were compared with the questionnaire and numerical values. This simulation supported analytic hierarchy method is applied for the “bus way” and “tramway” options in public transportation within Istanbul city [7].

Huo et al. [11] conducted a study to prevent a bus from entering and leaving a stop at the same time by other buses and traffic lights. He modelled each type of delay under this phenomenon and the delays experienced by a bus at one stop in general. Occupancy based delay, transfer block-based delay and block-based delay have been defined and modelled. The bus delay at the stop is the sum of these three types of delays. During the modelling delay, bus arrival rate, bus service rate, number of stops and traffic lights were taken into account. The delay due to occupancy is modelled according to the average waiting time, transfer block-based delay and block-based delay, standard deviation of the waiting time and the probability of occurrence.

A study was conducted to model passenger landing and boarding times which are effective on the reliability of public transportation lines by utilizing smart card data and field observations used in the operation of the public transportation system in İzmir. In the study, it was determined that the boarding time was 4.23 seconds per passenger and the descent was approximately 1.0 seconds [9].

Waiting time in public transportation is one of the most important dimensions of the level of service perceived by the passengers. Particularly in urban bus transportation operated under the influence of traffic conditions, the excessive waiting time can become a benefit function component that can change the type and route selection of the passengers. In [2] studies, the waiting time encountered in urban bus transportation was modelled by considering the physical conditions of the line and station as well as the impact of reliability and passenger information systems. As a result of the linear models, it was seen that the presence of the information system shortened the waiting time by an average of 2 minutes and the reliability by an average of 1.3 minutes. In addition, it was concluded that passenger information systems would be more efficient to use in the stops used by the lines coming from the city center and used in accordance with the geometry [4].

One of the major challenges of the public transport system is to ensure that a compromise between the satisfaction of the passengers and the requirements of the transport companies is required and the waiting time is optimized. A detailed review of the existing literature on the passenger transport problem is presented to optimize the passenger waiting time at the station and to meet the needs of companies (maximizing profit or minimizing cost) and the capacity of the vehicles. In the study, appropriate algorithms are presented to solve the set of optimization models [5].

Jolliffe et al. [6], examined the arrival times of passengers and buses. He examined the different bus stops on different days. He observed that the waiting times of the passengers changed randomly. Changes in these expectations; It depends on the socioeconomic characteristics of the passengers, the proximity of bus stops, bus routes and so on. The biggest change in waiting times for passengers and buses is due to the number of passengers arriving and the small size of the bus.

In this study, Tirachini [2], examined the variables that caused changes in the travel times of buses. He examined the effect of delays caused by traffic lights and intersections on the duration of bus travel. He proposed two policies aimed at reducing bus travel time; a) providing dedicated busways and upgrading the fare collection system, b) shows that the number of passengers is crucial in determining the advantage of one or the other in increasing bus operating speed.

3. Materials and Methods

3.1. Simulation Assisted Passenger Waiting Time Analysis

Passenger boarding/landing speed, traffic lights, the behaviour of other vehicles, accidents and failure of public transport constitute waiting times. In order to reduce these times and to analyse the waiting times in urban transportation and to find a solution, passenger waiting and transportation times for buses were obtained with the help of a simulation program.

3.2. Unit Costing

The road distance between Isparta Centre and Suleyman Demirel University West Campus is 8 km. A tour is 16 km. The cost of the bus in one tour is 12.32 TL. The monthly working fee of a driver is 2558 TL. The number of drivers working on this route is 3. The duration of a tour is 40 minutes. The number of tours is 32 for 80 people capacity and 39 for 60 people capacity in 20 minutes period. It is 33 for 80 people capacity and 37 for 60 people capacity in 30 minutes period. Two buses were used in the simulation. So, other costs are shown in Table 1.

Table 1. Cost

Fixed Cost	Investment Cost	400.000 TL/per
	Staff Cost	25558 TL/Month
	Depreciation	200 TL/per
Variable Cost	Fuel Cost	12,32 TL/Tour
	Maintenance Cost	100 TL/Month

4. Simulation Assisted Passenger Waiting Time Analysis

A simulation model has been developed with the help of buses, analysis of bus stops, departure times, number of passengers on the bus stop, bus stop between Isparta – Centre and University – West Campus. In the simulation supported research, it is aimed to determine how often the bus company will move vehicles and whether it will increase the capacity of buses (use of large buses) during rush hours. Rush hours are between 08:00 - 09:00 and 16:00 - 17:00. In the data's, it was observed that the average time of landing and boarding was 4 minutes in the stations where there were a lot of passengers and 1 minute in the stations with fewer passengers. The length of time the bus travels from one stop to another can also vary depending on the traffic intensity and the duration of the traffic lights. All these variables were observed and added to the model.

4.1. Status: Bus for 80 Person

On the days of university education, buses generally depart every 20 minutes. In normal-sized buses, a total of 80 people can travel with 30 people sitting and 50 people standing. Bus run time total 18 hours, including between 06:00 and 00:00. We boarded the bus on different days and times and observed the number of passengers get on and get off at each stop. The route stops and average hourly passengers (y / h) where the bus runs are given in Figure 1.

The simulation bus was operated with a capacity of 60 people and 80 people. Other scenarios of the simulation move in 20 minutes and 30 minutes. Scenarios were applied and the following results were obtained.

4.2. Simulation Scenarios and Findings

A) Large Bus (80 Persons) Moves Every 20 Minutes: The model was run for 18 hours with a period of 20 minutes between 06:00 - 24:00. When the program is run for a period of 20 minutes, the total number of trips is 32. As a result, the total number of passengers boarded is 2560. The number of passengers on landing is 2327.

The simulation model with a capacity of 80 people operated for 8 hours and a period of 20 minutes has a total waiting time of 363.39 minutes. The total waiting time in a round is 13.46 minutes.

B) Small Bus (60 Persons) Moves Every 20 Minutes: The number of tours required for the program to run 60 people and 20 minutes period is 39. As a result, the total number of passengers boarded is 2290. The number of passengers is 2110.

Total waiting time of the simulation model with a capacity of 60 people and run for 8 hours and a period of 20 minutes is 376.91 minutes. The total waiting time in a round is 13.95 minutes.

C) Large Bus (80 Persons) Moves Every 30 Minutes: When the program is run for 30 minutes, the number of tours is 33. As a result, the total number of passengers boarded is 2570. The number of passengers in landing is 2397.

The simulation model with a capacity of 80 people operated for 8 hours and a period of 30 minutes has a total waiting time of 430.35 minutes. The total waiting time in a round is 23.9 minutes.

D) Small Bus (60 Persons) Moves Every 30 Minutes: The number of tours required for the program to run 60 people and 30 minutes period is 37. According to the model, the total number of boarding passengers is 2182 and the total number of passengers is 2006. The model has a total standby time of 441.21 minutes. The total waiting time in a round is 11.92 minutes.

4.3. Evaluation

Simulation results and total waiting time for buses running between Isparta-Centre and Suleyman Demirel University West Campus are given in Table 2.

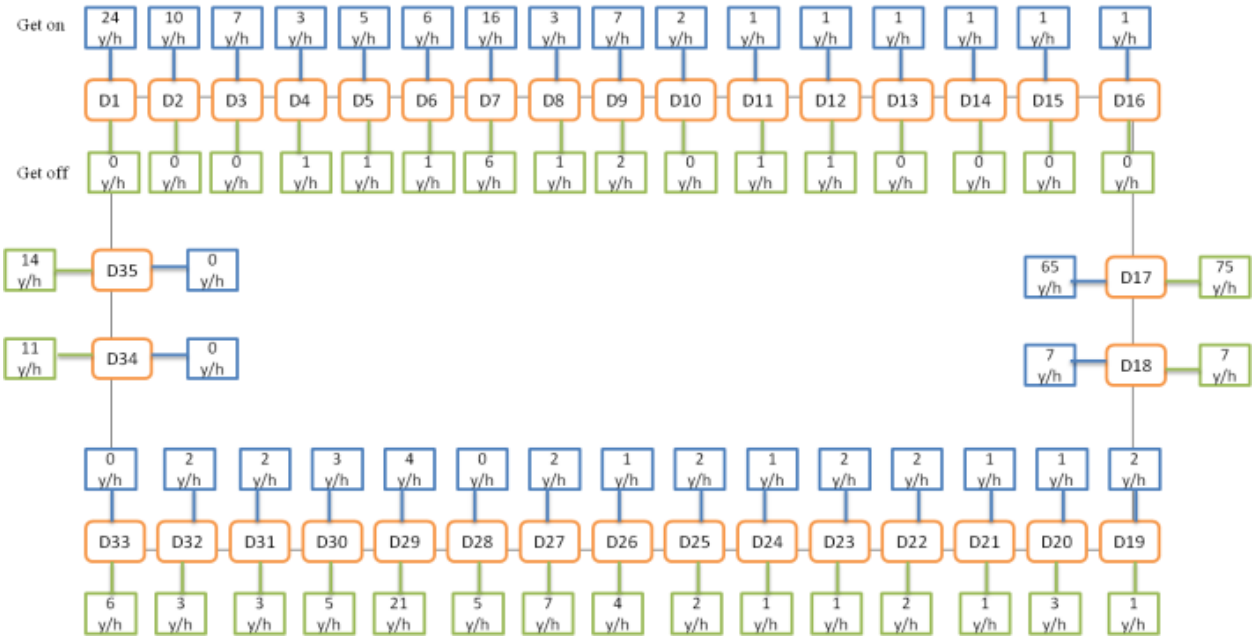

Fig. 1. Isparta Centre - SDU Bus Stations

Table 2. Number of Passengers and Waiting Times

Capacity and Period	*Number of Passengers*		*Waiting Time*	*Occupancy Rate of Bus*
	Number of Boarding Passengers	*Number of Landing Passengers*		
60 Person and 20 Minutes Period	2290	2110	376,91	%83,33
80 Person and 20 Minutes Period	2560	2327	363,39	%81,25
60 Person and 30 Minutes Period	2182	2006	441,21	%96,67
80 Person and 30 Minutes Period	2570	2397	430,35	%90

The student tariff fee foreseen by Isparta Municipality is TL 1 (Turkish Lira). Accordingly, the fees received from the passengers according to the simulation results and the profit/loss situation is given in Table 3. Total cost; daily fuel cost, daily maintenance cost and daily employee cost.

Table 3. Profit/Loss Status

Capacity and Period	*Payment*	*Total Cost*	*Cost Difference*	*Status*
60 Person and 20 Minutes Period	2290 TL	802,95 TL	1487,05 TL	Profit
80 Person and 20 Minutes Period	2560 TL	716,71 TL	1843,29 TL	Profit
60 Person and 30 Minutes Period	2182 TL	778,31 TL	1403,69 TL	Profit
80 Person and 30 Minutes Period	2570 TL	729,03 TL	1840,97	Profit

As a result, the total waiting time of buses with a capacity of 60 people and a period of 20 minutes is 376.91 minutes and a profit of TL 1487,05 is obtained. The total waiting time of the buses with a capacity of 80 people and a period of 20 minutes was 363.39 minutes and TL 1843,29 profit was achieved. The total waiting time of buses with a capacity of 60 people and 30 minutes period was 441.21 minutes and 1403,69 TL profit was obtained. The total waiting time of the buses with a capacity of 80 people and a period of 30 minutes is 430,35 minutes and a profit of TL 1840,97 is obtained.

5. Conclusion

In this study, bus stops between Isparta - Center and Suleyman Demirel University - West Campus were examined and simulated. The number of passengers on and off the bus was observed at different days and times for a week. As the buses used in Isparta are private, the number of buses is not known clearly. The buses operate alternately on different routes. Based on these observations, the simulation was performed with four different scenarios and the results were analysed. As a result, there are two options when waiting times are considered: a) bus capacity can be increased b) the time between two departures can be reduced. Considering the costs and occupancy rate, it would be more profitable to choose a bus with a capacity of 80 people and a 20 minute period. According to passenger waiting time, it is recommended to choose buses with a capacity of 80 people during rush hours of the day and with a capacity of 60 people during non-busy hours.

5.1. Future Research

In this study, between Isparta Center and Suleyman Demirel University - West Campus was simulated. As a continuation of the study, the number of scenarios and the number of observations can be increased. It can be simulated by selecting a different route.

Conflict of Interest

No conflict of interest was declared by the authors

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