Simulation analysis of transportation system in Erzurum

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Keywords

Transportation,
Transportation Systems,
Simulation,
ARENA.

Abstract

In recent years, the increase of population in cities has become one of the most important problems considered for municipalities providing transportation services. In terms of municipal services, the number of lines, capacity, and occupancy rates of public transportation vehicles providing transportation within the cities should be scientifically monitored and evaluated. In this study, we analyzed the current situation of municipal buses and public buses providing public transportation in Erzurum. For analyzing, we consider some performance criteria such as number of lines, capacity, vehicle occupancy rates, and passenger waiting. The current situation was modeled by simulation using the system approach. The interactions between entities are examined, sub-systems are identified, and the current situation is revealed. Results show that about 104.400 passengers benefit from public transportation daily, and performance criterias determined in the system are adequate.

1. Introduction

In general, information and capital produced by people, the form, volume and scope of transportation, which means the transfer of goods and services, from one place to another, has been greatly expanded with the effect of increasing and constantly changing social and economic factors (Sandal 2009)[1]. Transportation has seen the necessary importance in all stages of human history and has been one of the most studied areas. Transportation, which has an important share in the establishment of civilizations in different parts of the world, has undoubtedly made significant contributions to the development and change of human history. Although there are many theories and approaches about the establishment and development of cities, one of the most important approaches is transportation (Aliağaoğlu 2010) [2] and transportation has played an important role in the formation of today's crowded cities. Specially, the impact of transport activities on the development and change of urban settlements cannot be underestimated (Tümertekin 1987) [3].

In recent years, migration from village to city has increased uncontrolled, and transportation in urban centers has been adversely affected. Due to population growth, the boundaries of the settlements have expanded and transportation has become an essential problem that is difficult to solve. There are several theories and approaches about the development of cities. One of these is transportation (Aliağaoğlu 2010) [4].

In the solution of transportation problems, efforts are made to spread the use of public transportation vehicles considering both environmental pollution and traffic congestion.

1.1. The Aim and Scope of the Study

Increasing number of vehicles due to development of cities; unplanned public transport systems, has caused dissatisfaction with passengers, and wasted public resources. This is true for all major cities and is a valid problem for the province of Erzurum. When the public transportation system of Erzurum is examined, problems such

as long line routes, bus occupancy rates vary widely, density at stops at work and departure times, excess passengers and waiting time at stops are observed. Based on the metropolitan municipality responsible for transportation in the city and central districts, the current situation was analyzed and the observed problems were examined by considering the performance criteria.

With the help of system analysis, the purpose, objectives, elements, parameters and variables of the system were determined by evaluating the current situation of municipal and private public buses from public transportation vehicles serving within the borders of EBB (city center and central districts). Using the system approach, the interactions between the elements were examined, sub-systems were identified, and the current situation was revealed. As a result, the system performance criteria such as vehicle occupancy rates, passenger waiting times and daily transportation costs were taken into consideration and the current situation was modeled by simulation. The modeled system was run in ARENA program and the problems in the current system were determined by considering the performance criteria determined by system analysis.

1.2. Literature Search

As a result of literature review, some studies related to public transportation systems are given in Table 1.1. Furthermore, the study has been added to the last line and its difference from the literature has been shown.

2. Theoretical Foundations

The dizzying development of technology in recent years has forced countries to compete economically with each other. Therefore, it is becoming more and more important for countries to plan and use their resources correctly. One of the most important factors in the resource use process is defined as any movement from one point to another in order to ensure the transfer of people, goods and / or goods between settlements. In particular, it is one of the most basic elements of human transport. Therefore, although there are many different areas of transport, this study focuses on human transport.

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Table 1.1.(Some studies on transportation)

Author Name (Year of publication)	Inputs	Outputs	Topic
Yılmaz (2005) [5]	- Number of passengers - Number of lines - Number of vehicles - station - Line length	-Transmission time - Passenger waiting time - Vehicle full rates -line planning	According to determined parameters, simulation of the public transport was performed in the Crystal Ball program, the current situation was removed, 2 different scenarios were proposed, the parameters were improved, and line planning was made.
Brueckner and Selod (2006)[6]	- urban public policy decisions - Homogeneous and heterogeneous cities	-time -cost	Comparing the transport system for homogeneous and heterogeneous cities, considering urban public policies and land ownership an optimal model is proposed.
Damart and Roy(2009)[7]	-Air pollution -noise pollution -public resources	-cost, benefit analysis - socioeconomic impact on investment of public resources	Cost-benefit analysis of public resources has been made by considering air and noise pollution which are environmental factors in public transportation decisions.
Lin (2010)[8]	- time constraint -cost -capacity	-Transport system performance - Quality level - Transportation complexity	They proposed a new algorithm to evaluate the performance of stochastic transport systems. The proposed algorithm was applied for factories in 4 different cities and the quality level was measured.
Hatipoğlu and Öztürk (2012)[9]	-public transport - density of private vehicles during peak hours	- Trip demand forecast - Vehicle sharing system and tele work	They have developed travel demand method strategies to reduce the number of private vehicles during peak hours in the institution where the number of office workers is determined and the start and end hours are busy.
Sawicki and Zak(2013)[10]	-Transport infrastructure -Technical equipment -Organization rule	-customer happiness - level of meeting customer requirements	It measures the level of meeting the customer needs by making transportation classification in the light of the data obtained by using dominance based coarse set theory method.
Solecka and Zak (2014)[11]	-Transport infrastructure - Transportation usage rate -cost	- Transport types integration -performance criteria	Designing transport solutions that result in the integration of an urban public transport system and the general methodology for their evaluation.
Milevich et al. (2016)[12]	- road network modeling - Population synthesis data	- Analysis of the transport zone	Planning of 2018 World Cup semi-final match entrance and exit of the traffic from stadium have occurred.
Özuysal and Gülhan (2017)[13]	-Traffic perspective - factors affecting accessibility	- Transportation planning policy - Transportation system performance	Definition of accessibility approach as a measure of transportation system performance, mission and sees the advantages that other approaches provide.
This study (2019)	- Number of passengers - Number of lines - Number of vehicles -station	-Passenger waiting time -cost - Vehicle occupancy rates	In the light of the determined performance criteria, the simulation of public transport was performed in the Arena program and the current situation was revealed and the problems in the system were determined.

Public transportation is the general name of the transportation systems that can be used by everyone that has a certain route and price tariff in order to provide transportation between people in and out of the city. The aim of public transportation systems is to make the most economical and shortest time to reach people in order to reduce the traffic density. It has become an important situation that cities and countries should plan public transport and increase their competitiveness in terms of their contribution to economy, human health, energy efficiency and environment. Cities and countries that work more on public transport have always been one step ahead of others. The mode of transportation varies between states in the United States, still rail and bus systems are widely used. In Europe, it is observed that bus systems and rail systems are used frequently, especially in England and Germany, as well as bicycle and pedestrian transportation is preferred especially in the Netherlands and Denmark. In the Far East countries, Korea and Singapore, rail systems are used extensively. In addition, bus systems support rail systems (Cirit 2014) [14]. As shown in Figure 2.1, the use of rail systems and daily passenger numbers in some metropolises are given.

In our country, although the metropolitan rail and bus systems are used predominantly, the percentage of bus system usage is higher. In other cities, the bus system is used and work is being carried out in order to switch to the rail system.

Figure 2.1. (Use of rail system (left)and length of rail system (right) in some metropolises (km))

Turkey's largest and most advanced subway in Istanbul with the transport network, light rail, tram, cable car, but also the rail system, such as the funicular and Marmaray bus system and the sea route has different alternative modes of transport such as system.

The railway system serves approximately 2.7 million people daily, approximately 11.7 million daily by road transport such as buses, minibuses, taxis and shuttles, and approximately 500,000 daily by sea transportation. There are 11,795 stops and 2756 buses in the bus system, which is mainly used (İETT, 2019) [15]. The Metropolitan Municipality buses, private public buses and minibuses provide public transport in Erzurum province. There are 6 different lines of minibuses and 95 minibuses serve in these lines. There are 35 different lines in the buses and a total of 249 buses operate in these lines. 80 of 249 buses belong to EBB and the remaining 169 buses belong to persons. In this study, the buses that are subject to the Kardelen card system examined. Although the number of passengers served during the week is between 105-120 thousand per day, this number decreases to approximately 70 thousand at the weekend.

3. Material and Method

The system approach is a perspective and behavior that uses the system analysis in this process to understand and evaluate the subsystems that make up the whole system and the relations between them to solve the problems that will occur in the system (Koçel 1982) [16]. In addition, it can be defined as the point of view that all the sub-elements are taken into consideration when examining the problems identified and that makes this problem understood (Aydın 1988) [17]. The system approach, which assists in decision-making, is a method that enables decision-makers to see the problems on the system under uncertainty by examining the system.

In this sense, the system analysis involves the best definition of the identified objectives and the identification of alternative scenarios to achieve these objectives. System analysis is used in the planning and programming of defense systems as well as in other areas where it is desirable to develop social systems through scientific means. General system theory includes some rules that classify the relationship between systems in and around themselves and govern the behavior of classes. It is the process of developing a mathematical and logical model of the system and producing different scenarios on this model in order to predict the result of the change in the system which is more cost-effective in terms of the determined time cost. Simulation is a process that enables us to obtain unbiased information about the processes that are available today, and more importantly, that may be available tomorrow. When we consider a real life system, it refers to a process in which the input and output of the system and other elements are taken into consideration where the results of different decisions taken on a model can be applied and the results can be examined as it saves time and money. Provides the possibility to produce scenarios on the system by simulating the system one by one in order to make predictions about the system and determine the decisions based on implementation with the data obtained.

When analyzing a system or trying to solve a problem, simulation is one of the best methods for presenting the current situation, identifying the problems and producing alternative solutions as a result of the problems. In addition, it provides a very convenient solution in terms of time and cost in analyzing complex systems and solving problems. All scenarios that are wanted to be tested in the real system can be tried on the model in a short time and the results can be analyzed. Therefore, simulation method was preferred in this study in order to better observe the problems in the public transportation system of Erzurum.

4. Research Findings

In our study, in order to determine problems of the current system of transportation system in Erzurum province, input, output, purpose, objectives and elements of the current system were taken into consideration while the more specific elements for simulation were taken into consideration in order to obtain effective results. From this

point of view, passengers, lines, buses and stops are identified as inputs to the system. The aim of the system is to minimize the waiting time and the number of waiting passengers and ensure the optimum cost of the system in addition to quality and comfortable transportation while meeting the transportation demand of the people requesting travel.

The objective of the system is to ensure that the system achieves its purpose and to make transportation planning that will increase the rate of passengers using public transportation in order to reduce air pollution and traffic density. The aim of the system seems to be related to each other. As the aim of the system is realized, the objective of the system will be realized in time.

The elements of the system are passengers, buses, drivers, stops, lines, card system, transportation department, snowdrop card management and other vehicles. Interactions exist between the elements of the system. The determination of the lines is carried out by the Department of Transportation. The number of laps which vehicle will carry on which line and the fare to be charged to the passengers are determined here. The waiting times of the passengers depend on the determined line route and lap time. As can be seen, there is interaction between the elements. The number of lines, number of vehicles and number of passengers are the system parameters, vehicle occupancy rates, number of passengers waiting at the stops and waiting time at the stops constitute the system performance criteria. As the output of the system, the transportation demand met and the transportation cost was determined.

4.1. Current Situation Analysis

With the study, the places where the bus lines crossed were examined and 250 different stops were identified after some of the close stops were combined. Other data required for simulation of the system were obtained from Erzurum Metropolitan Municipality Department of Transportation and Kardelen Card Directorate. One of the observed problems in general is the length of the line.

This is true for many lines and the length of the B2 and G3 lines is shown in Figure 4.1 and Figure 4.2 for understanding. Inter-stop times are determined in seconds for each line route. The one-hour chart obtained from the Kardelen Card Directorate was examined and the weight coefficient was established for the 250 stops determined. Passengers getting on and off were determined by taking into consideration the weight coefficients.

Figure 4.1. B2 line route

4.1.1. Stops and codes used in the program

The urban transportation network of Erzurum province was examined and the route where 35 lines crossed and the stops they stopped were determined. Some of the stops that are close to each other are considered as one stop and they are named after their location, street or street. For the convenience of the program, the station names were formed according to the alphabetical order of the letter D representing the coding stop and the letter number '1' representing the order.

Figure 4.2. G3 line route

4.1.2. Lines and routes

There are a total of 35 lines in the card system that provides transportation in Erzurum. 12 of these lines are the northern line and are represented by the letter K. 14 of them are the southern line and are represented by the letter G. 8 is the western line and is represented by the letter B. Lastly, one of them is the eastern line and is represented by the letter D. The round-trip routes and stops of these lines have been taken from the Kardelen Card Directorate and simulated in the arena program.

4.1.3. Number of times between stops and number of passengers

The lap times of the lines and the elapsed time between stops were received from the snowdrop card management and the times for some combined stops in the system were revised. The revised times are entered into the simulation program.

4.1.4. Station weight coefficients

While determining the number of passengers landing at the stops, the passengers arriving as a result of the passenger records taken from the Kardelen card serving within the EBB and the observations made were created in tables for the stops where each line passes. The scoring system was used according to the number of passengers descending and the number of lines passing through the stops. When calculating weight coefficients at the stops, as a result of the Kardelen card data, the calculation of the number of passengers' lines passing from that station was reduced to one time was given numerical points.

Table 4.1. Station weight coefficient calculation method

Single Passenger	Interval Range	Numerical Score
Between 0-30		1
Between 31-50		2
Between 51-80		3
Between 81-100		4
Between 101-120		5
Between 121-140		6
Greater than 140		7
Number of Lines		Numerical Score
<= 7		0
> 7		1
Station Weight Coefficient = Number of Passengers Landing at the Station + Number of Lines Passing from the Station		

The number of the descending passengers was examined and a numerical score was given according to the concentration of the descending passengers at the stops. In addition, considering the number of lines passing the station, the weight coefficient was calculated for each station. Weight coefficient calculation is shown in Table 4.1.

4.1.5. Passenger numbers in March

Data obtained from EBB Kardelen card is taken as hourly chart in daily passenger numbers in March 2018. The hourly charts of the stops for the lines have been formed by the determined weight coefficients. Average monthly number of passengers is given in Table A1 of ANNEX A.

4.1.6. Simulation of the current situation in the arena program

First of all, 250 stops and separate queues have been created for each line passing through the stops. Passengers arriving at the stops are derived from hourly schedules as a result of the available data. Passengers arriving for the lines passing through the stops are queued according to the percentage slices obtained from the data. In the system, 14 G lines, 12 K lines, 8 B lines and 1 D lines were simulated. The current system is modeled in the Arena Program. The program view is given in Figure A1 in ANNEX A. In Figure 4.3, animation image of the B8 line is given.

Figure 4.3. B8 line animation view

5. Conclusions and Recommendations

When the program output was examined, 104.400 passengers benefit from public transportation daily. Program reports were based on considering system performance criteria determined for all stops and all lines. The performance criteria determined in the system are shown in Appendix A Table A2, some of the waiting number values are shown in Appendix A Table A3 and waiting time at stops are shown in Appendix A Table A4. Program outputs and some data shown through snowdrop card is another system performance called the vehicle occupancy value which is shown in Appendix A table A5. While simulating the system, we take into consideration passenger waiting time, number of waiting and occupancy status reports, When the system outputs are examined it is observed that the lines with longer waiting times have generally higher queue than the other lines, When the long queues were examined it is observed that the number of lines passing through the station is low for some stops and the number of lines passing in the direction of the route where transportation is high is low. By reviewing the current situation, vehicle occupancy rates were compared and the densities of the lines were determined. In the current model, the daily fuel price is calculated as 146.550,94 TL. While calculating the cost, the average daily route in the system is calculated as 236 km and the calculation is made for both diesel bus and CNG (compressed natural gas) bus and given in Appendix A Table A6. By taking into consideration the current performance criteria, in order to solve the problems observed or to improve the determined performance criteria, advancing studies can be carried out on alternative models.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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How to Cite This Article

Yiğit, V., Yiğit, E., Simulation analysis of transportation system in Erzurum, *Brilliant Engineering*, 2(2021), 20-30. <https://doi.org/10.36937/ben.2021.002.003>.

APPENDIX A**Table A1. Average Monthly Passengers**

Line Name / Hourly Passenger	Time	Number of Hourly Passengers on Lines																	
		07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00	
Line number	Total number																		
B2-DADAŞKENT - CITYCENTER	6008	787	393	295	197	393	492	393	197	246	442	688	393	295	197	344	197	29	
B3-DADAŞKENT-CITYCENTER	6138	804	402	301	201	402	502	402	201	251	452	703	402	301	201	352	201	20	
B5-CITYCENTER-SÖĞÜTLÜ KÖYÜ	354	46	23	17	12	23	29	23	12	14	26	41	23	17	12	20	12	3	
B6-D.KENT-Y.KENT	2386	312	156	117	78	156	195	156	78	98	176	273	156	117	78	137	78	23	
B7-İLİCA-D.KENT	3527	462	231	173	115	231	289	231	115	144	260	404	231	173	115	202	115	35	
B1-İLİCA-ERZURUM	5854	766	383	287	192	383	479	383	192	240	431	671	383	287	192	335	192	57	
D1-YONCALIK-M.EFENDİ	1152	151	75	57	38	75	94	75	38	47	85	132	75	57	38	66	38	11	
G1-Y.EMRE-ÜNİ.	8577	1123	562	421	281	562	702	562	281	351	632	983	562	421	281	491	281	34	
G2-YONC-SUDEPOSU	506	66	33	25	17	33	41	33	17	21	37	58	33	25	17	29	17	5	
G3-Y.KENT 10KATLILAR	7460	977	488	366	244	488	610	488	244	305	549	855	488	366	244	427	244	40	
G4-KAYAKYOLU-YENİŞEHİR	5141	673	337	252	168	337	421	337	168	210	379	589	337	252	168	295	168	35	
G5-YONCALIK-K.YOLU	3032	397	198	149	99	198	248	198	99	124	223	347	198	149	99	174	99	30	
G6-STATION	1390	182	91	68	45	91	114	91	45	57	102	159	91	68	45	80	45	14	
G7-YONCALIK-YILDIZKENT	3815	499	250	187	125	250	312	250	125	156	281	437	250	187	125	219	125	37	
G8-YNC-DUTÇU K	933	122	61	46	31	61	76	61	31	38	69	107	61	46	31	53	31	9	
G9-H.KENT-Y.KENT	11874	1555	767	583	389	787	972	777	389	486	874	1360	777	583	389	680	389	60	
G10-Y.EMRE-M.BAŞI-K.YURDALAN	2547	333	167	125	83	167	208	167	83	104	188	292	167	125	83	146	83	25	
K1-DADAŞKÖY-KAN YOLU	1477	193	97	73	48	97	121	97	48	60	109	169	97	73	48	85	48	15	
K2-İBRAHİM HAKKI-TEAŞ	7232	947	473	355	237	473	592	473	237	296	533	829	473	355	237	414	237	35	
K3-HİLALKENT-TORTUM WAY	4710	617	308	231	154	308	385	308	154	193	347	540	308	231	154	270	154	46	
K4-YONCALIK	2490	326	163	122	81	163	204	163	81	102	183	285	163	122	81	143	81	24	
K5-YONC-ŞEHİTLER	591	77	39	29	19	39	48	39	19	24	43	68	39	29	19	34	19	6	
K6-YONCALIK-ŞEHİTLER	673	88	44	33	22	44	55	44	22	28	50	77	44	33	22	39	22	7	
K7-Ş.PAŞA-A.UNİVERSİTY	3065	401	201	151	100	201	251	201	100	125	226	351	201	151	100	176	100	30	
K8-DUMLU-ERZURUM	890	117	58	44	29	58	73	58	29	36	66	102	58	44	29	51	29	9	
G 12 CITYCENTER-KONAKLI TESİSLERİ	171	22	11	8	6	11	14	11	6	7	13	20	11	8	6	10	6	2	
K9-ÇİFTLİK KÖYÜ CITYCENTER	212	28	14	10	7	14	17	14	7	9	16	24	14	10	7	12	7	2	
G4-A MAHALLEBAŞI-TERMİNAL	2357	309	154	116	67	154	193	154	77	96	174	270	154	116	87	135	77	23	
G13 CAT-Center	158	21	10	8	5	10	13	10	5	6	12	18	10	8	5	9	5	2	
K10-ŞÜKRÜPAŞA-ÜNİ	1920	251	126	94	63	126	157	126	63	79	141	220	126	94	63	110	63	19	
K7-A H.KENT AVM	2170	284	142	107	71	142	178	142	71	89	160	249	142	107	71	124	71	21	
B8 N.TOPÇU-ERZURUM	2973	389	195	146	97	195	243	195	97	122	219	341	195	146	97	170	97	29	
B2/A D.KENT	994	130	65	49	33	65	81	65	33	41	73	114	65	49	33	57	33	10	
G7/A Y.KENT/MNG AVM	1420	186	93	70	46	93	116	93	46	58	105	163	93	70	46	81	46	14	
Total	104192	05.03.2018-01.04.2018 Monthly average

Figure A1. Arena Program Overview (G2 Line)

Figure A2. Arena Program G2 Line Simulation View

Table A2. Waiting Time of Passengers in the Station

10:45:15

Category Overview

Ekim 9, 2018

Values Across All Replications

Unnamed Project

Replications: 10

Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Durak12 B8.Queue	0.1688	0.01	0.1427	0.1911	0.00013238	0.9356
Durak120 G4A.Queue	0.1799	0.00	0.1799	0.1799	0.01361111	0.4014
Durak121 D1.Queue	0.1497	0.01	0.1236	0.1776	0.00008415	0.4915
Durak121 G10.Queue	0.1385	0.00	0.1280	0.1551	0.00035493	0.2828
Durak121 G2.Queue	0.1820	0.01	0.1603	0.2091	0.00146438	0.4616
Durak121 G4A.Queue	0.1145	0.01	0.1031	0.1300	0.00007830	0.4164
Durak121 K5.Queue	0.1593	0.01	0.1287	0.1845	0.00138155	0.4997
Durak121 K6.Queue	0.1395	0.01	0.1191	0.1707	0.00036044	0.5361
Durak122 D1.Queue	0.1837	0.00	0.1837	0.1837	0.00694444	0.4883
Durak123 G5.Queue	0.08692619	0.01	0.07488046	0.0990	0.00011938	0.6582
Durak123 G6.Queue	0.1880	0.02	0.1582	0.2246	0.00074220	0.4798
Durak123 G7.Queue	0.04321125	0.00	0.03969222	0.04758658	0.00003642	0.2460
Durak124 G3.Queue	0.04986041	0.00	0.04986041	0.04986041	0.00027778	0.4436
Durak125 B1.Queue	0.1051	0.00	0.0964	0.1130	0.00023646	0.3544
Durak125 B3.Queue	0.04276403	0.00	0.03356304	0.05181840	0.00000656	0.4186
Durak125 B5.Queue	0.5227	0.04	0.3878	0.5868	0.00410646	1.1862
Durak125 G1.Queue	0.05285212	0.00	0.04694127	0.06078216	0.00003623	0.4894
Durak125 G12.Queue	0.6886	0.12	0.4943	1.0595	0.01309625	1.6825
Durak125 G13.Queue	0.5887	0.10	0.3156	0.7734	0.00887400	1.3805
Durak125 K1.Queue	0.2098	0.01	0.1811	0.2460	0.00107446	0.4951
Durak125 K11.Queue	0.4881	0.03	0.4326	0.5853	0.00796562	0.9911
Durak125 K3.Queue	0.2679	0.02	0.2143	0.3141	0.00008836	1.4646
Durak125 K4.Queue	0.2018	0.02	0.1537	0.2580	0.00247093	1.0752
Durak125 K7.Queue	0.3178	0.02	0.2844	0.3603	0.00017055	1.3860
Durak125 K8.Queue	0.2394	0.02	0.2066	0.2837	0.00030763	0.4971
Durak125 K9.Queue	0.5931	0.09	0.3899	0.8472	0.01393212	1.2790
Durak126 B6.Queue	0.2802	0.00	0.2802	0.2802	0.00916667	1.0892
Durak127 B2.Queue	0.08514474	0.01	0.07245409	0.1003	0.00002345	0.8702
Durak127 B3.Queue	0.03392134	0.00	0.03059790	0.03685102	0.00004028	0.2884
Durak127 G1.Queue	0.05477052	0.00	0.04653894	0.06338375	0.00009432	0.4928
Durak128 B3.Queue	0.02088619	0.00	0.02024638	0.02187648	0.00000000	0.06644444
Durak128 B5.Queue	0.2673	0.04	0.2051	0.4039	0.00161111	0.6598
Durak128 B6.Queue	0.1650	0.01	0.1555	0.1762	0.00044444	0.4875
Durak129 B2A.Queue	0.1504	0.01	0.1339	0.1756	0.00009722	0.8075
Durak129 G4.Queue	0.3241	0.03	0.2755	0.4096	0.00029697	1.7937
Durak129 G4A.Queue	0.1968	0.01	0.1801	0.2154	0.00001428	0.8057
Durak129 G7A.Queue	0.06120727	0.00	0.05533870	0.07214199	0.00000845	0.5695
Durak129 K10.Queue	0.05754909	0.00	0.05261243	0.06306076	0.00007876	0.3515
Durak129 K3.Queue	0.1506	0.01	0.1349	0.1683	0.00007710	0.9724
Durak129 K4.Queue	0.1317	0.01	0.1211	0.1402	0.00003391	0.5097
Durak129 K9.Queue	0.3405	0.03	0.2849	0.3964	0.00193611	0.8536

Table A3. Number of Passengers Waiting at Station

10:45:15

Category Overview

Ekim 9, 2018

Values Across All Replications

Unnamed Project

Replications: 10 Time Units: Hours

Queue

Other

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Durak248 B7.Queue	0.6866	0.00	0.6866	0.6866	0.00	7.0000
Durak249 G3.Queue	0.4297	0.00	0.4297	0.4297	0.00	5.0000
Durak25 B2.Queue	0.3538	0.06	0.2284	0.5022	0.00	16.0000
Durak25 B5.Queue	0.1229	0.03	0.07309371	0.1921	0.00	3.0000
Durak25 G6.Queue	0.2100	0.05	0.0950	0.2989	0.00	5.0000
Durak25 G7.Queue	0.1905	0.02	0.1479	0.2572	0.00	11.0000
Durak25 K4.Queue	0.2025	0.02	0.1628	0.2570	0.00	4.0000
Durak25 K9.Queue	0.1449	0.05	0.07605377	0.2702	0.00	3.0000
Durak250 K8.Queue	0.3438	0.00	0.3438	0.3438	0.00	2.0000
Durak26 G1.Queue	0.2518	0.00	0.2518	0.2518	0.00	4.0000
Durak27 B6.Queue	0.06559531	0.02	0.03913379	0.1221	0.00	2.0000
Durak27 G1.Queue	0.02924698	0.01	0.01195818	0.04821788	0.00	2.0000
Durak27 G2.Queue	0.04961180	0.02	0.00492266	0.1175	0.00	2.0000
Durak27 G3.Queue	0.06877694	0.02	0.02765713	0.1025	0.00	3.0000
Durak27 G7A.Queue	0.01398345	0.00	0.00623403	0.02340732	0.00	2.0000
Durak27 G9.Queue	0.3052	0.07	0.1790	0.4588	0.00	17.0000
Durak27 K7.Queue	0.04579932	0.01	0.02387957	0.07975776	0.00	3.0000
Durak27 K7A.Queue	0.0916	0.04	0.03879691	0.2069	0.00	4.0000
Durak28 B6.Queue	1.0251	0.15	0.7389	1.4644	0.00	14.0000
Durak28 B7.Queue	0.9179	0.08	0.7387	1.0745	0.00	20.0000
Durak28 D1.Queue	0.1475	0.03	0.1037	0.2283	0.00	4.0000
Durak28 G10.Queue	0.3984	0.06	0.2394	0.5257	0.00	7.0000
Durak28 G12.Queue	0.1395	0.07	0.03729604	0.2998	0.00	4.0000
Durak28 G13.Queue	0.1098	0.05	0.04006582	0.2176	0.00	2.0000
Durak28 K1.Queue	0.1782	0.04	0.0953	0.2726	0.00	5.0000
Durak28 K5.Queue	0.1248	0.04	0.05748912	0.2183	0.00	4.0000
Durak28 K6.Queue	0.1265	0.04	0.05199522	0.1988	0.00	4.0000
Durak28 K8.Queue	0.2112	0.04	0.1170	0.2947	0.00	4.0000
Durak29 K10.Queue	0.1658	0.02	0.1008	0.1887	0.00	5.0000
Durak29 K7.Queue	0.2757	0.03	0.2158	0.3245	0.00	5.0000
Durak29 K7A.Queue	0.2559	0.04	0.1816	0.3267	0.00	6.0000
Durak3 G8.Queue	0.1907	0.00	0.1907	0.1907	0.00	1.0000
Durak30 K9.Queue	0.1202	0.00	0.1202	0.1202	0.00	1.0000
Durak31 G1.Queue	0.3105	0.00	0.3105	0.3105	0.00	6.0000
Durak32 B6.Queue	0.3961	0.00	0.3961	0.3961	0.00	2.0000
Durak33 B3.Queue	0.4716	0.10	0.3058	0.7041	0.00	22.0000
Durak33 B7.Queue	0.7858	0.11	0.5737	1.0864	0.00	10.0000
Durak34 K9.Queue	0.1034	0.03	0.06404981	0.2004	0.00	2.0000
Durak36 G1.Queue	0.2594	0.00	0.2594	0.2594	0.00	5.0000
Durak37 B2A.Queue	0.2173	0.01	0.1834	0.2512	0.00	4.0000
Durak37 B7.Queue	0.2356	0.02	0.1833	0.2818	0.00	2.0000

Table A4. Waiting Time at Station

11:13:26		Queues		Ekim 9, 2018	
Unnamed Project		Replications: 10			
Replication 1		Start Time:	0,00	Stop Time:	24,00
		Time Units:		Hours	
Time		Waiting Time			
Durak1 B2A.Queue		0.15			
Durak1 B8.Queue		0.15			
Durak1 G4.Queue		0.21			
Durak1 G4A.Queue		0.17			
Durak1 G7A.Queue		0.06			
Durak1 K10.Queue		0.06			
Durak1 K3.Queue		0.13			
Durak1 K4.Queue		0.17			
Durak10 B6.Queue		0.17			
Durak10 B8.Queue		0.06			
Durak100 K3.Queue		0.16			
Durak101 K5.Queue		0.18			
Durak101 K6.Queue		0.09			
Durak102 B6.Queue		0.28			
Durak102 G4.Queue		0.08			
Durak102 G4A.Queue		0.12			
Durak103 G10.Queue		0.12			
Durak103 G5.Queue		0.10			
Durak104 G4.Queue		0.12			
Durak105 G10.Queue		0.10			
Durak105 G4.Queue		0.12			
Durak105 G4A.Queue		0.15			
Durak106 G3.Queue		0.07			
Durak107 B1.Queue		0.11			
Durak107 B2.Queue		0.10			
Durak107 B2A.Queue		0.24			
Durak107 B5.Queue		0.47			
Durak107 B8.Queue		0.13			
Durak107 G1.Queue		0.05			
Durak107 G3.Queue		0.09			
Durak107 K4.Queue		0.16			
Durak107 K7.Queue		0.21			
Durak107 K8.Queue		0.23			
Durak108 G13.Queue		0.88			
Durak108 G2.Queue		0.15			
Durak108 G5.Queue		0.11			
Durak108 G8.Queue		0.35			
Durak108 K2.Queue		0.19			
Durak108 K3.Queue		0.12			
Durak109 K9.Queue		0.57			
Durak111 B2.Queue		0.05			
Durak111 G7.Queue		0.05			
Durak110 G12.Queue		0.18			
Durak111 G10.Queue		0.09			
Durak111 G2.Queue		0.18			
Durak111 G9.Queue		0.03			
Durak111 K11.Queue		0.48			
Durak111 K2.Queue		0.07			
Durak111 K3.Queue		0.09			

Table A5. Vehicle Occupancy

Line Name	Passengers	Vehicle(s)	Tours	People per Tour
B1	5854	9	88	67
B2	6008	22	218	28
B2A	1140	4	32	36
B3	6138	22	218	28
B5	354	1	10	35
B6	2608	4	35	75
B7	3527	6	58	61
B8	2973	4	40	74
D1	1152	3	32	36
G1	8577	12	118	73
G2	506	2	25	20
G3	7460	14	110	68
G4	5141	8	85	60
G5	3032	9	114	27
G4A	2357	5	35	67
G6	1390	5	54	26
G7	3750	14	79	47
G8	933	3	30	31
G9	11874	20	165	72
G10	2547	6	47	54
G12	171	1	3	57
G13	158	1	3	53
K1	1477	3	40	37
K2	7232	13	119	61
K3	4710	10	74	64
K4	2490	4	51	49
K5	591	4	42	14
K6	873	3	42	21
K7	3065	6	50	61
K7A	2170	5	36	60
K8	890	2	15	59
K9	212	1	10	21
K10	1850	7	96	19

Table A6. Total Road and Fuel Consumption

Line Name	Tour Length (km)	Total Number of Tour Lines(CNG)	Total Number of Tour Lines(diesel)	Total Number of Vehicles on Line	Number of Diesel Vehicles	Number of Vehicles with CNG	Average Fuel (lt / km - Diesel)	Average fuel (m³/km - CNG)	Fuel Price per Diesel (TL)	Fuel m³ Price CNG (TL)	Daily Fuel Cost on Line (TL)	Total Lines (km)
B1	34	0	74	8	8	0	0,45	0,6	6,45 ₺	3,30 ₺	7.302,69 ₺	2516
B2	19	22	196	20	18	2	0,45	0,6	6,45 ₺	3,30 ₺	11.636,55 ₺	4142
B2A	25	0	32	4	4	0	0,45	0,6	6,45 ₺	3,30 ₺	2.322,00 ₺	800
B3	19,5	22	196	20	18	2	0,45	0,6	6,45 ₺	3,30 ₺	11.942,78 ₺	4251
B5	23	0	10	1	1	0	0,45	0,6	6,45 ₺	3,30 ₺	667,58 ₺	230
B6	20	0	39	5	5	0	0,45	0,6	6,45 ₺	3,30 ₺	2.263,95 ₺	780
B7	28	0	38	5	5	0	0,45	0,6	6,45 ₺	3,30 ₺	3.088,26 ₺	1064
B8	22	0	41	3	3	0	0,45	0,6	6,45 ₺	3,30 ₺	2.618,06 ₺	902
D1	21,5	0	32	3	3	0	0,45	0,6	6,45 ₺	3,30 ₺	1.996,92 ₺	688
G1	17	0	130	10	10	0	0,45	0,6	6,45 ₺	3,30 ₺	6.414,53 ₺	2210
G2	14	0	25	2	2	0	0,45	0,6	6,45 ₺	3,30 ₺	1.015,88 ₺	350
G3	23	0	97	10	10	0	0,45	0,6	6,45 ₺	3,30 ₺	6.475,48 ₺	2231
G4	24,6	0	85	9	9	0	0,45	0,6	6,45 ₺	3,30 ₺	6.069,13 ₺	2091
G4A	39	7	24	5	4	1	0,45	0,6	6,45 ₺	3,30 ₺	3.257,28 ₺	1209
G5	35	14	100	9	8	1	0,45	0,6	6,45 ₺	3,30 ₺	11.128,95 ₺	3990
G6	22,5	0	54	6	6	0	0,45	0,6	6,45 ₺	3,30 ₺	3.526,54 ₺	1215
G7	13,5	39	40	7	4	3	0,45	0,6	6,45 ₺	3,30 ₺	2.609,82 ₺	1066,5
G7A	21	40	92	14	10	4	0,45	0,6	6,45 ₺	3,30 ₺	7.270,83 ₺	2772
G8	31	0	30	3	3	0	0,45	0,6	6,45 ₺	3,30 ₺	2.699,33 ₺	930
G9	26	0	165	18	18	0	0,45	0,6	6,45 ₺	3,30 ₺	12.451,73 ₺	4290
G10	24	0	47	5	5	0	0,45	0,6	6,45 ₺	3,30 ₺	3.274,02 ₺	1128
G12	50	0	3	1	1	0	0,45	0,6	6,45 ₺	3,30 ₺	435,38 ₺	150
G13	100	0	3	1	1	0	0,45	0,6	6,45 ₺	3,30 ₺	870,75 ₺	300
K1	22	0	40	3	3	0	0,45	0,6	6,45 ₺	3,30 ₺	2.554,20 ₺	880
K2	20	0	119	12	12	0	0,45	0,6	6,45 ₺	3,30 ₺	6.907,95 ₺	2380
K3	34	24	50	10	7	3	0,45	0,6	6,45 ₺	3,30 ₺	6.549,93 ₺	2516
K4	31	51	0	4	0	4	0,45	0,6	6,45 ₺	3,30 ₺	3.130,38 ₺	1581
K5	21	24	22	4	2	2	0,45	0,6	6,45 ₺	3,30 ₺	2.338,88 ₺	966
K6	20,5	0	46	4	4	0	0,45	0,6	6,45 ₺	3,30 ₺	2.737,06 ₺	943
K7	35	21	13	5	2	3	0,45	0,6	6,45 ₺	3,30 ₺	2.775,94 ₺	1190
K7A	27	14	22	5	3	2	0,45	0,6	6,45 ₺	3,30 ₺	2.472,53 ₺	972
K8	53	5	0	1	0	1	0,45	0,6	6,45 ₺	3,30 ₺	524,70 ₺	265
K9	25	0	16	1	1	0	0,45	0,6	6,45 ₺	3,30 ₺	1.161,00 ₺	400
K10	27	21	31	5	3	2	0,45	0,6	6,45 ₺	3,30 ₺	3.552,05 ₺	1404
K11	25	0	7	1	1	0	0,45	0,6	6,45 ₺	3,30 ₺	507,94 ₺	175
Total Number of Vehicles				224					Daily Total Fuel Price		146.550,9 ₺	52977,5