ANALYSIS OF THE PASSENGER FLOW IN İZMİR METRO TRAIN STATIONS

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ANALYSIS OF THE PASSENGER FLOW IN İZMİR METRO TRAIN STATIONS

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Approval of the Graduate School of Natural and Applied Sciences

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I certify that this thesis satisfies all the requirements as a thesis for the degree of **Master of Science** in **Industrial Engineering.**

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ABSTRACT

ANALYSIS OF THE PASSENGER FLOW IN İZMİR METRO TRAIN STATIONS

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Interarrival times (IATs) of entities of a system is studied in various fields including transportation. Traffic of vehicles on highways and passengers using subways were studied to find out the distribution which will correctly capture the characteristics of the transportation systems. Interarrival time distributions that accurately capture the dynamics of passenger flows are essential parts in efficient strategic decision making and developing efficient schedules for subway systems. In this thesis, we aim to find a generalized passenger IAT distribution for the subway system in İzmir. Instead of finding different distributions for each of the 17 stations, we checked if there was a generalized common passenger IAT distribution. Kolmogorov - Smirnov tests were conducted for the generalization, and rank order clustering method is

adapted to our problem in order to group these stations. The stations with similar cumulative density functions are presented, and the corresponding cumulative IATs were found according to the 6 groups. Hyperbolic and exponential models were fitted to the data of passenger volume - IATs. Suggested hyperbolic models were found to outperform exponential models when their Bayesian information criterion values were compared. Furthermore, hourly and station adjustment factors are evaluated to estimate the passenger flow at any hour for any station. The data used for the analysis is two weeks of passenger arrival times, which are gathered from İzmir Metro smart ticketing system.

Keywords: interarrival time distribution, passenger flow, adjustment factor, public transportation

ÖZ

İZMİR METRO TREN İSTASYONLARI İÇİN YOLCU AKIŞI ANALİZİ

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Sistemlerde varlıkların gelişler arası zaman aralığı dağılımı, ulaşım dahil olmak üzere çeşitli alanlarda çalışılmaktadır; otobandaki araç trafiği ve metroyu kullanan yolcular, ulaşımdan örnekler olarak verilebilir. Sistem karakteristiğini ve yolcu akışı dinamiklerini doğru bir şekilde belirleyebilecek yolcu geliş aralığı süresi dağılımlarını elde etmek, sistemle ilgili alınacak olan stratejik kararlardaki ve verimli/etkin metro çizelgelemelerinin geliştirilmesindeki en temel gereksinimlerdendir. Bu tezde İzmir metrosunu kullanan yolcular için genelleştirilmiş bir geliş aralığı süresi dağılımı bulmayı amaçladık. 17 istasyonun her birisi için ayrı dağılımlar bulmak yerine, ortak bir genel yolcu geliş aralığı dağılımı bulup bulamayacağımızı değerlendirdik.

Kolmogorov - Smirnov testleri kullanılarak genelleştirmeler yapılmış ve istasyon gruplamaları için “Rank order clustering” yöntemi probleme adapte edilmiştir. Benzer kümülatif yoğunluk fonksiyonlarına sahip istasyonlar sunularak, 6 istasyon grubunun kümülatif yolcu geliş aralığı süreleri bulunmuştur. Yolcu yoğunluğu - geliş aralığı süresi verileri hiperbolik ve üstel fonksiyonlar ile modellenmiştir. Bayes bilgi kriteri değerleri bu iki modeli kıyaslamak üzere hesaplanmış ve önerilen hiperbolik fonksiyonun üstel fonksiyondan daha iyi uyum sağladığı gösterilmiştir. Ek olarak, saatlik ve istasyon ayarlama faktörleri, herhangi bir saat ve herhangi bir istasyondaki yolcu akışını tahminlemek için, hesaplanmıştır. Analizlerde kullanılan iki haftalık yolcu geliş süresi verileri İzmir Metro akıllı kart sisteminden alınmıştır.

Anahtar Kelimeler: gelişlerarası zaman aralığı dağılımı, yolcu akışı, ayarlama faktörü, toplu taşıma

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This thesis I dedicate to my family and Sertuğ Güler.

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CHAPTER 1: INTRODUCTION

Izmir is the third most populous metropolitan city in Turkey with a population of over 4 million according to City population, “Turkey: Major cities and provinces”. Public transportation is highly used in İzmir. Özuysal (2011) stated that an average of 1 million 750 thousand passengers use public transportation on a daily basis.

Public transport use reaches its highest levels at particular hours, called the peak hours, during the day. Efficient strategic decisions have to be made for public transportation services in order to prevent decreased performance and quality measures of mobility during these times. Increased passenger travel times, long waiting times of passengers, and traffic congestion are some of the consequences to be faced if no precautions are taken.

There are four main modes of public transportation in İzmir, bus, ferry, subway trains (metro) and local İzban trains. The subway train system will be described in detail since its passenger flow is the subject of this thesis.

1.1 Subway system

Subway systems use electrical power and differ from the fuel mode systems. It is possible to compare the approximate pollution levels according to fuel types of vehicles. In Tzeng et al. (2009), several types of fuels are regarded as alternative-fuel modes, i.e., electricity, fuel cell (hydrogen), and methanol; and expressed that vehicles using electricity cause the lowest levels of air-pollution amongst the alternative-fuel using vehicles. From this point of view, increased use of subway system will clearly result in reduced emissions.

The subway system is also considered to be a complement to the other modes of public transport, and they act as alternative transportation systems to buses where routes coincide. A route map of metro system and each station is given with blue marks in Figure 1 taken from Metro A.Ş., ”Ulaşım ağ planı”.

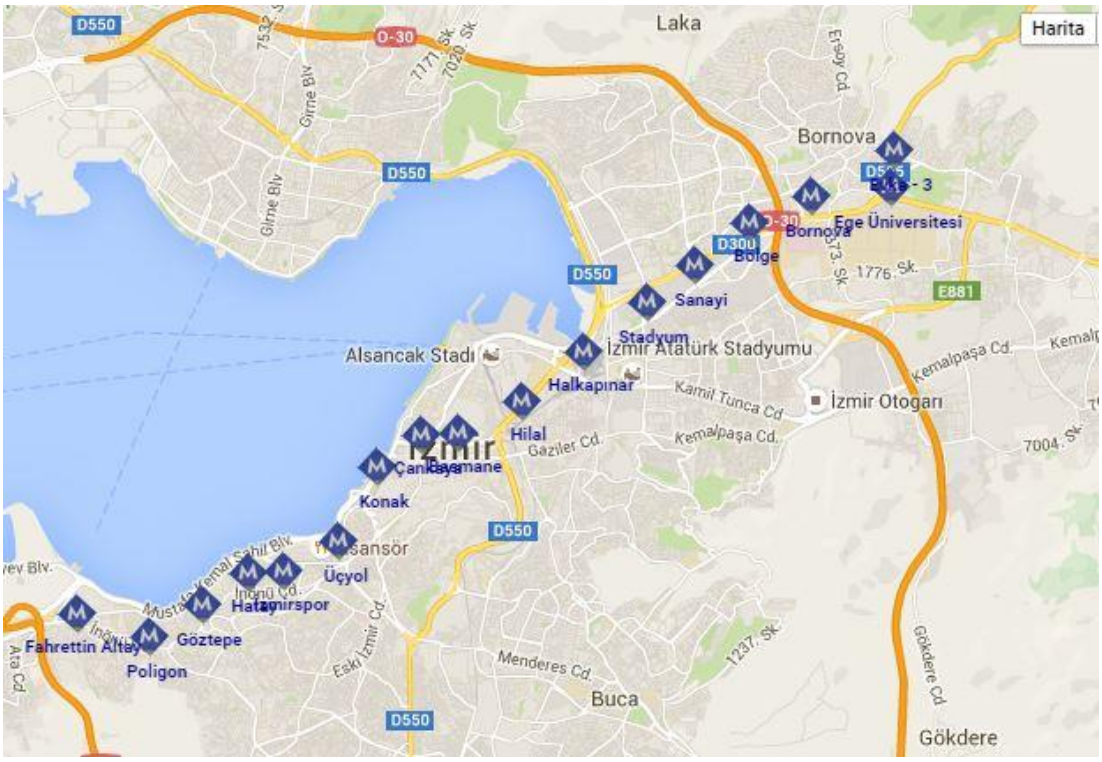


Figure 1 Route map of stations of metro system

Metro system has a simple network structure in the form of one line in each direction, and no traffic congestion affects the system. The route is approximately 20 kms long with 17 stations, starting from Fahrettin Altay station and ending at Evka 3 station. The names of the stations are as follows; Fahrettin Altay, Poligon, Goztepe, Hatay, Izmirspor, Ucyol, Konak, Cankaya, Basmane, Hilal, Halkapınar, Stadyum, Sanayi, Bolge, Bornova, Ege Universitesi and Evka 3. Their locations are mapped in Figure 1 above. In Figure 2, the route of metro line is shown with the blue line.

Halkapınar and Hilal stations differ from the others, as they are the transfer stations of the İzban line. An important number of passengers transfer through these two stations and transfer to subway system. According to Rail Turkey, Total daily usage of these two integrated light rail systems is 630,000 passengers; 350,000 and 280,000 passengers for metro and İzban, respectively.

Since there is no traffic congestion, the subway system can be considered to be one of the fastest modes of transportation in the city. Thus, the system is a widely used transportation mode compared to other modes of public transportation. The subway system has intersections with other modes of transportation, such as the transfer stations to the local train service, İzban. The route of İzban is shown by a red line in Figure 2, which is taken from Metro A.Ş., “Sefer planı”. As it can be seen from the figure, these two transportation modes cover most of the city, making them the heart of the public transportation in İzmir.

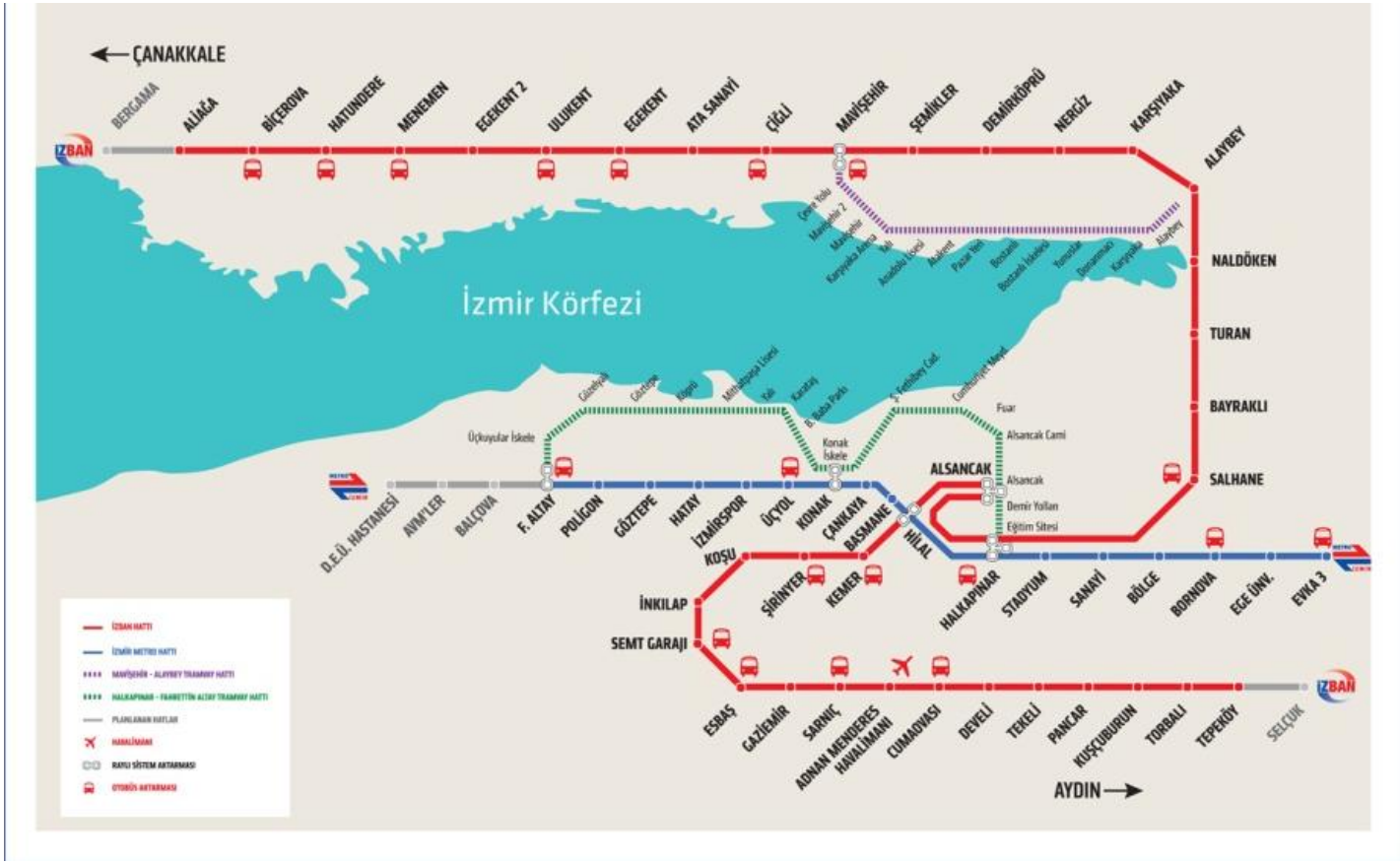


Figure 2 Route map of subway and izban in Izmir

Physical appearance of a subway train and station waiting hallway of Fahrettin Altay station can be seen from Figure 3 below, taken from Metro A.Ş., “İstasyonlar ve aktarma merkezleri_Rakamlarla istasyonlar”. Frequency of trips corresponding to specified time intervals are taken from Metro A.Ş., “Sefer planı” and given in Table1.

Figure 3 Subway train and station waiting hallway of Fahrettin Altay station

Table 1 Frequency of trips corresponding to specified time intervals

Week days	
Time interval	**Frequency**
06:00 - 06:30	10 minutes
06:30-20:30	5 minutes
20:30- 00:20	10 minutes

Saturday	
Time interval	**Frequency**
06:00 - 07:00	10 minutes
07:00 - 20:30	5 minutes
20:30- 00:20	10 minutes

Sunday	
Time interval	**Frequency**
06:00 - 12:00	10 minutes
12:00-20:30	7 minutes
20:30- 00:20	10 minutes

1.2. Smartcard system

Smartcard system is an electronic ticketing system used by public transportation system passengers in İzmir. It is a plastic card with an integrated chip. Smart cards are charged through automatic machines or via charging stations. When placed against the sensor, the ticket fare is charged and both the payment amount and the remaining balance of the card is displayed on the machine, as shown in Figure 4. Smart card applies for each of the four modes of transportation mentioned above, and it can be used in different transportation modes without additional charges for 90 minutes after first use.

Passengers swipe their smart cards across sensors in order to pass the turnstiles at station entrances. Photos of turnstiles and vending machines placed on them at the entrance of Fahrettin Altay station can be seen in Figure 4. The smartcard is a tool which makes the modern ticketing system easy to use.

Figure 4 Sensors and turnstiles at Fahrettin Altay station entrance

The smartcard ticketing system makes it possible to record relevant system information, such as passenger arrival times, and counts of arriving passengers at stations. This information can be used to determine demand, peak hours, to find adjustment factors, to schedule the service, to construct timetables or interarrival time (IAT) distributions for passenger flow.

The outline of the thesis is as follows: in chapter 2, the problem definition is given, while in Chapter 3, the objectives of the study are stated. Chapter 4 presents the literature review of the topic. A statement of the methodology used throughout the data analysis appears in Chapter 5. Results are given in Chapter 6 and finally conclusions and future work are given in Chapter 7.

CHAPTER 2: PROBLEM DEFINITION

Traffic congestion during peak hours also affects the system performance and quality measures of public transportation system. Quality of service is inevitably decreased at peak hours, when passenger waiting times and traffic congestion reach highest levels. In order to prevent unsatisfactory consequences, strategic planning decisions of transportation systems should be taken.

Mayer et al. (2015) stated that accessing passenger flow data is not challenging with modern technologic tools, but effective utilization of data is complex. It needs a clear understanding of the processes and the ability to distinguish useful and peripheral data. Interarrival time distribution is one of the most important flow characteristics of traffic according to May (1990). It affects performance measures of systems such as level of service, passenger waiting times and capacity of the system. In order to improve these performance measures, simulation studies can be performed. The usage of more accurate inputs of IAT distributions can help to obtain more accurate results. Thus, in this thesis, we aim to find a generalized distribution for IAT data of passengers using subway system.

Interarrival times of entities of a system have been studied in various fields including transportation; traffic of vehicles on highways and passengers using subways to find the distribution which will accurately capture the characteristics of the transportation systems. IAT distributions that accurately reflect the dynamics of passenger flow are an essential part of efficient strategic decision-making and developing efficient schedules for subway systems. As mentioned above, IAT distributions also serve as a reliable input for the simulation studies of the systems.

The evaluation of hourly and station adjustment factors for daily passenger volumes is another important aspect of transportation systems for making forecasts for the planning of the metro system schedules. For instance, by using the hourly adjustment factors evaluated for each of the 17 stations, we are able to estimate passenger volume for a specific time interval of the day when the total daily passenger volume of the system is given.

Similarly station adjustment factors can be used to calculate the passenger flow volume for a specific station, given the total daily passenger volume for the system.

By using adjustment factors, for any “station and time interval” combination, the demand can be estimated, given the total daily demand of the system.

CHAPTER 3 OBJECTIVES OF THE STUDY

The aim of this thesis is to find an accurately defined generalized IAT distribution of passenger flow for metro transportation system. Our main motivation is to use this data as an input for simulation studies to improve the subway system's performance measures, and also to use it to obtain efficient schedulings for the system.

Two conditions should be investigated in order to be able to generalize IAT distributions for hourly intervals. First, we need to find if there are daily differences in cumulative probability density functions between the pairs of hourly IATs obtained from two different day's data. The second condition is that the cumulative probability density functions of hourly IAT pairs for different stations with similar sample sizes should be similar. If no difference is indicated for the two conditions, then we can aggregate hourly IATs, and have a generalized cumulative IAT distribution, which can characterize hourly IATs for any day of any station.

Our second objective is finding adjustment factors for estimating passenger volume data. This information allows us to forecast the demand of the subway system. The aim is to evaluate two types of adjustment factors, namely adjustment factors for stations and for hour intervals.

CHAPTER 4 LITERATURE REVIEW

Flow characteristics of entities for various systems are present in the literature. There are studies of passenger flow on physical phenomena, such as passenger velocity, trajectories, density, and avoiding passenger collision at busy stations.

Interarrival times of entities of a system are studied in various fields, including transportation; traffic on highways and passengers using subways, in order to find out the distribution which will correctly capture the characteristics of the transportation systems. Gramaglia et al. (2014) present a novel method for generating microscopic IATs of vehicles on highways; this new method is able to obtain the correlations that are lost in distribution-fitted models. They state that distributions based on fittings of empirical distributions cannot capture the correlations since these distributions assume independent IATs. Thus, they use a measurement based Hidden Markov Model to capture the distribution, which effectively imitates the real world interarrivals. Their results suggest that the traffic of vehicles might be in one of three states, congested, free flow or mixed state, and that each state may be represented effectively via the parametrization of the Markov model.

In the field of public transportation, limited attention has been given to developing the IAT distributions of passengers. Related studies in the literature are stated below. Feng et al. (2009) studied Beijing Subway Line 1, checking the consistency of station facilities with the increasing passenger flow (investigating the relevance between facilities and passenger flow), and

presented recommendations for enhancing the passing capacity and quality of the service.

Jiang et al. (2013) studied arrival interval of passenger flow on urban rail transit stations in China. They referred to the subjected system, as a stochastic service system and proposed that phase type distribution accurately fits the data, but has a large number of parameters to be calibrated. They concluded that hyper erlang distribution, which is a dense subset of phase type, resulted in highest level of accuracy and the most stable fitting effect amongst the 7 most widely used distributions investigated for their fitting ability to arrival interval data. They point out that hyper erlang distribution has only two parameters to be determined, and it provided an innovative alternative to phase type distribution, with its accurate and stable fitting properties.

Özuysal et al. (2011) proposed an analysis on passenger flow of light rail transit (LRT) system in İzmir, Turkey. They stated that passenger flow modeling of LRT is a seldomly studied area in public transportation. Estimation of boarding and alighting passenger flows is done by multiple regression analysis for 10 stations on the line. Root mean square errors and efficiency factors were evaluated to compare the predictive power of the models. Some of the stations were found to have poor accuracy in their regression models, because of high variation in trip demand. Thus artificial neural networks (ANN) were used as an alternative approach for passenger flow estimations of these stations. The models found by two approaches were compared, and it is stated that ANN approach gives significantly better estimation results for low passenger attractive stations.

CHAPTER 5: METHODOLOGY

In this section, the steps for finding the generalized IAT distributions and adjustment factors are explained.

5.1 Data collection

The data obtained from smart card ticketing system consists of metro passengers' arrival time and ID of the turnstiles, which the passengers passed through to enter the station. For example, at Üçyol station, there exist 11 turnstiles whose IDs are 70009, 70010, 70011, 70012, 70013, 70014, 70015, 70016, 70017, 70018 and 70019. There is a total of 125 turnstiles in 17 stations operating in coordination with sensors. Passenger arrival time is kept in the system when the smartcard is swiped across the machine to pass the turnstile.

A brief section of raw data can be seen in Table 2. Arrival times are represented as the year, month, day, hour, minute and second information of the arrival time of a passenger, i.e. an arrival time of 20150126054334 means that the arrival occured on 26.01.2015, at 05:43:34. This representation is converted into a second format for calculation of interarrival times. While constructing IAT distributions for a station, all turnstiles in a station are considered as one, thus passengers that enter from different turnstiles at the same time have an interarrival time of zero. However since

we considered all of the data from different turnstiles combined, we assigned 0.1 seconds of interarrival time for the passengers passing the turnstiles at the same time.

The IAT values were found for hourly time intervals of the day. The service of metro begins by 5:00 am and ends at 00:59:59 am, i.e. there exist 20 service hours in a day. 5:00 - 6:00 and 00:00 - 00:59 intervals are not used in the analysis of IAT values. These two hourly intervals are assumed as outliers, since their passenger flow amounts were very low compared to other time intervals. They commonly had less than 6-7 passenger volumes. Thus, in the analysis, 18 hour intervals of service are used for each day.

Histograms can be obtained in order to gain insight into hourly IAT distributions' shape. As an example the histogram obtained from January 24th, 07:00 – 08:00 hour interval for Bölge station is given in Figure 5. Bins are selected as 1 second intervals and bin ranges start from 1 and ends with the maximum interarrival time value observed in that hour interval. Bin range for each hour interval is calculated automatically by using macros.

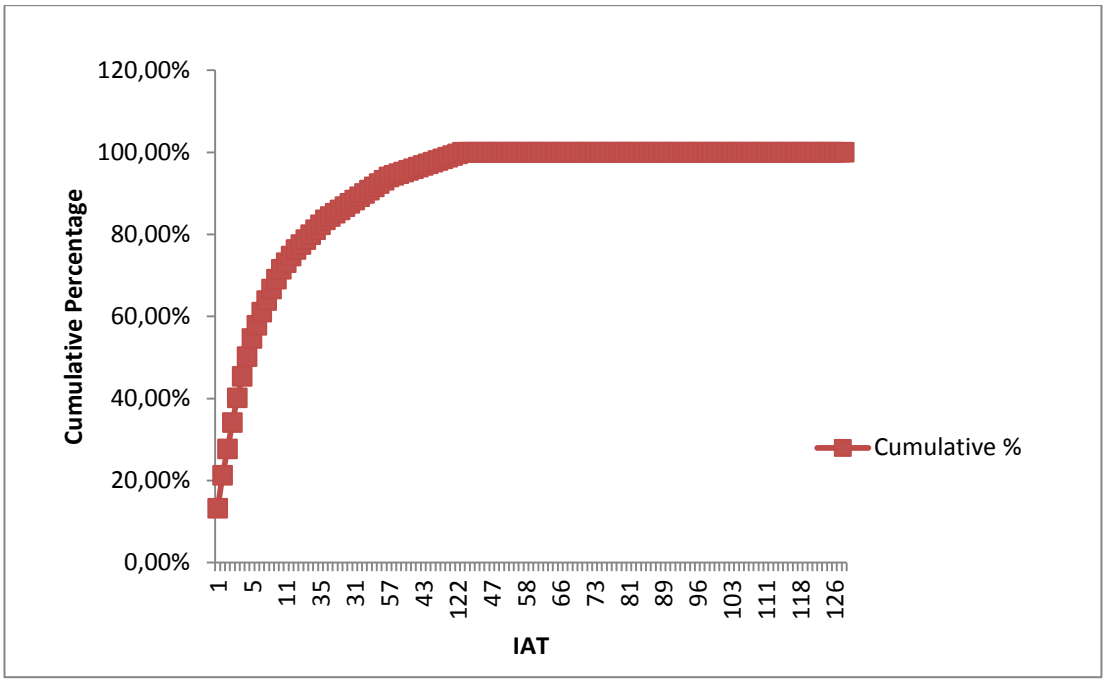


Figure 5 Cumulative Frequency Distribution for Bölge station on January 24 at 07:00-08:00 hour interval

Table 2 Example of raw data

TURNSTILE ID	ARRIVAL TIME
70201	20150126054334
70207	20150126054358
70065	20150126054401
70043	20150126054506
70042	20150126054543
70042	20150126054629
70195	20150126054638
70043	20150126054639
70020	20150126054721
70060	20150126054724
70021	20150126054742
70193	20150126054755
70207	20150126054757

Our analysis is performed on two weeks data, 14 days, including both weekdays and weekends (from January 19 to February 1 of 2015), numbered from 1 to 14. Schools were open in the first week data whereas the semester holiday began by the second week, which made our study suitable for investigating the effects of holiday season on passenger flows as well.

Hourly passenger flow data and hourly interarrival times are extracted from raw data automatically by written codes in Excel VBA. Detailed explanation of how the data is extracted and how the extracted data is used in the analysis is presented throughout this chapter.

5.2 Data analysis

In this section, the methods used in the analysis of the 14 day passenger arrival data are given.

5.2.1 Extraction of hourly passenger interarrival times and passenger volume

Excel macros are coded via VBA, which are used for the filtering and counting operations, calculation of the interarrival times in terms of seconds, finding bin ranges and finding the percentile values of IAT distributions for a specific time interval of the day and station. Extraction of any kind of information used in the analysis is conducted using these codes.

The first step in our study is the extraction of data from the raw data. By filtering for station ID's, and hour intervals, we can easily extract hourly arrival times of passengers for a station and hour pair. Passenger volume data is found by counting the number of rows in the hourly arrival time data for a station.

The passenger IATs were needed to construct hourly IAT distributions and the hourly passenger volumes were needed for the adjustment factors. . There are 17 stations, 14 days and 20 hour intervals in each day, thus a total of 4760 intervals were extracted, and then their IATs and passenger volumes were evaluated for each interval. After that, outlier hour intervals, whose passenger volumes were less than 5 passengers per hour were excluded.

5.2.2 Kolmogorov - Smirnov two sample test

According to Siegel (1956), Kolmogorov - Smirnov two-sample test can be used to check whether the two empirical cumulative distributions are drawn from the same population. In order to find whether two empirical distributions are the same, Kolmogorov - Smirnov two sample test was applied, where the test of hypothesis is as shown below, according to Sheskin (2004),

Null hypothesis H_0: $F_1(X) = F_2(X)$, for all values of X

Null hypothesis simply means that at no point of the cumulative probability distributions of the two samples, the maximum vertical distance is greater than the tabulated critical value, if the two samples are coming from the same population. Here $F_j(X)$ corresponds to the cumulative density function for the population where jth sample is derived from.

Alternative hypothesis H_1: $F_1(X) \neq F_2(X)$, for at least one value of X

Null hypothesis is rejected if there exists a large deviation between cumulative distributions of the two samples at any point of X, concluding that two samples distribution's are not equal, and they come from different populations.

The test statistic for a two tailed KS test is found by the equation below:

$$D = maximum \mid S_{n_1}(X) - S_{n_2}(X) \mid$$

D refers to the greatest absolute value of the difference between the two cumulative distributions. For the first sample, $S_{n_1}(X) = k/n_1$ represents the cumulative proportions of data points in specified intervals. k is the number of occurrence times of the ordered observations and it is evaluated cumulatively for each ordered observation.

Kolmogorov - Smirnov test is a nonparametric test. For $n_1, n_2 > 40$ (n_1 and n_2 being sample sizes of first and second samples, respectively), calculated test statistic D should be compared to Kolmogorov - Smirnov M table critical values for a prespecified significance level of α. n_1 and n_2 are not necessarily equal to each other.

5.2.2.1 Kolmogorov - Smirnov test for hourly interarrival times of daily pairs and station pairs

Two important characteristics of passenger IATs have to be investigated for establishing generic IAT distributions of hourly passenger volumes. First, it is important to identify if there are daily differences in IAT distributions and second if the hourly IAT distributions are different for different stations. If the two criteria above reveal no significant difference between the distributions, then it is possible to aggregate hourly IATs and construct a cumulative IAT distribution for any day of any station. The investigation of these two criteria is stated in the following part of this section.

5.2.2.1.1 Checking the similarity of daily passenger flow data

Our first aim is to find whether the daily pairs of IAT distribution share the same population distribution or not. Kolmogorov - Smirnov tests are conducted in SPSS for 91 pairs of days for each level of hourly passenger traffic volumes, namely the low, medium and high. The applied tests are two sided tests, and a confidence level of 0.95 is used.

The next stage is to determine common passenger volumes for low, medium and high levels. We would like to find 3 common passenger volume values that are similar for all days for all three levels. The common values of hourly passenger flow is determined by checking the graphics in Figures 6 and 7, which shows the hourly passenger flows for all 14 days for F.Altay station. Each day consists of 20 hourly intervals. The diagram of two weeks data for F. Altay station is given as an example. In order to find the common values, all of the 17 stations were investigated.

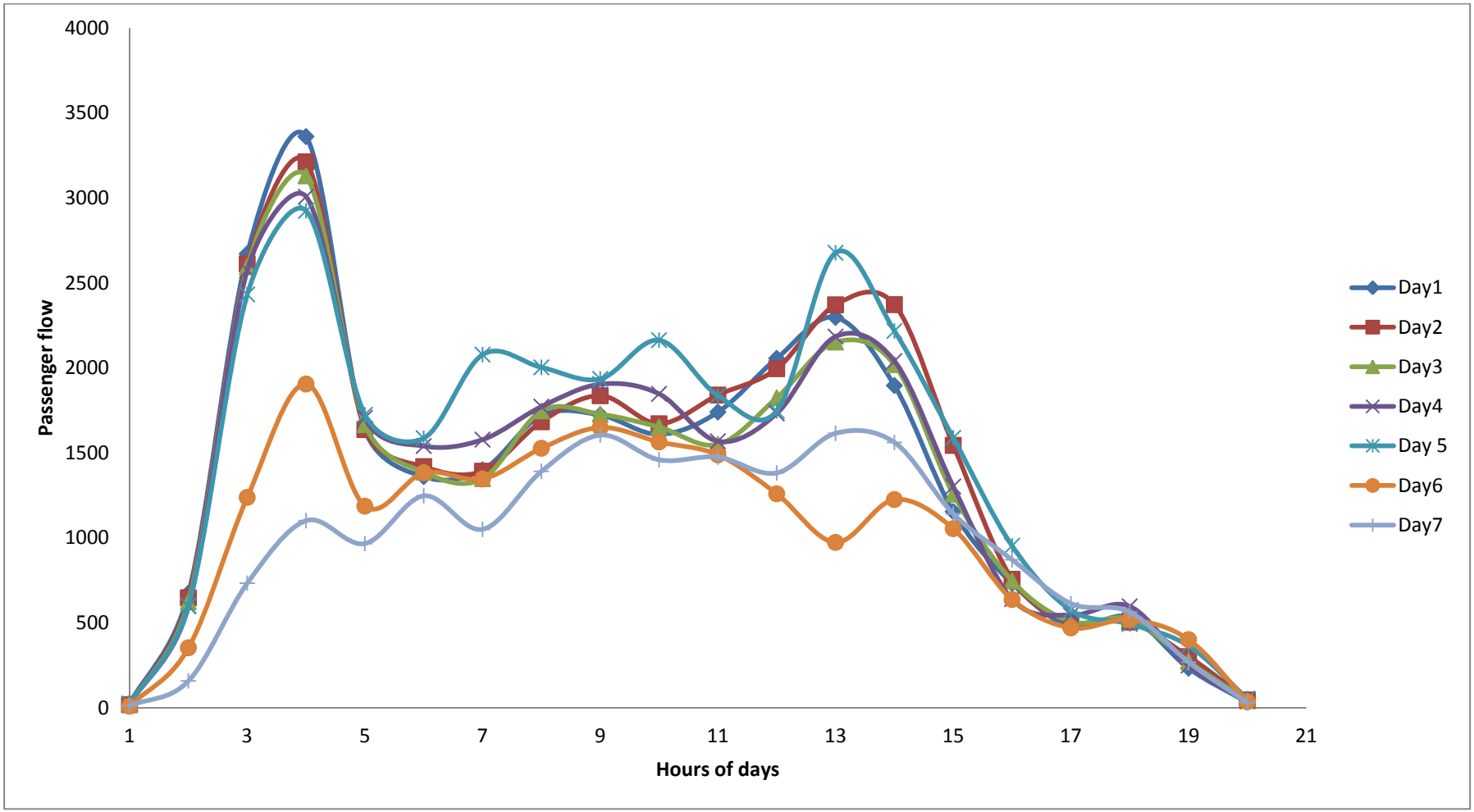


Figure 6 Passenger flow data in hourly time intervals of the first week at F. Altay station

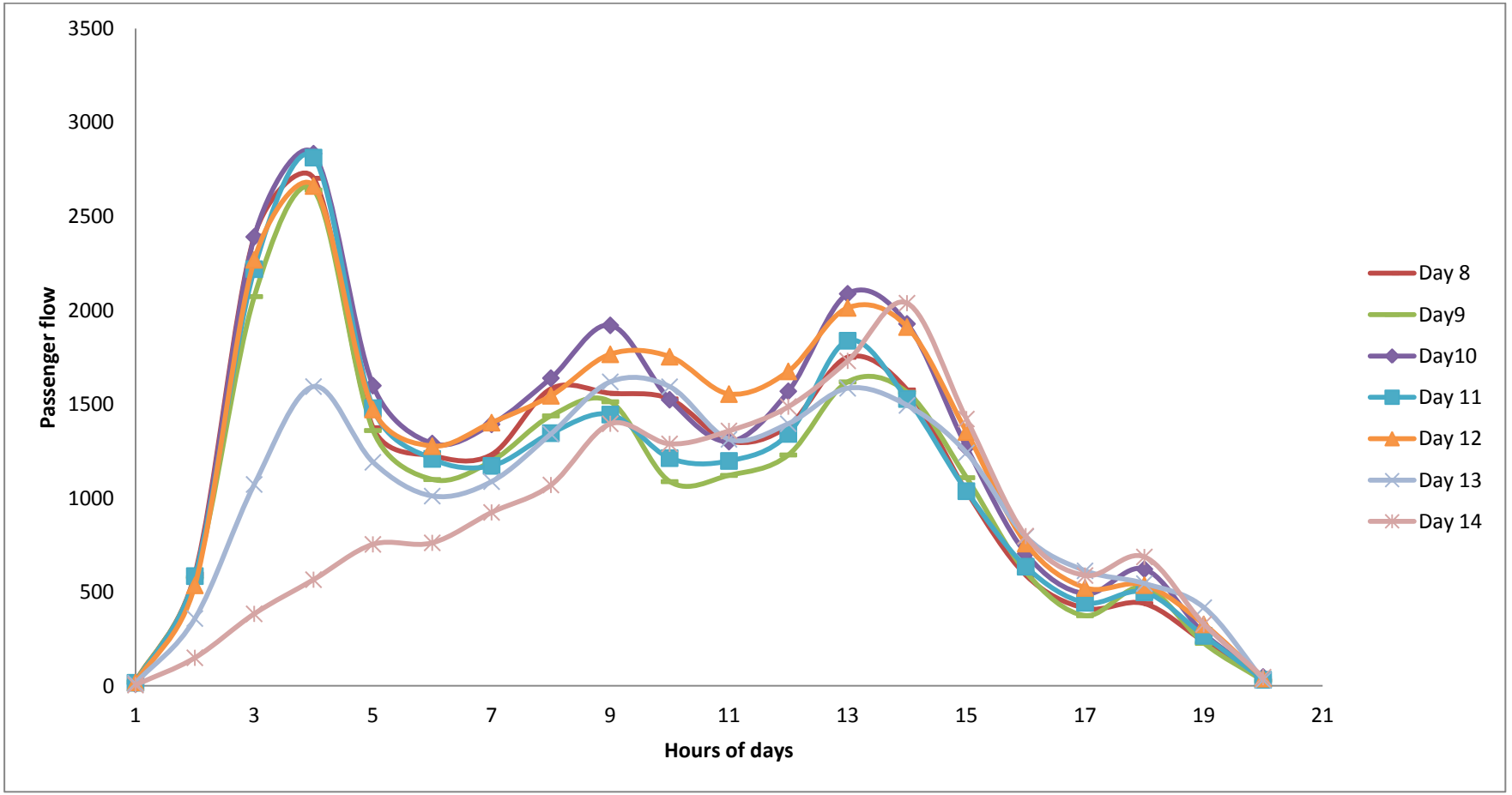


Figure 7 Passenger flow data in hourly time intervals of the second week at F. Altay station

Sanayi station narrows down our range of possible common values. By further investigating the data on hand, passenger volumes of three levels are selected as 300, 600, and 1600 for low, medium and high levels, respectively. The test results are shown in Table 3, Table 4 and Table 5 for low, medium and high levels, respectively.

Table 3 K-S test results for low passenger volume level (day pairs)

	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun
days	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	reject	reject
2	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	reject
3	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	reject
4	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
5	reject	do not	do not	do not	do not	do not	reject	reject	reject	reject	do not	do not	do not	do not
6	reject	do not	do not	do not	do not	do not	do not	reject	do not	reject	do not	do not	do not	reject
7	do not	do not	do not	do not	reject	do not	do not	do not	do not	do not	do not	do not	reject	reject
8	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	reject	reject	reject
9	do not	do not	do not	do not	reject	do not	do not	do not	do not	do not	do not	do not	reject	reject
10	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	reject	reject
11	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
12	do not	do not	do not	do not	do not	do not	do not	reject	do not	do not	do not	do not	do not	do not
13	reject	do not	do not	do not	do not	do not	reject	reject	reject	reject	do not	do not	do not	reject
14	reject	reject	reject	do not	do not	reject	reject	reject	reject	reject	do not	do not	reject	do not

Table 4 K-S test results for medium passenger volume level (day pairs)

	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun
days	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
2	do not	do not	do not	do not	do not	reject	do not	do not	do not	reject	do not	reject	do not	do not
3	do not	do not	do not	do not	do not	do not	do not	do not	do not	reject	do not	reject	do not	do not
4	do not	do not	do not	do not	do not	reject	do not	do not	do not	do not	do not	reject	do not	do not
5	do not	do not	do not	do not	do not	reject	do not	do not	do not	reject	do not	reject	do not	do not
6	do not	reject	do not	reject	reject	do not	do not	do not	do not	reject	do not	do not	reject	do not
7	do not	do not	do not	do not	do not	do not	do not	do not	do not	reject	do not	reject	do not	do not
8	do not	do not	do not	do not	do not	do not	do not	do not	do not	reject	do not	reject	do not	do not
9	do not	do not	do not	do not	do not	do not	do not	do not	do not	reject	do not	do not	do not	do not
10	do not	reject	reject	do not	reject	reject	reject	reject	reject	do not	reject	reject	do not	reject
11	do not	do not	do not	do not	do not	do not	do not	do not	do not	reject	do not	reject	do not	do not
12	do not	reject	reject	reject	reject	do not	reject	reject	do not	reject	reject	do not	reject	reject
13	do not	do not	do not	do not	do not	reject	do not	do not	do not	do not	do not	reject	do not	do not
14	do not	do not	do not	do not	do not	do not	do not	do not	do not	reject	do not	reject	do not	do not

Table 5 K-S test results for high passenger volume level (day pairs)

	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun
days	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
2	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
3	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
4	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
5	do not	do not	do not	do not	do not	reject	do not	do not	do not	do not	do not	do not	do not	reject
6	do not	do not	do not	do not	reject	do not	do not	do not	do not	do not	do not	do not	do not	do not
7	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
8	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
9	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
10	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
11	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
12	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
13	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not	do not
14	do not	do not	do not	do not	reject	do not	do not	do not	do not	do not	do not	do not	do not	do not

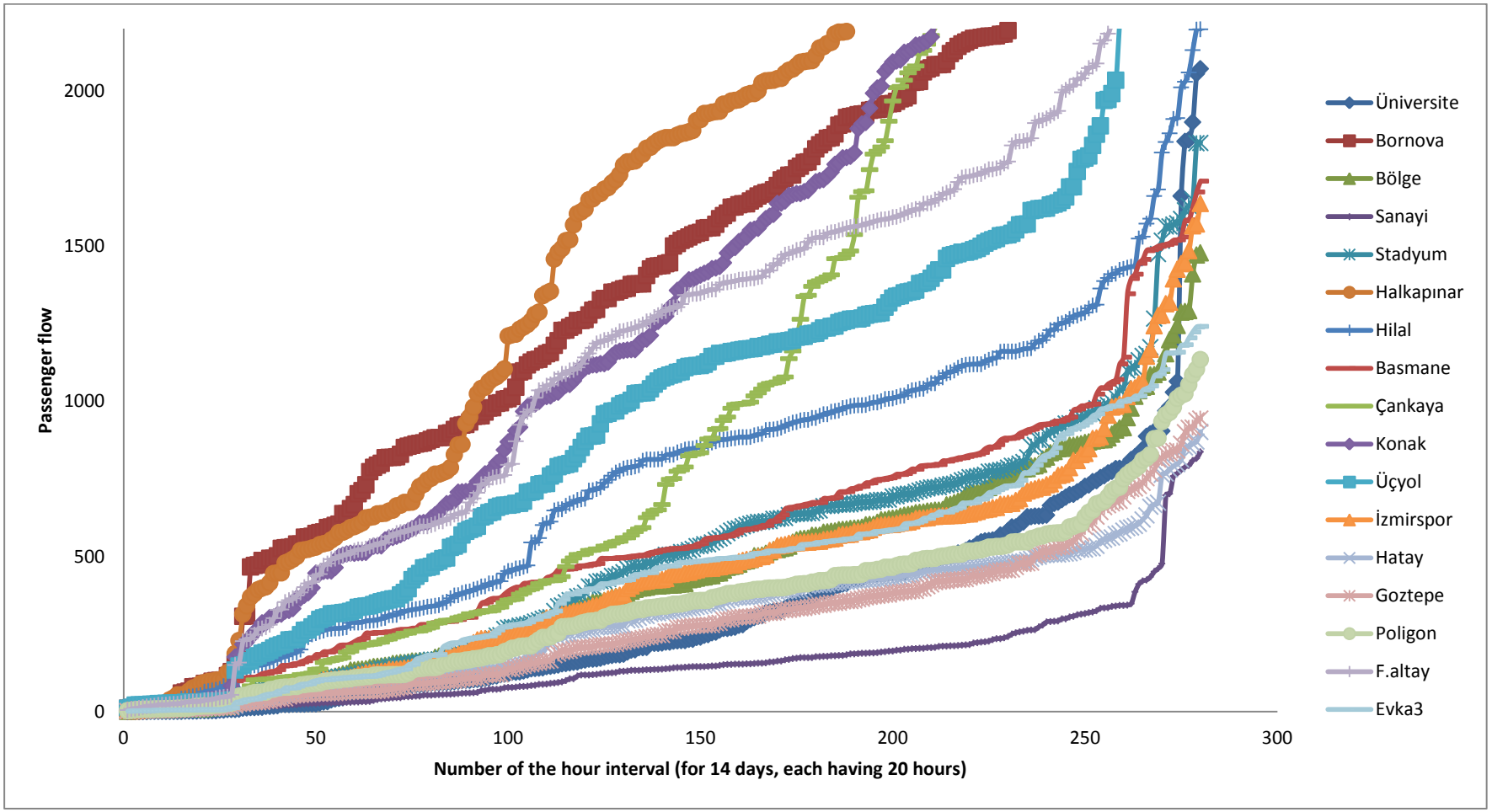
When the result of “do not” is obtained, it means “failing to reject the null hypothesis”, thus, we conclude that the two samples are coming from the same population. Results show that there seems to be a little difference between the daily cdfs in low passenger flow level. However, as the sample size of the passenger flow levels increase no difference is observed as seen in Tables 3, 4 and 5. We can conclude that there is no significant difference in cdf’s between the daily pairs of hourly IATs.

5.2.2.1.2 Checking the similarity of station pairs

For the analysis of the second criteria, we obtained Kolmogorov - Smirnov test results for station pairs in SPSS for three different passenger volume levels, which are named as low, medium and high volume levels. For each level, a common volume value is selected which had an occurrence in every station, which are around 250 for low level, 500 for medium level and 750 for high level of passenger volume. Amongst 17 stations, 14 days of 20 hourly passenger volumes, one hourly interval with the common passenger volume was selected for each station at each level. IAT values were calculated for these selected hourly intervals, and then used in Kolmogorov - Smirnov test. The applied tests were two sided tests, and a confidence level of 0.95 was used.

Determination of common values was conducted by checking the diagrams shown in Figure 8 below.

Figure 8 Hourly passenger flow of all the stations narrowed to 0 - 2200 interval on the y axis



K - S test analysis was conducted in SPSS for 136 station pairs for each level. Obtained test results can be seen in Table 6, Table 7 and Table 8 for low, medium and high passenger volume levels respectively.

Table 6 K-S test results for low passenger volume level (station pairs)

Stations	Evka 3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Göztepe	Poligon	F. Altay
Evka 3	do not	reject	do not	reject	reject	reject	do not	do not	reject	reject	reject	reject	reject	reject	reject	reject	do not
Üniversite	reject	do not	reject	do not	do not	do not	reject	reject	do not	do not	reject	do not	do not	do not	do not	do not	reject
Bornova	do not	reject	do not	reject	reject	reject	reject	do not	reject	reject	reject	reject	reject	reject	reject	reject	reject
Bölge	reject	do not	reject	do not	do not	do not	reject	reject	do not	do not	reject	reject	do not	do not	do not	do not	reject
Sanayi	reject	do not	reject	do not	do not	do not	reject	reject	do not	do not	reject	reject	do not	do not	do not	do not	reject
Stadyum	reject	do not	reject	do not	do not	do not	reject	reject	do not	do not	do not	reject	do not	do not	do not	do not	reject
Halkapınar	do not	reject	reject	reject	reject	reject	do not	reject	reject	reject	do not	do not	reject	reject	reject	reject	do not
Hilal	do not	reject	do not	reject	reject	reject	reject	do not	reject	reject	reject	reject	reject	reject	reject	reject	reject
Basmane	reject	do not	reject	do not	do not	do not	reject	reject	do not	do not	do not	do not	reject	do not	do not	do not	reject
Çankaya	reject	do not	reject	do not	do not	do not	reject	reject	do not	do not	do not	reject	do not	do not	do not	do not	reject
Konak	reject	reject	reject	reject	reject	do not	do not	reject	do not	do not	do not	do not	reject	reject	reject	do not	do not
Üçyol	reject	do not	reject	reject	reject	reject	do not	reject	do not	reject	do not	do not	reject	reject	reject	reject	do not
İzmirspor	reject	do not	reject	do not	do not	do not	reject	reject	reject	do not	reject	reject	do not	do not	do not	do not	reject
Hatay	reject	do not	reject	do not	do not	do not	reject	reject	do not	do not	reject	reject	do not	do not	do not	do not	reject
Göztepe	reject	do not	reject	do not	do not	do not	reject	reject	do not	do not	reject	reject	do not	do not	do not	do not	reject
Poligon	reject	do not	reject	do not	do not	do not	reject	reject	do not	do not	do not	reject	do not	do not	do not	do not	reject
F. Altay	do not	reject	reject	reject	reject	reject	do not	reject	reject	reject	do not	do not	reject	reject	reject	reject	do not

Table 7 K-S test results for medium passenger volume level (station pairs)

Stations	Evka 3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	Izmirspor	Hatay	Göztepe	Poligon	F. Altay
Evka 3	do not	do not	do not	do not	reject	do not	reject	reject	do not	reject	reject	do not	reject	reject	do not	reject	reject
Üniversite	do not	do not	do not	do not	do not	do not	reject	reject	reject	reject	reject	do not	do not	reject	do not	reject	reject
Bornova	do not	do not	do not	do not	do not	do not	reject	reject	reject	do not	reject	do not	do not	do not	do not	do not	reject
Bölge	do not	do not	do not	do not	do not	do not	reject	reject	do not	do not	reject	do not	do not	do not	do not	do not	reject
Sanayi	reject	do not	do not	do not	do not	do not	reject	reject	do not	do not	reject	reject	do not	do not	do not	do not	reject
Stadyum	do not	do not	do not	do not	do not	do not	reject	reject	reject	reject	reject	do not	reject	reject	do not	reject	reject
Halkapınar	reject	reject	reject	reject	reject	reject	do not	reject	reject	reject	do not	do not	reject	reject	reject	reject	do not
Hilal	reject	reject	reject	reject	reject	reject	reject	do not	reject	reject	do not	reject	reject	reject	reject	reject	reject
Basmane	do not	reject	reject	do not	do not	reject	reject	reject	do not	do not	reject	reject	do not	do not	do not	do not	reject
Çankaya	reject	reject	do not	do not	do not	reject	reject	reject	do not	do not	reject	reject	do not	do not	do not	do not	reject
Konak	reject	reject	reject	reject	reject	reject	do not	do not	reject	reject	do not	reject	reject	reject	reject	reject	do not
Üçyol	do not	do not	do not	do not	reject	do not	do not	reject	reject	reject	reject	do not	reject	reject	do not	reject	reject
Izmirspor	reject	do not	do not	do not	do not	reject	reject	reject	do not	do not	reject	reject	do not	do not	do not	do not	reject
Hatay	reject	reject	do not	do not	do not	reject	reject	reject	do not	do not	reject	reject	do not	do not	do not	do not	reject
Göztepe	do not	do not	do not	do not	do not	do not	reject	reject	do not	do not	reject	do not	do not	do not	do not	do not	reject
Poligon	reject	reject	do not	do not	do not	reject	reject	reject	do not	do not	reject	reject	do not	do not	do not	do not	reject
F. Altay	reject	reject	reject	reject	reject	reject	do not	reject	reject	reject	do not	reject	reject	reject	reject	reject	do not

Table 8 K-S test results for high passenger volume level (station pairs)

Stations	Evka 3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Göztepe	Poligon	F. Altay
Evka 3	do not	do not	do not	reject	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	do not	do not	do not
Üniversite	do not	do not	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	reject	do not	reject
Bornova	do not	do not	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	reject	do not	reject
Bölge	reject	do not	do not	do not	do not	do not	reject	reject	do not	reject	reject	do not	do not	do not	reject	do not	reject
Sanayi	do not	do not	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	do not	do not	reject
Stadyum	do not	do not	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	do not	do not	do not
Halkapınar	reject	reject	reject	reject	reject	reject	do not	reject	reject	reject	reject	reject	reject	reject	do not	reject	do not
Hilal	reject	reject	reject	reject	reject	reject	reject	do not	reject	reject	reject	reject	reject	reject	reject	reject	reject
Basmane	do not	do not	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	reject	do not	reject
Çankaya	do not	do not	do not	reject	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	do not	do not	do not
Konak	do not	do not	do not	reject	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	reject	do not	reject
Üçyol	do not	do not	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	reject	do not	reject
İzmirspor	do not	do not	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	reject	do not	reject
Hatay	do not	do not	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	do not	do not	do not
Göztepe	do not	reject	reject	reject	do not	do not	do not	reject	reject	do not	reject	reject	reject	do not	do not	reject	do not
Poligon	do not	do not	do not	do not	do not	do not	reject	reject	do not	do not	do not	do not	do not	do not	reject	do not	reject
F. Altay	do not	reject	reject	reject	reject	do not	do not	reject	reject	do not	reject	reject	reject	do not	do not	reject	do not

Our aim is to find whether or not the station pairs share the same population distribution. A result of “do not” was obtained, meaning “failing to reject the null hypothesis”, thus we concluded that the two samples were coming from the same population. With the 3 tables shown above, we investigated the second criteria; “cdfs of hourly IAT pairs for different stations having similar sample sizes should be similar”, i.e. resulted in a “do not”, thus aggregation of the hourly IATs can be made. The tables do not show similarity between every station pair, rather it shows similarity between some of the station pairs. The next step is identifying which pairs show similarity, and group them.

5.2.3 Developing the station groups with rank order clustering method

Our next step was to find the group of stations with similar cumulative probability density functions, which was decided with a “do not” result in the Kolmogorov - Smirnov test.

The technique used to solve the problem of grouping the stations was the rank order clustering method. Rank order clustering method decides the grouping of machines into machine cells, which is considered to be an “efficient and easy-to-use algorithm” by Groover (1987). If the similarity of finding the machine groups and finding the station groups considered, this method can be adapted to our problem of grouping stations.

First, we formed a 17×17 matrix of station pairs containing binary values, as the part machine incidence matrix is formed in rank order clustering. For each station pair, if one of the 3 cases below was obtained then it was assigned with the value of 1 to the corresponding station pair in the matrix. A value of 0 is assigned if the case is different.

Case 1: Test results are all “do not” for each of the three passenger volume levels.

Case 2: Test results of low and high levels are “do not” but medium level is “reject”. In this case, the medium level pair was assumed to have some outlier interarrival time that causes the test to reject the hypothesis despite their similar cdfs. Otherwise, both low and high volumes would not result in a “do not”.

Case 3: A “reject” in low level test; “do not” results in medium and high level tests. This case may occur according to small sample sizes in low passenger volume samples. Thus, the result of “reject” can be ignored.

Value of 1 in the matrix means that corresponding station pair is similar in their cumulative density functions, thus, they can be assigned to the same group. The evaluated beginning matrix, according to the rules defined above is shown in Table 9.

According to Groover (1987), rank order clustering algorithm steps are as follows:

1. For each row of the matrix, the series of binary numbers, 1’s and 0’s (we can assume having a 0 entry in blank spaces) are read from left to right and converted to decimal numbers. The converted values are ranked and written by the side of each row.
2. If the rank values from top to bottom are the same as the order of the rows, then the stopping condition is reached, go to step 7. If not go to step 3.
3. Rearrange the rows according to decreasing order starting from the top.

4. For each row of the matrix, the series of binary numbers are read from top to bottom and converted to decimal numbers. The converted values are ranked and written by the down side of each column.
5. If the rank values from left to right is the same as the order of the columns, then the stopping condition is reached, go to step 7. If not go to step 6.
6. Rearrange the columns according to decreasing order starting from the left. Go to step 1.
7. Stop.

Table 9 Beginning matrix of rank order clustering method

	Evka 3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Göztepe	Poligon	F. Altay
Evka 3	1	1	1	0	0	1	0	0	1	0	0	1	0	0	1	0	1
Üniversite	1	1	1	1	1	1	0	0	1	1	0	1	1	1	0	1	0
Bornova	1	1	1	1	1	1	0	0	0	1	0	1	1	1	0	1	0
Bölge	0	1	1	1	1	1	0	0	1	0	0	1	1	1	0	1	0
Sanayi	0	1	1	1	1	1	0	0	1	1	0	0	1	1	1	1	0
Stadyum	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0
Halkapınar	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Hilal	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Basmane	1	1	0	1	1	1	0	0	1	1	1	1	1	1	0	1	0
Çankaya	0	1	1	0	1	1	0	0	1	1	1	0	1	1	1	1	0
Konak	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	1	0
Üçyol	1	1	1	1	0	1	0	0	1	0	1	1	0	0	0	0	0
İzmirspor	0	1	1	1	1	1	0	0	1	1	0	0	1	1	0	1	0
Hatay	0	1	1	1	1	1	0	0	1	1	0	0	1	1	1	1	0
Göztepe	1	0	0	0	1	1	0	0	0	1	0	0	0	1	1	0	0
Poligon	0	1	1	1	1	1	0	0	1	1	1	0	1	1	0	1	0
F. Altay	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1

Rank order clustering method is applied to the beginning matrix, as shown in Table 9 above. Stopping condition is reached at the 4th iteration, and the resulting matrix can be seen in Table 10, in which grouping of the stations is identified and each group shaded with a different color. As a result, 17 stations were grouped into 6 station groups by applying rank order clustering method. Two of the stations were not similar to any of others, and couldn't be assigned to any group. Groups are named as group 1, group 2, group 3, group 4, group 5, and group 6 and listed in Table 11.

Table 10 Final matrix obtained for rank order clustering method and stations groups

	Stations	Evka 3	Stadyum	Üniversite	Üçyol	Bornova	Bölge	Sanayi	Hatay	Çankaya	Poligon	İzmirspor	Basmane	Konak	Göztepe	F. Altay	Halkapınar	Hilal
65536	Stadyum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
32768	Üniversite	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
16384	Bornova	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
8192	Üçyol	1	1	1	1	1	1	0	0	0	0	0	1	1	0	0	0	0
4096	Evka 3	1	1	1	1	1	0	0	0	0	0	0	1	0	1	1	0	0
2048	Basmane	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0
1024	Göztepe	1	1	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0
512	F. Altay	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
256	Bölge	0	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0
128	Poligon	0	1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0
64	Sanayi	0	1	1	0	1	1	1	1	1	1	1	1	0	1	0	0	0
32	Hatay	0	1	1	0	1	1	1	1	1	1	1	1	0	1	0	0	0
16	İzmirspor	0	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0
8	Çankaya	0	1	1	0	1	0	1	1	1	1	1	1	1	1	0	0	0
4	Konak	0	1	0	1	0	0	0	0	1	1	0	1	1	0	0	0	0
2	Halkapınar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
1	Hilal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		130560	130556	129528	129284	127480	125424	118264	118264	118012	117244	117240	113148	75916	70760	4610	514	1
RANK		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**

Table 11 List of station groups

Group1	KONAK – ÇANKAYA
Group2	F.ALTAY – HALKAPINAR
Group3	EVKA 3 - STADYUM - ÜNİVERSİTE - ÜÇYOL - BORNOVA
Group4	BASMANE - BÖLGE - POLİGON - SANAYİ - HATAY - İZMİRSPOR
Group5	HİLAL
Group6	GÖZTEPE

We conclude that these stations are coming from the same population within groups, meaning that they have no significant difference in their cdfs. Thus, we conclude that cumulative IAT samples can be constructed according to these 6 groups.

5.2.4 Developing passenger interarrival time distributions

Ranges of hourly IAT distributions differ substantially, making it impossible to compare or cumulate the distributions of station groups. In order to overcome this difficulty we used the inverse of cumulative distribution function, which corresponds to percentile values.

It seems that the cumulative IAT distributions defined by 24 percentile points (1%, 2%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 98%, 99% and 100%) for any of the station groups for any selected hourly passenger volume are the accurate and efficient way of characterizing IAT distributions. In order to obtain this distribution, we first need to calculate the 24 percentile points' corresponding IAT values.

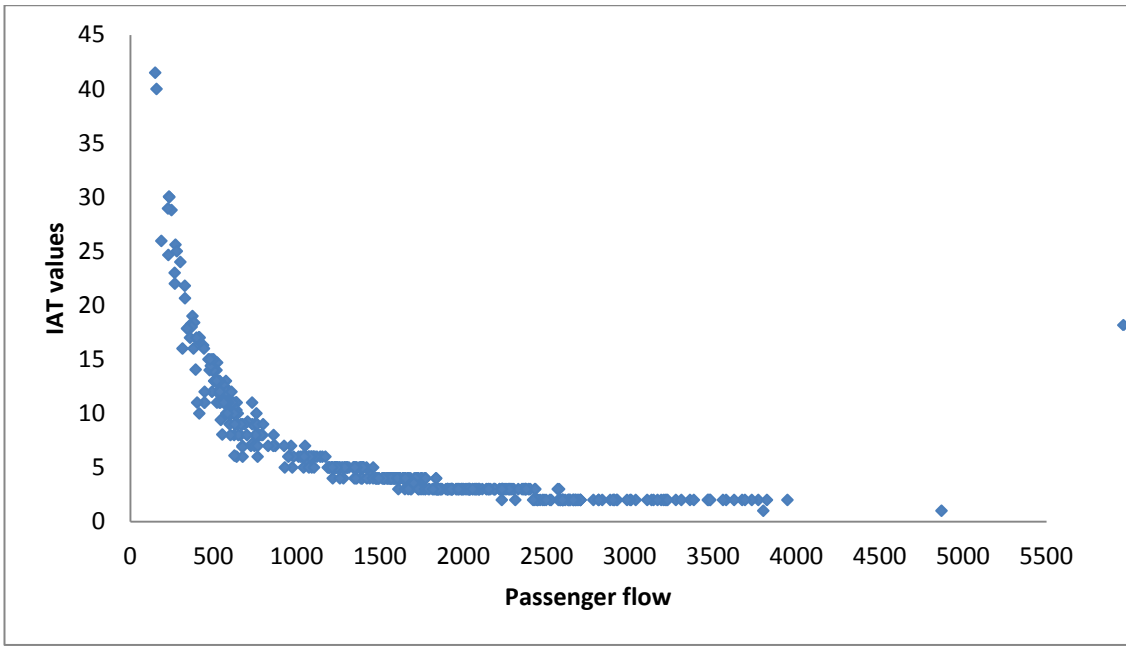
5.2.5 Evaluating percentile values of cumulative IAT distributions

First, for each station group, we used scatter diagrams to examine the shape of cumulative IAT distributions, and check whether there is a correlation between the passenger volume and IATs. A scatter diagram is constructed for each of the 24 percentile points, thus we obtained 24 scatter diagrams for each group. An example of a scatter diagram developed for Group_2 at 0.85 percentile point is given in Figure 9.

IAT values for $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points are calculated for each hourly passenger volume as shown in Table13. We have 24 different percentile values for each of the 18 hourly intervals of

14 days and 17 stations, where a total of 102,816 percentile values are calculated using a written code in Visual Basic of Applications, Excel. In Table 13 the IATs for the 85th percentile for F. Altay station on Jan 19th is given as an example.

Figure 9 Scatter diagram for Group 2 at $\mathbf{0.85}$th percentile



The sample sizes of groups of stations differ according to the number of stations in a group. Each station includes 18 hourly intervals for 14 days data, a total of 252 passenger volume and IAT pairs. Sample sizes of 6 groups of stations can be seen from the Table 12.

Table 12 Sample sizes of groups of stations

Group	# of Stations	Calculation of sample size	Sample size
Group1	2	252×2	504
Group2	2	252×2	504
Group3	5	252×5	1260
Group4	6	252×6	1512
Group5	1	252×1	252
Group6	1	252×1	252

The p-th percentile value is defined as $Y_{(p)}$ where at most $(100p)\%$ of the observations are less than $Y_{(p)}$.

Percentile values are calculated with a weighted average at $Y_{(n+1)p}$ method stated in Engineering statistics handbook. In this method, percentile values are found with the equations below, where n is number of observations or the sample size of the hourly IATs, and p is the percentile divided by 100. $Y_{[i]}$ values are order statistics of the sample.

$$(n+1)p = i + f \quad where \begin{cases} i\ is\ the\ integer\ part\ of\ (n+1)p \\ f\ is\ the\ fractional\ part\ of\ (n+1)p \end{cases}$$

$$Y_{(p)} = (1-f)Y_{[i]} + f\ Y_{[i+1]}$$

Table 13 Calculated percentile values of hourly IATs for Fahrettin Altay station on19th of January

Station Name	Day	Hour	Passenger Volume	Cumulative Percentage (%)																							
				1	2	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	98	99	100
F.ALTAY	19	6	674	0,1	0,1	0,1	0,1	1	1	1	1	2	2	2	2	3	3	4	4	5	6	9	13	19,3	29	46,3	158
F.ALTAY	19	7	2671	0,1	0,1	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	1	1	2	2	2	2	3	4	7	8	24
F.ALTAY	19	8	3361	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	1	1	2	2	2	3	5	6	13
F.ALTAY	19	9	1636	0,1	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	2	2	2	2	3	3	4	5	7	10	12,64	21
F.ALTAY	19	10	1360	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	2	2	2	2	3	3	3	4	5	6	8	12	16	28
F.ALTAY	19	11	1400	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	2	2	2	2	3	3	4	5	6	8	13	15	37
F.ALTAY	19	12	1720	0,1	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	2	2	2	2	3	3	4	5	7	10	14	28
F.ALTAY	19	13	1723	0,1	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	2	2	2	2	3	3	4	5	7	9	11,77	21
F.ALTAY	19	14	1609	0,1	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	2	2	2	2	3	3	4	5	7	10	12,91	52
F.ALTAY	19	15	1740	0,1	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	2	2	2	2	2	3	3	4	7	10,2	14	32
F.ALTAY	19	16	2056	0,1	0,1	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	2	2	2	2	3	3	4	6	8	10	23
F.ALTAY	19	17	2297	0,1	0,1	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	1	2	2	2	2	3	3,3	5	7	9	17
F.ALTAY	19	18	1896	0,1	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	1	2	2	2	2	3	3	4	6	9	12	27
F.ALTAY	19	19	1154	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	2	2	2	2	3	3	4	5	6	8	11	16	21,46	36
F.ALTAY	19	20	732	0,1	0,1	0,1	0,1	1	1	1	1	2	2	2	3	3	4	4	5	6	8	11	12	17,4	23,72	29,36	62
F.ALTAY	19	21	477	0,1	0,1	0,1	0,1	1	1	1	2	2	3	3	3	4	5	6	7,9	10	12	14	19,3	26,15	47,38	57,23	86
F.ALTAY	19	22	533	0,1	0,1	0,1	0,1	1	1	1	1	1	2	2	3	3	4	5	6	7	10	13	19	28,35	42,34	61,34	75
F.ALTAY	19	23	233	0,1	0,1	0,1	1	1	1	2	2	3	3	4	6	7	8	11	15	18	23	30,05	38	65,35	109,56	152,67	181

5.2.6 Modeling passenger interarrival time distributions

The main objective of this study was to build generalized models of IAT distribution that effectively captures the passenger arrivals to the İzmir Metro stations. The next stage is to examine the shape of the generalized probability distribution functions of the IAT distributions of 6 groups obtained from data analysis, and check if they can be modeled using a hyperbolic model or an exponential distribution.

The IAT distributions for passenger arrivals were modeled via Origin Lab's originpro software nonlinear curve fit option for two different models. The first model was the hyperbolic fit function in the form of, $y = \frac{a}{x} + b$. Hyperbolic model has 2 parameters, a and b. In contrast the second model is the exponential distribution, which is widely used for modeling IAT values in the literature. The exponential distribution function that is used in our analysis is stated below, where it has three parameters y_0, A and R_0.

$$y = y_0 + A \times \mathrm{e}^{(-R_0 x)}$$

The nonlinear curve fitting operation in originpro software evaluates the parameters of the model by iteratively changing the parameter values until a reduced chi-square tolerance value of 10^{-9} is reached, with an upper limit on the iteration number of 400, where iteration algorithm is selected as orthogonal distance regression.

5.2.6.1 Fitting hyperbolic models to IAT data

The first model is the suggested hyperbolic function in the form of,

$$y = \frac{a}{x} + b$$

Hyperbolic model function has independent variable x of passenger flow and dependent variable y of IAT's. In order to determine the fitting model, 2 parameters, a and b need to be calibrated. This determination is done via originpro software, nonlinear curve fitting operation, and the resulting fitting models for each percentile point are given in the results chapter on Tables 18, 19, 20, 21, 22 and 23.

Adjusted R^2 values and the residual plots were analyzed to check the accuracy of the hyperbolic model. We also compared the suggested hyperbolic models with exponential distribution, since it is a widely used model for IAT distributions.

Parameters of the models and corresponding adjusted coefficient of determination (adjusted R^2) values were found for 24 percentile points for each of the 6 groups of stations is shown in Table 18 in the results section also in Tables 21 – 25 in Appendix A . Adjusted R^2 values in the tables are all very close to 1. However, an R^2 value close to 1 does not always guarantee a good fitting. We also need to check the residual plots. If there is a non-random effect on residuals, we conclude that the model does not sufficiently fit the data, even if the R^2 values are high.

Thus in our study, graphical residual analysis was also included. Residual plots were checked for each model and a random pattern is seen in almost every sample data. Thus we concluded that the model adequately fits the data. The suggested hyperbolic models for the 6 groups for 24 percentile points correctly represented our IAT data.

5.2.6.2 Fitting negative exponential models to IAT data

The second model was the negative exponential distribution, which is widely used for modeling IAT values in the literature.

Exponential model function has the independent variable x of passenger flow and dependent variable y of IAT's. Thus, the predictor value of our regression model was passenger flow. In order to determine the fitting model, 3 parameters, y_0, A and R_0 needed to be calibrated for each of the 6 stations groups and 24 percentile values, thus, parameters should be obtained for a total of 144 fitting functions. Fitting the model was done via originpro software, nonlinear curve fitting operation, and resulting fitting models were evaluated by the function and the adjusted R^2 values for each of percentile points as shown in Table 19 in the results chapter also in Tables 26 – 30 in Appendix B.

5.2.6.3 Comparison of two fitting models

The fitting part of our results provided insight into the nature of IATs of passengers. Further, fitting performances of the two models were compared using Bayesian information criterion (BIC) test values calculated using Originpro software. Table 14 shows the resulting BIC values for the

comparison of the two models. The model with a lower BIC value was considered to have a more accurate representation of the IAT data.

Neath and Cavanaugh (2011) stated that the Bayesian information criterion is one of the most widely used statistical model selection tool. It was presented to “serve as an asymptotic approximation to a transformation of the Bayesian posterior probability of a candidate model.” BIC is very commonly used in specifying time series and comparing regression models.

Table 14 Comparison of BIC values of two models

	Bayesian Information Criterion Test Values											
	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6	
Percentiles	Hyperbolic	Exponential	Hyperbolic	Exponential	Hyperbolic	Exponential	Hyperbolic	Exponential	Hyperbolic	Exponential	Hyperbolic	Exponential
0,15	-985,7128	**-1226,5656**	-1394,0692	**-1418,5721**	244,9113	**-119,6212**	1543,3603	**1113,1275**	-713,5558	**-720,9167**	325,0484	**151,2288**
0,2	**-741,8122**	-589,0444	-1079,9745	**-1195,0698**	715,3577	**452,1765**	2062,8484	**1883,7791**	-661,2045	**-703,0365**	409,0677	**393,0863**
0,25	**-673,7540**	-469,0438	-1019,2932	**-1099,2590**	**992,4838**	1054,8681	**2385,3534**	2625,6354	-521,8143	**-584,0474**	**489,6866**	**491,1444**
0,3	**-578,2374**	-303,0187	-916,0306	**-951,3599**	**1332,6433**	1772,4370	**2642,8418**	3199,8911	-466,2966	**-533,9783**	**515,4259**	530,3544
0,35	**-386,9311**	-125,5948	**-933,3189**	-846,6821	**1749,6293**	2382,7654	**2759,2738**	3438,6258	-485,6566	**-552,7232**	**550,1772**	558,7272
0,4	**-278,3922**	10,0394	**-1045,8864**	-965,2823	**1979,1243**	2905,5482	**2831,3023**	3688,3795	-465,8768	**-544,1363**	548,0882	**537,4299**
0,45	**-139,8413**	218,3912	**-852,7166**	-736,6431	**2180,6167**	3242,3639	**2902,7934**	3905,7201	-465,5859	**-539,4740**	**563,9367**	617,0030
0,5	**55,2292**	380,4802	**-753,8086**	-611,6098	**2340,0137**	3475,2982	**3061,2642**	4137,7479	-373,4820	**-463,8213**	**581,7248**	656,2223
0,55	**69,1818**	443,6075	**-671,9799**	-507,3457	**2492,8952**	3710,3639	**3048,8544**	4270,8165	-332,3239	**-420,6155**	**623,6461**	703,0084
0,6	**91,8259**	685,4667	**-539,2304**	-356,4504	**2595,7551**	3918,3719	**3003,8916**	4456,8232	-265,7048	**-355,3478**	**682,4163**	828,9197
0,65	**177,1631**	771,2838	**-373,7857**	-183,1010	**2702,9634**	4134,6983	**3026,1392**	4729,6197	-192,5600	**-263,9919**	**700,6574**	852,8676
0,7	**283,2449**	891,4625	**-233,0900**	-44,0242	**2879,9116**	4377,8912	**2820,0883**	4989,5672	-148,7948	**-225,3951**	**687,1319**	863,5338
0,75	**471,4453**	1080,3184	**-128,4886**	44,6467	**2381,6480**	4472,6979	**2768,5055**	5255,7158	32,0735	**-44,4436**	**599,1241**	852,4658
0,8	**412,6057**	1273,2491	**-38,3285**	158,6405	**2481,0934**	4807,0097	**3182,6913**	5649,4795	191,3927	**132,6882**	**556,7245**	874,7193
0,85	**557,1938**	1444,0211	**-1,8582**	232,7083	**2342,0885**	5179,6917	**3437,7252**	5939,0121	**400,9130**	403,4438	**527,8565**	901,0483
0,9	**861,7797**	1779,4326	**158,5980**	460,6293	**2769,7616**	5611,3610	**3909,1251**	6383,5034	**713,2916**	774,1434	**722,6727**	1028,7251
0,95	**1131,9967**	2028,8515	**713,8370**	915,3399	**3861,8611**	6138,7425	**5139,7132**	7080,9746	**882,2521**	995,6355	**842,3870**	1095,7031
0,98	**1809,5085**	2325,2633	**1634,9423**	1795,5481	**6257,7104**	7009,8217	**7465,7066**	8200,9022	**1189,5572**	1254,8145	**1203,5696**	1311,6027
0,99	**2500,09351**	2784,98321	**2291,5948**	2395,6968	**7969,6063**	8167,9537	**9521,7747**	9776,7237	**1505,7543**	1537,5411	**1608,4420**	1665,0234
1	**3644,843**	3729,83335	**4049,74623**	4050,74806	**8397,19548**	8828,2663	**9569,61801**	9931,40161	2015,16706	**1996,04869**	**1507,49603**	1571,06348

Lower BIC values were bolded, as they show a higher accuracy of fitting effect. (If difference in BIC values for two stations is lower than 10, the result is indecisive. This case occurred on group 6's 0.25th percentile) The results show that, the suggested hyperbolic models for cumulative IAT distributions indicate a better fitting performance in almost every group compared to exponential models. Fitting performance of exponential model was better than hyperbolic one only for the 5th group.

Hyperbolic model accurately fitted the extracted IAT data, which was found by the analysis of the adjusted R^2 values. The fitting performance of the exponential model was also good; however the hyperbolic model outperformed it in almost every station group, when we compared their BIC values.

5.2.7 Adjustment Factors

Evaluation of station adjustment factors and hourly adjustment factors for passenger volumes can be used to make demand forecasts for the planning phase of the system. As mentioned before, extracting the hourly passenger volume data from raw data was performed using Excel VBA. We used this data to evaluate the adjustment factors for both station and daily factors. Table 15 contains extracted passenger flows which were needed for the evaluation of both factors.

Table 15 Extracted hourly passenger volume data for stations

Station:	Evka 3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Göztepe	Poligon	F.Altay	SUM
Time interval:																		
5:00-6:00	73	18	226	109	33	50	231	160	171	80	85	369	282	98	139	251	245	2620
6:00-07:00	3188	233	6129	913	365	2066	7925	3255	3398	1332	6395	8118	2884	1354	1272	2084	7037	57948
7:00-08:00	12028	1687	23260	6630	1625	9290	31633	17595	11123	3579	17507	31932	12785	6600	7139	9252	27660	231325
8:00-09:00	13532	2770	28158	10176	2358	12624	47430	24675	9666	4776	19958	42976	17046	9617	9965	11980	34452	302159
9:00-10:00	7119	3222	16952	5505	1618	6914	28663	14321	6649	6024	13523	19795	7976	5351	5085	6242	19751	174710
10:00-11:00	6270	8052	18551	5419	1909	8438	23399	10636	6519	8981	14140	15201	7004	4561	5810	5549	17797	168236
11:00-12:00	7208	6702	21343	5997	2106	7908	25999	11556	6970	13034	17984	16300	7778	4955	5112	5868	18600	185420
12:00-13:00	8481	5576	24145	7922	2331	8434	32859	13108	7696	19422	22024	19808	8702	6365	5486	7082	21805	221246
13:00-14:00	9945	6099	28498	10665	3277	10512	37516	15876	10438	32206	28393	24471	10781	7415	7156	8327	23596	275171
14:00-15:00	8033	10469	29399	8673	2778	9774	31997	14395	10355	28141	33355	20289	9124	6325	6880	7184	21953	259124
15:00-16:00	7042	10955	31192	8718	2877	8990	28134	12454	10704	33476	37853	17884	8322	5866	5794	6289	20646	257196
16:00-17:00	7908	9995	33549	8579	3369	8546	26918	13220	11883	38696	43079	16016	7533	5698	4267	5233	22079	266568
17:00-18:00	10152	8802	31967	13053	4689	11557	33338	14622	18605	47832	50318	16862	6818	6046	4478	6329	26893	312361
18:00-19:00	11679	6320	30638	14822	8265	17105	39451	16145	17352	69557	40636	14963	5934	4659	3388	4708	25368	330990
19:00-20:00	5982	4025	21416	7703	3624	7937	26574	10873	11809	41562	27355	11185	4423	3680	2638	3681	17506	211973
20:00-21:00	2683	2904	14918	4078	1601	3608	14419	5701	5509	11795	14451	6795	2356	1976	1544	2080	10220	106638
21:00-22:00	1612	1683	11743	2272	763	1906	9387	4215	4082	6616	9275	4739	1705	1229	927	1672	7139	70965
22:00-23:00	1456	1221	12421	2225	758	3269	10499	4513	2680	3683	7639	4187	1422	1138	899	1388	7583	66981
23:00-00:00	684	384	8159	1564	215	1257	7253	2298	1836	2671	4100	2590	841	654	495	967	4171	40139
00:00-00:59	69	39	1261	163	27	151	1274	923	275	366	543	410	143	115	56	117	536	6468
SUM	125144	91156	393925	125186	44588	140336	464899	210541	157720	373829	408613	294890	123859	83702	78530	96283	335037	2938013

Passenger volume can be estimated for any “station and hour interval” combination, by using adjustment factors, when the total daily passenger volume of the system is available. When total daily volume is multiplied by the corresponding adjustment factors from the table, estimated passenger volume for the corresponding “station and hour interval” pair is obtained.

5.2.7.1 Station adjustment factors for passenger flow

Station adjustment factors can be used to estimate the passenger flow volume for a specific station, given the total daily passenger volume for the system. Calculated station adjustment factors are given in Table 16 below.

Let *Total Count* be the total daily passenger volume for an hourly interval; and let *Hour Count* be the passenger volume of a station for that specific time interval. Then *Station Adjustment Factor* is found as given in the equation:

$$Station\ Adjustment\ Factor = \frac{Hour\ Count}{Total\ Count}$$

Table 16 Station adjustment factors

Station:	Evka 3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Göztepe	Poligon	F.Altay
Time interval																	
05:00-06:00	0,0279	0,0069	0,0863	0,0416	0,0126	0,0191	0,0882	0,0611	0,0653	0,0305	0,0324	0,1408	0,1076	0,0374	0,0531	0,0958	0,0935
06:00-07:00	0,0550	0,0040	0,1058	0,0158	0,0063	0,0357	0,1368	0,0562	0,0586	0,0230	0,1104	0,1401	0,0498	0,0234	0,0220	0,0360	0,1214
07:00-08:00	0,0520	0,0073	0,1006	0,0287	0,0070	0,0402	0,1367	0,0761	0,0481	0,0155	0,0757	0,1380	0,0553	0,0285	0,0309	0,0400	0,1196
08:00-09:00	0,0448	0,0092	0,0932	0,0337	0,0078	0,0418	0,1570	0,0817	0,0320	0,0158	0,0661	0,1422	0,0564	0,0318	0,0330	0,0396	0,1140
09:00-10:00	0,0407	0,0184	0,0970	0,0315	0,0093	0,0396	0,1641	0,0820	0,0381	0,0345	0,0774	0,1133	0,0457	0,0306	0,0291	0,0357	0,1131
10:00-11:00	0,0373	0,0479	0,1103	0,0322	0,0113	0,0502	0,1391	0,0632	0,0387	0,0534	0,0840	0,0904	0,0416	0,0271	0,0345	0,0330	0,1058
11:00-12:00	0,0389	0,0361	0,1151	0,0323	0,0114	0,0426	0,1402	0,0623	0,0376	0,0703	0,0970	0,0879	0,0419	0,0267	0,0276	0,0316	0,1003
12:00-13:00	0,0383	0,0252	0,1091	0,0358	0,0105	0,0381	0,1485	0,0592	0,0348	0,0878	0,0995	0,0895	0,0393	0,0288	0,0248	0,0320	0,0986
13:00-14:00	0,0361	0,0222	0,1036	0,0388	0,0119	0,0382	0,1363	0,0577	0,0379	0,1170	0,1032	0,0889	0,0392	0,0269	0,0260	0,0303	0,0858
14:00-15:00	0,0310	0,0404	0,1135	0,0335	0,0107	0,0377	0,1235	0,0556	0,0400	0,1086	0,1287	0,0783	0,0352	0,0244	0,0266	0,0277	0,0847
15:00-16:00	0,0274	0,0426	0,1213	0,0339	0,0112	0,0350	0,1094	0,0484	0,0416	0,1302	0,1472	0,0695	0,0324	0,0228	0,0225	0,0245	0,0803
16:00-17:00	0,0297	0,0375	0,1259	0,0322	0,0126	0,0321	0,1010	0,0496	0,0446	0,1452	0,1616	0,0601	0,0283	0,0214	0,0160	0,0196	0,0828
17:00-18:00	0,0325	0,0282	0,1023	0,0418	0,0150	0,0370	0,1067	0,0468	0,0596	0,1531	0,1611	0,0540	0,0218	0,0194	0,0143	0,0203	0,0861
18:00-19:00	0,0353	0,0191	0,0926	0,0448	0,0250	0,0517	0,1192	0,0488	0,0524	0,2101	0,1228	0,0452	0,0179	0,0141	0,0102	0,0142	0,0766
19:00-20:00	0,0282	0,0190	0,1010	0,0363	0,0171	0,0374	0,1254	0,0513	0,0557	0,1961	0,1290	0,0528	0,0209	0,0174	0,0124	0,0174	0,0826
20:00-21:00	0,0252	0,0272	0,1399	0,0382	0,0150	0,0338	0,1352	0,0535	0,0517	0,1106	0,1355	0,0637	0,0221	0,0185	0,0145	0,0195	0,0958
21:00-22:00	0,0227	0,0237	0,1655	0,0320	0,0108	0,0269	0,1323	0,0594	0,0575	0,0932	0,1307	0,0668	0,0240	0,0173	0,0131	0,0236	0,1006
22:00-23:00	0,0217	0,0182	0,1854	0,0332	0,0113	0,0488	0,1567	0,0674	0,0400	0,0550	0,1140	0,0625	0,0212	0,0170	0,0134	0,0207	0,1132
23:00-00:00	0,0170	0,0096	0,2033	0,0390	0,0054	0,0313	0,1807	0,0573	0,0457	0,0665	0,1021	0,0645	0,0210	0,0163	0,0123	0,0241	0,1039
00:00-00:59	0,0107	0,0060	0,1950	0,0252	0,0042	0,0233	0,1970	0,1427	0,0425	0,0566	0,0840	0,0634	0,0221	0,0178	0,0087	0,0181	0,0829

5.2.7.2 Hourly adjustment factors

By using the hourly adjustment factors evaluated for each of the 17 stations, we are able to estimate passenger volume for a specific time interval of the day, given the total daily passenger volume of the system. Hourly adjustment factors are given in Table 17.

Let *Total Count* be the total daily passenger volume for a station; and let *Station Count* be the passenger volume of a station for a specific hourly time interval. Then *Hourly Adjustment Factor* for stations is found as given in the equation below:

$$Hourly\ Adjustment\ Factor = \frac{Station\ Count}{Total\ Count}$$

Table 17 Hourly adjustment factors

Station:	Evka 3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Göztepe	Poligon	F.Altay
Time interval:																	
05:00-06:00	0,0006	0,0002	0,0006	0,0009	0,0007	0,0004	0,0005	0,0008	0,0011	0,0002	0,0002	0,0013	0,0023	0,0012	0,0018	0,0026	0,0007
06:00-07:00	0,0255	0,0026	0,0156	0,0073	0,0082	0,0147	0,0170	0,0155	0,0215	0,0036	0,0157	0,0275	0,0233	0,0162	0,0162	0,0216	0,0210
07:00-08:00	0,0961	0,0185	0,0590	0,0530	0,0364	0,0662	0,0680	0,0836	0,0705	0,0096	0,0428	0,1083	0,1032	0,0789	0,0909	0,0961	0,0826
08:00-09:00	0,1081	0,0304	0,0715	0,0813	0,0529	0,0900	0,1020	0,1172	0,0613	0,0128	0,0488	0,1457	0,1376	0,1149	0,1269	0,1244	0,1028
9:00-10:00	0,0569	0,0353	0,0430	0,0440	0,0363	0,0493	0,0617	0,0680	0,0422	0,0161	0,0331	0,0671	0,0644	0,0639	0,0648	0,0648	0,0590
10:00-11:00	0,0501	0,0883	0,0471	0,0433	0,0428	0,0601	0,0503	0,0505	0,0413	0,0240	0,0346	0,0515	0,0565	0,0545	0,0740	0,0576	0,0531
11:00-12:00	0,0576	0,0735	0,0542	0,0479	0,0472	0,0564	0,0559	0,0549	0,0442	0,0349	0,0440	0,0553	0,0628	0,0592	0,0651	0,0609	0,0555
12:00-13:00	0,0678	0,0612	0,0613	0,0633	0,0523	0,0601	0,0707	0,0623	0,0488	0,0520	0,0539	0,0672	0,0703	0,0760	0,0699	0,0736	0,0651
13:00-14:00	0,0795	0,0669	0,0723	0,0852	0,0735	0,0749	0,0807	0,0754	0,0662	0,0862	0,0695	0,0830	0,0870	0,0886	0,0911	0,0865	0,0704
14:00-15:00	0,0642	0,1148	0,0746	0,0693	0,0623	0,0696	0,0688	0,0684	0,0657	0,0753	0,0816	0,0688	0,0737	0,0756	0,0876	0,0746	0,0655
15:00-16:00	0,0563	0,1202	0,0792	0,0696	0,0645	0,0641	0,0605	0,0592	0,0679	0,0895	0,0926	0,0606	0,0672	0,0701	0,0738	0,0653	0,0616
16:00-17:00	0,0632	0,1096	0,0852	0,0685	0,0756	0,0609	0,0579	0,0628	0,0753	0,1035	0,1054	0,0543	0,0608	0,0681	0,0543	0,0544	0,0659
17:00-18:00	0,0811	0,0966	0,0811	0,1043	0,1052	0,0824	0,0717	0,0694	0,1180	0,1280	0,1231	0,0572	0,0550	0,0722	0,0570	0,0657	0,0803
18:00-19:00	0,0933	0,0693	0,0778	0,1184	0,1854	0,1219	0,0849	0,0767	0,1100	0,1861	0,0994	0,0507	0,0479	0,0557	0,0431	0,0489	0,0757
19:00-20:00	0,0478	0,0442	0,0544	0,0615	0,0813	0,0566	0,0572	0,0516	0,0749	0,1112	0,0669	0,0379	0,0357	0,0440	0,0336	0,0382	0,0523
20:00-21:00	0,0214	0,0319	0,0379	0,0326	0,0359	0,0257	0,0310	0,0271	0,0349	0,0316	0,0354	0,0230	0,0190	0,0236	0,0197	0,0216	0,0305
21:00-22:00	0,0129	0,0185	0,0298	0,0181	0,0171	0,0136	0,0202	0,0200	0,0259	0,0177	0,0227	0,0161	0,0138	0,0147	0,0118	0,0174	0,0213
22:00-23:00	0,0116	0,0134	0,0315	0,0178	0,0170	0,0233	0,0226	0,0214	0,0170	0,0099	0,0187	0,0142	0,0115	0,0136	0,0114	0,0144	0,0226
23:00-00:00	0,0055	0,0042	0,0207	0,0125	0,0048	0,0090	0,0156	0,0109	0,0116	0,0071	0,0100	0,0088	0,0068	0,0078	0,0063	0,0100	0,0124
00:00-00:59	0,0006	0,0004	0,0032	0,0013	0,0006	0,0011	0,0027	0,0044	0,0017	0,0010	0,0013	0,0014	0,0012	0,0014	0,0007	0,0012	0,0016

CHAPTER 6: RESULTS AND DISCUSSION OF RESULTS

In this thesis, 17 stations were grouped into 6 station groups by applying rank order clustering method. Grouping was done by using Kolmogorov - Smirnov two sample tests. The applied tests were two sided tests, and a confidence level of 0.95 was used. Cumulative IATs were found for the 6 groups and 24 percentile values were evaluated for each group.

Also resulting fitting models for the suggested hyperbolic and exponential functions for station group 1 are given in Table 18 and Table 19, respectively. The IAT values were all 0.1 seconds for the $0.01, 0.02, 0.05, 0.1, \text{and } 0.15$ th percentile points. Thus, we assigned a constant value of 0.1 for those percentiles.

The hyperbolic model adequately fitted the extracted IAT data, which was confirmed by checking adjusted R^2 values, and investigating the residual plots. All of the R^2 values were close to 1, and the residuals seem acceptable. Thus, we concluded that the hyperbolic models we suggested for the 6 groups for 24 percentile points accurately fitted our distributions. These fitted distributions can be applied on a range of passenger volumes. Otherwise, extrapolation should be done to estimate the resulting dependent variable. The ranges of passenger flow for each station group are given in the Table 18.

Table 18 Ranges of application for passenger flow data

Group	Lower limit	Upper limit
Group1	40	6789
Group2	150	4870
Group3	7	3945
Group4	5	1709
Group5	68	2198
Group6	22	944

Hyperbolic models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4{,}0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 1 is given in Table 19.

Table 19 Hyperbolic models for IAT values for group 1

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	1
5	y = 0,1	1
1	y = 0,1	1
15	y = 0,1	1
20	y = 332,5655/x + 0,2906	1
25	y = 455,4660/x + 0,37176	1
30	y = 598,3467/x + 0,3718	1
35	y = 810,6364/x + 0,4810	1
40	y = 1060,7512/x + 0,4903	1
45	y = 1441,7234/x + 0,3431	1
50	y = 1758,8818/x + 0,3107	1
55	y = 2155,4820/x + 0,2198	1
60	y = 2631,6841/x + 0,2198	1
65	y = 3205,2782/x + 0,1292	1
70	y = 3825,7839/x + 0,1286	1
75	y = 4629,3148/x + 0,0334	1
80	y = 5597,2336/x + 0,0080	1
85	y = 7177,2053/x - 0,3292	1
90	y = 9287,0773/x - 0,5847	1
95	y = 13741,8839/x - 1,5153	1
98	y = 19864,1076/x - 2,2858	0,99999
99	y = 24572,9918/x -2,5832	0,99995
100	y = 32948,1177/x + 6,8007	0,9995

Exponential models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 1 is given in Table 20.

Table 20 Exponential models for IAT values for group 1

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	1
5	y = 0,1	1
10	y = 0,1	1
15	y = 0,1	1
20	y = 0,2725 + 3,3098 $e^{-0,0024x}$	1
25	y = 0,6415 + 7,6752 $e^{-0,0057x}$	1
30	y = 0,8798 + 10,9045 $e^{-0,0063x}$	1
35	y = 1,1013 + 17,762 $e^{-0,0077x}$	1
40	y = 1,3418 + 25,0077 $e^{-0,0083x}$	1
45	y = 1,5932 + 38,2049 $e^{-0,0093x}$	1
50	y = 1,7512 + 42,3604 $e^{-0,0085x}$	1
55	y = 1,9641 + 48,7674 $e^{-0,0080x}$	1
60	y = 2,3624 + 63,9771 $e^{-0,0085x}$	1
65	y = 2,5671 + 71,0904 $e^{-0,0077x}$	1
70	y = 2,9235 + 79,4502 $e^{-0,0073x}$	1
75	y = 3,3825 + 94,5082 $e^{-0,0072x}$	1
80	y = 4,1874 + 120,2822 $e^{-0,0075x}$	1
85	y = 5,0171 + 152,1165 $e^{-0,0074x}$	1
90	y = 6,5296 + 205,4828 $e^{-0,0078x}$	1
95	y = 8,7505 + 288,3164 $e^{-0,0074x}$	1
98	y = 11,1139 + 349,0229 $e^{-0,0062x}$	1
99	y = 13,2942 + 398,2433 $e^{-0,0058x}$	0,9999
100	y = 22,8603 + 388,5802 $e^{-0,0042x}$	0,9994

CHAPTER 7: CONCLUSIONS AND FUTURE WORK

In this thesis, we aimed to find an accurate representation of IAT distributions for passenger arrivals to the Izmir metro stations. Instead of finding different distributions for each of the 17 stations, we developed a generalized passenger IAT distribution, which correctly captures the characteristics of the system for every station.

Brief information on the data analysis is as follows: after the extraction phase of hourly passenger interarrival times from raw data, we analyzed whether there were any daily differences between the cumulative density functions (cdf) of hourly IAT's. In order to investigate the similarity of daily cdfs, Kolmogorov - Smirnov two sample tests were applied using SPSS. Results showed that there was no difference in daily IAT cdfs. Furthermore, the same investigation was repeated for the cdfs of IATs, for each station pair. Kolmogorov - Smirnov tests on SPSS were applied for station pairs with similar sample sizes for three different levels of passenger flows. There were certain stations whose distributions were similar, but results of K-S tests showed that IAT distibutions differ amongst some station pairs. Thus, we aimed to find the groups of stations with similar distributions. In order to group the stations, "rank order clustering" method was adapted and applied, which is generally used for grouping the parts and machines in production flow analysis. 17 stations were grouped into 6 station groups by applying the adapted method. Two of the stations were not similar to any of the others; therefore we had two groups with only one station. By grouping, we obtained stations with similar cdf's within each group. Cumulative IATs were found according to the 6 groups. Hyperbolic and exponential models were fitted to

the data of passenger volume - IATs with Origin Lab's Originpro software. The suggested hyperbolic model accurately fitted the extracted IAT data when the adjusted R^2 values were analyzed. Exponential model's fitting performance was also good, however, our suggested hyperbolic model was found to outperform it when their BIC values were compared.

Furthermore, we evaluated adjustment factors for both stations and hours and these factors can be used for estimating passenger flow at any hour of any station when given the total passenger flow of the system is known.

A comprehensive study of simulation of the subway system is a possible future work, in which our generalized IAT distributions can be used as an input. Evaluating efficient schedulings and time tables for the subway system may be one of the aims of these simulation studies.

Different models which were suggested in the literature can be tried for the fitting phase of the IAT distributions of passenger flow. Erlang $K = 2$, Erlang $K = 3$ and Pearson type III are some of the distributions from the literature that are potentially worth modeling.

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APPENDICES

Appendix A : Hyperbolic models for station groups

Hyperbolic models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4{,}0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 2 is given in Table 21.

Table 21 Hyperbolic models for IAT values for group 2

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	1
5	y = 0,1	1
1	y = 0,1	1
15	y = 0,1	1
20	y = 444,2323/x + 0,1046	1
25	y = 464,9976/x + 0,2301	1
30	y = 494,2674/x + 0,3164	1
35	y = 597,6442/x + 0,4458	1
40	y = 691,4439/x + 0,5512	1
45	y = 898,3135/x + 0,5445	1
50	y = 1082,3841/x + 0,5968	1
55	y = 1353,3494/x + 0,5906	1
60	y = 1684,9518/x + 0,5120	1
65	y = 2155,7491/x + 0,4099	1
70	y = 2766,2656/x + 0,3794	1
75	y = 3550,6243/x + 0,2793	1
80	y = 4744,6673/x + 0,0683	1
85	y = 6342,5278/x - 0,1087	1
90	y = 9335,6366/x - 0,6544	1
95	y =15591,5468 /x -1,6337	1
98	y = 26226,9525/x -3,25633	0,99999
99	y = 35724,2710/x - 4,2681	0,99995
100	y = 68319,2772/x + 2,4166	0,99841

Hyperbolic models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4{,}0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 3 is given in Table 22.

Table 22 Hyperbolic models for IAT values for group 3

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	1
5	y = 0,1	1
1	y = 0,1	1
15	y = 0,1	1
20	y = 246,5292/x + 0,4551	1
25	y = 323,4746/x + 0,6009	1
30	y =426,2227/x + 0,7635	1
35	y = 590,5131/x + 0,8117	1
40	y = 801,3976/x + 0,8342	0,99999
45	y = 1128,7669/x + 0,7319	0,99999
50	y = 1506,1981/x + 0,5683	0,99999
55	y = 1933,9222/x + 0,4179	0,99999
60	y = 2449,3374/x + 0,2711	0,99999
65	y =3069,9317 /x + 0,0515	0,99999
70	y =3810,8526 /x - 0,1465	0,99999
75	y = 4726,9871/x - 0,4184	0,99999
80	y =6118,4541 /x - 0,9541	0,99999
85	y =7600,1870 /x - 1,0410	0,99999
90	y =9920,3902 /x - 1,2801	0,99999
95	y =14000,6029 /x - 1,3450	0,99997
98	y =19057,7479 /x + 0,0999	0,99982
99	y = 20542,8212/x + 4,9776	0,9993
100	y =27093,7343 /x + 17,68813	0,999

Hyperbolic models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4{,}0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 4 is given in Table 23.

Table 23 Hyperbolic models for IAT values for group 4

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	1
5	y = 0,1	1
10	y = 0,1	0,99999
15	y = 0,1	0,99999
20	y = 252,0982 /x + 0,91204	0,99998
25	y = 384,3903/x + 1,01901	0,99997
30	y = 554,5463/x + 1,07868	0,99997
35	y = 798,0752/x + 1,0211	0,99997
40	y = 1080,6287/x + 0,93498	0,99996
45	y = 1407,8659/x + 0,86513	0,99996
50	y = 1800,6269/x + 0,68974	0,99996
55	y = 2255,5877/x + 0,49849	0,99996
60	y = 2781,7496/x + 0,26115	0,99996
65	y = 3406,3177/x + 0,02622	0,99996
70	y = 4087,9483/x - 0,12268	0,99996
75	y = 4946,6115/x - 0,38084	0,99996
80	y = 5996,8841/x - 0,59787	0,99995
85	y = 7413,5260/x - 0,93645	0,99994
90	y = 9422,2724/x - 1,28496	0,99992
95	y = 13027,3124/x - 1,93744	0,99982
98	y = 17627,2793/x - 1,6268	0,99914
99	y = 17892,0486/x + 6,3277	0,99653
100	y = 22832,5501/x + 15,46591	0,99641

Hyperbolic models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 5 is given in Table 24.

Table 24 Hyperbolic models for IAT values for group 5

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	1
5	y = 0,1	1
10	y = 0,1	1
15	y = 0,1	1
20	y = 195,7348/x - 0,0349	1
25	y = 187,4843/x + 0,1072	1
30	y = 153,5157/x + 0,4184	1
35	y = 145,6324/x + 0,6488	1
40	y = 227,8733/x + 0,6567	1
45	y = 293,8627/x + 0,6392	1
50	y = 329,0842/x + 0,6580	1
55	y = 424,3490/x + 0,7461	1
60	y = 493,5798/x + 0,8595	1
65	y = 613,3075/x + 1,0183	1
70	y = 813,6462/x + 1,1048	1
75	y = 1156,4238/x + 1,1246	1
80	y = 1784,9273/x + 1,0712	1
85	y = 3403,8382/x + 0,4311	0,99999
90	y = 8119,4639/x - 1,0712	0,99997
95	y = 19900,3678/x - 3,3302	0,99994
98	y = 40072,2928/x - 2,4333	0,99978
99	y = 59021,9669/x - 4,6210	0,99919
100	y = 72023,2962/x + 61,9683	0,99298

Hyperbolic models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4{,}0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 6 is given in Table 25.

Table 25 Hyperbolic models for IAT values for group 6

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	1
5	y = 0,1	1
1	y = 0,1	0,99999
15	y = 0,1	0,99996
20	y = 286,7641/x + 0,7252	0,99995
25	y = 425,6880/x + 0,7892	0,99993
30	y = 579,1483/x + 0,8840	0,99992
35	y = 831,8046/x + 0,8035	0,99991
40	y = 1160,0103/x + 0,5625	0,99991
45	y = 1415,9587/x + 0,7801	0,9999
50	y = 1761,4085/x + 0,9157	0,9999
55	y = 2215,6036/x + 0,8129	0,99988
60	y = 2701,4081/x + 0,7195	0,99984
65	y = 3359,6683/x + 0,3547	0,99983
70	y = 4185,9209/x - 0,2515	0,99984
75	y = 5044,1830/x - 0,5170	0,99988
80	y = 6023,1385 -0,42	0,9999
85	y = 7440,4968/x - 0,9501	0,99991
90	y = 9378,62096/x - 1,3444	0,9998
95	y = 12954,021/x -2,1621	0,99965
98	y = 17520,9855/x -1,9965	0,99848
99	y = 14797,4775/x + 14,8062	0,99259
100	y = 20513,9013/x + 21,3624	0,99507

Appendix B : Exponential models for station groups

Exponential models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4{,}0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 2 is given in Table 26.

Table 26 Exponential models for IAT values for group 2

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	1
5	y = 0,1	1
10	y = 0,1	1
15	y = 0,1	1
20	y = - 0,2010 + 1,8341 $e^{-0,0007x}$	1
25	y = - 0,5301 + 2,2537 $e^{-0,0004x}$	1
30	y = -0,4156 + 2,3008 $e^{-0,0004x}$	1
35	y = 0,7789 + 5,1876 $e^{-0,0036x}$	1
40	y = 0,9056 + 5,3998 $e^{-0,0032x}$	1
45	y = 1,0321 + 7,6674 $e^{-0,0035x}$	1
50	y = 1,2029 + 9,8329 $e^{-0,0037x}$	1
55	y = 1,3153 + 11,2847 $e^{-0,0034x}$	1
60	y = 1,4431 + 15,1010 $e^{-0,0036x}$	1
65	y = 1,5454 + 17,6561 $e^{-0,0034x}$	1
70	y = 1,9306 + 26,4102 $e^{-0,0038x}$	1
75	y = 2,2064 + 32,1981 $e^{-0,0036x}$	1
80	y = 2,5862 + 41,4593 $e^{-0,0035x}$	1
85	y = 3,1015 + 51,0834 $e^{-0,0032x}$	1
90	y = 4,1253 + 76,8607 $e^{-0,0033x}$	1
95	y = 6,3446 + 128,2333 $e^{-0,0033x}$	1
98	y = 10,3813 + 225,4615 $e^{-0,0034x}$	1
99	y = 13,7542 + 290,9418 $e^{-0,0032x}$	0,9999
100	y = 32,9212 + 407,5136 $e^{-0,0025x}$	0,9984

Exponential models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 3 is given in Table 27.

Table 27 Exponential models for IAT values for group 3

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	1
5	y = 0,1	1
10	y = 0,1	1
15	y = 0,1	1
20	y = 1,2162 + 6004,4856 $e^{-0,0032x}$	1
25	y = 1,5782 + 1965,4629 $e^{-0,0032x}$	1
30	y = 2,0036 + 470,5473 $e^{-0,0032x}$	1
35	y = 2,4114 + 215,0598 $e^{-0,0032x}$	1
40	y = 2,7711 + 149,6751 $e^{-0,0032x}$	1
45	y = 3,1096 + 142,2987 $e^{-0,0032x}$	1
50	y = 3,4667 + 154,9140 $e^{-0,0032x}$	1
55	y = 3,9231 + 175,7559 $e^{-0,0032x}$	1
60	y = 4,4843 + 196,0570 $e^{-0,0032x}$	1
65	y = 5,1489 + 223,5752 $e^{-0,0032x}$	1
70	y = 5,9717 + 254,0892 $e^{-0,0032x}$	1
75	y = 7,0350 + 305,3980 $e^{-0,0032x}$	1
80	y = 8,4653 + 383,8780 $e^{-0,0032x}$	1
85	y = 10,2736 + 431,4630 $e^{-0,0032x}$	0,9999
90	y = 12,9304 + 509,9565 $e^{-0,0032x}$	0,9999
95	y = 17,1457 + 549,5328 $e^{-0,0032x}$	0,9998
98	y = 20,6002 + 435,2489 $e^{-0,0032x}$	0,9997
99	y = 19,7434 + 316,0599 $e^{-0,0032x}$	0,9992
100	y = 46,5837 + 587,6096 $e^{-0,0032x}$	0,9986

Exponential models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4{,}0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 4 is given in Table 28.

Table 28 Exponential models for IAT values for group 4

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	1
5	y = 0,1	1
10	y = 0,1	1
15	y = 0,1	1
20	y = 2,0985 + 489869000 $e^{-0,7692x}$	1
25	y = 2,7541 + 14206600000 $e^{-0,8171x}$	1
30	y = 3,0863 + 88,5980 $e^{-0,0489x}$	1
35	y = 3,4166 + 72,5722 $e^{-0,0309x}$	1
40	y = 3,9530 + 86,9323 $e^{-0,0273x}$	0,9999
45	y = 4,5230 + 98,3196 $e^{-0,0240x}$	0,9999
50	y = 5,1187 + 113,1775 $e^{-0,0219x}$	0,9999
55	y = 5,7819 + 128,7427 $e^{-0,0201x}$	0,9999
60	y = 6,64 + 152,0867 $e^{-0,0193x}$	0,9999
65	y = 7,7362 + 181,9078 $e^{-0,0189x}$	0,9999
70	y = 9,0173 + 214,9912 $e^{-0,0185x}$	0,9999
75	y = 10,5080 + 254,1213 $e^{-0,0180x}$	0,9998
80	y = 12,3511 + 299,2679 $e^{-0,0175x}$	0,9998
85	y = 14,5853 + 344,3965 $e^{-0,0165x}$	0,9997
90	y = 17,9771 + 418,4066 $e^{-0,0158x}$	0,9996
95	y = 23,6179 + 536,6666 $e^{-0,0146x}$	0,9994
98	y = 28,8048 + 511,0648 $e^{-0,0112x}$	0,9986
99	y = 30,4227 + 357,1913 $e^{-0,0079x}$	0,9959
100	y = 53,8920 + 650,0934 $e^{-0,0109x}$	0,9955

Exponential models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4{,}0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 5 is given in Table 29.

Table 29 Exponential models for IAT values for group 5

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	1
5	y = 0,1	1
10	y = 0,1	1
15	y = 0,1	1
20	y = -0,0085 + 1,5756 $e^{-0,0025x}$	1
25	y = -0,2500 + 1,5956 $e^{-0,0011x}$	1
30	y = 206,4713 - 205,2189 $e^{-0,0000x}$	1
35	y = -415,7073 + 417,1505 $e^{-0,0,0000x}$	1
40	y = -3,2996 + 5,1705 $e^{-0,0002x}$	1
45	y = -0,3800 + 2,7249 $e^{-0,0007x}$	1
50	y = -0,3004 + 2,9596 $e^{-0,0008x}$	1
55	y = 0,5110 + 3,2709 $e^{-0,0017x}$	1
60	y = 0,6386 + 3,8103 $e^{-0,0018x}$	1
65	y = 0,7800 + 4,6314 $e^{-0,0018x}$	1
70	y = 0,9352 + 6,0932 $e^{-0,0020x}$	1
75	y = 0,9669 + 8,7227 $e^{-0,0020x}$	1
80	y = 1,3796 + 13,8438 $e^{-0,0024x}$	1
85	y = 2,5816 + 30,7235 $e^{-0,0036x}$	1
90	y = 5,7314 + 101,4905 $e^{-0,0054x}$	1
95	y = 15,0431 + 257,0965 $e^{-0,0055x}$	0,9999
98	y = 33,1689 + 480,4863 $e^{-0,0051x}$	0,9997
99	y = 52,5102 + 996,9900 $e^{-0,0064x}$	0,9991
100	y = 137,2821 + 2975,9559 $e^{-0,0097x}$	0,9936

Exponential models for IAT values for the $0.01, 0.02, 0.05, 0.1, 0.15, 0.2, 0{,}25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 0.98, 0.99$ and 1th percentile points and corresponding adjusted R^2 values for group 6 is given in Table 30.

Table 30 Exponential models for IAT values for group 6

Percentile point %	IAT distribution function	Adjusted R^2
1	y = 0,1	1
2	y = 0,1	0,9999
5	y = 0,1	0,9999
10	y = 0,1	0,9999
15	y = 0,1	0,9999
20	y = 2,1948+ 164,2776 $e^{-0,0911x}$	0,9999
25	y = 2,5062 + 47,7724 $e^{-0,0414x}$	0,9999
30	y = 2,8993 + 44,7056 $e^{-0,0305x}$	0,9999
35	y = 3,3465 + 46,6424 $e^{-0,0232x}$	0,9999
40	y = 3,7860 + 53,2263 $e^{-0,0192x}$	0,9999
45	y = 4,5153 + 66,3226 $e^{-0,0188x}$	0,9999
50	y = 5,338 + 75,9772 $e^{-0,0172x}$	0,9999
55	y = 6,1470 + 88,1198 $e^{-0,0159x}$	0,9998
60	y = 7,9939 + 133,1918 $e^{-0,0197x}$	0,9997
65	y = 9,3556 + 163,4055 $e^{-0,0193x}$	0,9997
70	y = 10,7197 + 193,6887 $e^{-0,0184x}$	0,9997
75	y = 12,3992 + 223,8404 $e^{-0,0176x}$	0,9997
80	y = 14,3783 + 245,3213 $e^{-0,0163x}$	0,9997
85	y = 17,0058 + 295,2098 $e^{-0,0158x}$	0,9996
90	y = 21,4749 + 390,4581 $e^{-0,0162x}$	0,9993
95	y = 27,0239 + 458,1252 $e^{-0,0139x}$	0,9990
98	y = 33,6381 + 523,9089 $e^{-0,0118x}$	0,9977
99	y = 40,7852 + 371,5634 $e^{-0,01x}$	0,9909
100	y = 62,5502+ 604,4571 $e^{-0,0117x}$	0,9938

Appendix C: Hourly passenger flow data for each station

Table 31 : Passenger volumes for 17 stations on day 1

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	1	0	11	1	0	1	2	0	7	1	1	11	5	2	1	3	5
06:00-07:00	2	0	13	3	0	1	2	1	8	3	2	14	7	2	2	4	9
07:00-08:00	2	0	14	4	0	2	2	6	9	4	3	21	7	2	2	6	10
08:00-09:00	2	0	15	4	0	2	2	6	10	4	4	22	7	2	3	7	12
9:00-10:00	3	0	15	5	0	2	3	10	11	4	4	22	8	3	3	8	15
10:00-11:00	3	0	15	6	0	3	5	12	11	4	5	23	9	4	3	8	17
11:00-12:00	3	1	17	6	0	3	6	13	11	5	5	24	9	5	3	8	18
12:00-13:00	4	1	17	6	0	4	10	15	11	5	6	24	9	5	4	9	19
13:00-14:00	4	1	17	6	0	4	13	15	12	6	7	26	9	6	4	9	22
14:00-15:00	4	1	17	7	0	4	25	16	12	6	7	26	9	6	4	9	22
15:00-16:00	5	1	18	8	1	5	25	16	13	6	7	27	9	6	4	10	22
16:00-17:00	5	1	18	8	1	5	38	16	15	7	8	27	12	6	4	10	24
17:00-18:00	5	1	19	8	1	6	44	17	15	10	12	27	12	7	5	10	25
18:00-19:00	5	1	20	8	1	6	54	17	15	10	14	28	12	7	5	11	25
19:00-20:00	5	1	60	9	1	7	54	42	15	10	22	28	14	7	6	11	27
20:00-21:00	5	2	63	9	1	7	55	43	16	13	24	30	15	7	8	11	30
21:00-22:00	5	2	66	9	1	8	66	48	17	15	28	31	17	7	8	12	31
22:00-23:00	5	2	80	9	1	9	76	49	17	18	29	31	18	7	9	14	32
23:00-00:00	6	2	81	10	1	10	80	51	18	18	31	31	19	8	9	17	32
00:00-00:59	6	3	82	10	2	10	90	53	18	18	35	31	20	9	10	17	33

Table 32 : Passenger volumes for 17 stations on day 2

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	6	3	91	10	2	10	93	64	18	20	35	32	22	10	11	18	36
06:00-07:00	6	3	92	12	2	10	97	66	20	23	39	33	22	10	11	18	38
07:00-08:00	6	3	98	13	2	11	98	68	20	24	40	34	23	11	11	19	39
08:00-09:00	6	3	100	15	3	11	101	70	20	34	41	34	24	11	12	21	43
9:00-10:00	6	5	101	16	4	12	102	73	24	39	42	34	25	14	13	21	46
10:00-11:00	8	5	102	16	4	14	104	82	26	40	44	35	25	15	13	23	47
11:00-12:00	12	7	116	17	4	17	126	86	27	44	50	35	27	15	13	27	48
12:00-13:00	12	7	129	21	5	17	132	90	30	46	83	38	30	19	14	27	54
13:00-14:00	28	7	154	27	6	43	187	103	99	49	176	134	34	19	22	43	150
14:00-15:00	31	8	168	32	9	55	229	106	103	54	183	147	41	32	25	50	158
15:00-16:00	36	11	307	41	13	56	314	128	106	62	217	150	43	32	25	52	227
16:00-17:00	38	12	308	41	13	57	341	140	109	67	225	161	45	33	28	53	233
17:00-18:00	40	13	466	57	14	59	369	140	110	83	240	164	48	34	29	58	235
18:00-19:00	41	13	471	61	15	60	380	149	110	102	256	175	56	38	30	61	248
19:00-20:00	45	14	473	63	16	67	393	149	115	102	267	180	60	40	30	62	267
20:00-21:00	50	14	487	67	16	71	398	150	122	103	286	188	62	42	31	63	268
21:00-22:00	54	17	487	76	16	72	402	153	124	105	286	191	65	43	35	63	272
22:00-23:00	56	17	494	78	17	74	415	162	128	105	303	197	67	44	35	71	280
23:00-00:00	58	18	494	80	18	74	445	163	129	106	304	205	69	45	38	72	301
00:00-00:59	65	19	502	80	18	81	447	171	135	107	312	211	72	46	42	76	328

Table 33 : Passenger volumes for 17 stations on day 3

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	66	23	526	82	19	81	447	173	147	107	314	215	75	51	42	78	329
06:00-07:00	76	23	528	83	21	81	479	178	148	111	324	219	76	55	43	79	353
07:00-08:00	76	23	529	84	21	86	484	183	149	112	326	231	80	57	49	79	359
08:00-09:00	77	24	531	86	22	86	491	190	153	113	332	232	82	59	52	81	365
9:00-10:00	82	24	540	92	22	89	500	191	154	114	365	233	82	61	53	81	374
10:00-11:00	87	24	540	97	24	90	519	200	160	119	366	248	85	63	54	86	384
11:00-12:00	88	24	562	100	25	93	521	228	164	120	375	262	86	64	55	87	401
12:00-13:00	90	25	563	102	25	95	523	240	172	121	383	263	86	69	56	89	413
13:00-14:00	96	25	565	103	26	97	527	249	172	124	399	273	89	69	57	90	417
14:00-15:00	99	25	574	106	26	98	530	253	183	136	446	283	89	70	58	91	438
15:00-16:00	102	28	577	108	27	101	538	258	183	137	446	297	96	71	58	92	443
16:00-17:00	103	31	579	109	28	105	541	261	192	158	452	302	103	74	59	97	470
17:00-18:00	103	32	593	111	28	107	544	266	192	163	453	305	103	74	59	99	477
18:00-19:00	106	38	595	111	28	109	553	267	195	165	453	315	104	77	59	100	491
19:00-20:00	106	41	600	114	28	112	561	268	202	168	464	316	104	79	60	102	493
20:00-21:00	107	43	604	118	29	112	577	268	212	171	499	317	106	79	61	102	499
21:00-22:00	109	45	638	122	29	114	578	270	214	174	504	319	106	83	62	105	504
22:00-23:00	109	49	638	123	30	114	584	272	214	191	508	320	107	83	63	105	507
23:00-00:00	111	50	654	134	30	117	593	286	218	195	510	323	110	84	64	106	508
00:00-00:59	111	50	667	134	31	119	596	287	225	207	510	327	113	84	65	109	518

Table 34 : Passenger volumes for 17 stations on day 4

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	112	51	702	136	31	120	602	287	232	207	512	336	119	86	65	110	522
06:00-07:00	114	52	712	137	32	124	608	288	237	214	512	338	120	88	66	111	522
07:00-08:00	114	58	731	138	32	126	624	292	252	215	513	340	125	89	66	113	525
08:00-09:00	114	61	773	142	33	129	626	293	252	217	526	341	126	90	66	113	533
9:00-10:00	115	63	787	145	36	131	628	294	254	218	533	345	127	91	66	117	536
10:00-11:00	118	69	794	146	39	136	637	295	254	223	534	350	128	92	67	118	537
11:00-12:00	122	74	800	147	41	139	638	300	254	224	534	354	130	92	68	118	545
12:00-13:00	125	75	818	149	42	140	639	302	256	232	553	357	130	92	71	118	545
13:00-14:00	127	76	819	150	43	146	646	311	256	234	559	360	136	93	71	119	563
14:00-15:00	130	77	819	155	44	146	649	311	259	240	561	363	136	94	73	119	566
15:00-16:00	134	77	821	156	45	150	663	312	262	243	565	364	137	96	75	119	575
16:00-17:00	136	78	829	158	45	150	665	322	264	246	570	376	138	102	78	119	578
17:00-18:00	138	82	851	158	48	152	674	322	264	252	576	384	140	102	79	120	578
18:00-19:00	150	86	855	160	48	155	674	326	265	253	582	396	141	106	83	124	585
19:00-20:00	153	87	858	163	49	158	675	328	268	259	589	425	144	108	89	133	588
20:00-21:00	168	87	862	163	50	158	701	330	269	259	595	436	145	109	90	138	589
21:00-22:00	172	87	864	164	50	159	725	332	279	260	607	445	147	111	90	139	597
22:00-23:00	177	88	866	164	53	161	732	335	280	264	609	463	148	111	90	140	597
23:00-00:00	181	90	872	165	53	165	746	338	280	269	610	465	155	116	91	142	597
00:00-00:59	181	92	877	166	53	167	752	339	285	272	624	468	161	117	94	142	601

Table 35 : Passenger volumes for 17 stations on day 5

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	183	93	882	175	54	167	765	341	286	285	634	481	165	118	94	142	605
06:00-07:00	184	93	883	179	55	168	765	343	289	286	642	485	166	118	95	145	613
07:00-08:00	207	94	883	180	55	172	770	351	290	291	657	493	169	122	96	154	613
08:00-09:00	215	94	896	180	56	174	775	354	291	294	670	495	175	123	99	154	622
9:00-10:00	220	95	898	181	56	175	786	365	291	294	673	529	180	125	99	156	624
10:00-11:00	221	97	909	182	57	177	828	374	295	295	679	533	181	125	99	162	635
11:00-12:00	222	98	920	182	58	184	859	375	297	302	707	539	184	125	101	162	637
12:00-13:00	230	100	923	185	59	187	861	382	303	305	708	569	193	126	105	163	639
13:00-14:00	233	101	925	187	60	191	928	385	304	308	709	581	194	127	105	166	647
14:00-15:00	236	101	933	187	60	195	949	387	304	315	710	587	196	130	108	167	674
15:00-16:00	237	103	951	190	61	199	981	393	318	315	723	591	222	134	108	170	687
16:00-17:00	239	104	952	195	62	201	1024	396	325	319	741	597	231	135	108	171	705
17:00-18:00	241	105	953	197	68	208	1041	403	348	321	742	627	235	137	111	173	732
18:00-19:00	244	107	965	202	68	214	1045	404	353	324	766	631	235	138	117	176	733
19:00-20:00	244	109	978	212	72	217	1063	413	360	324	771	641	235	139	119	180	747
20:00-21:00	253	114	979	215	72	236	1073	413	364	326	774	644	237	140	119	180	754
21:00-22:00	263	115	993	237	72	245	1079	420	364	335	801	658	240	141	120	183	756
22:00-23:00	272	119	995	250	73	246	1090	420	367	337	810	662	241	148	120	184	758
23:00-00:00	273	121	1006	260	77	266	1104	445	378	351	843	665	243	150	126	193	762
00:00-00:59	277	122	1008	260	78	270	1210	453	388	359	869	665	244	151	137	197	795

Table 36 : Passenger volumes for 17 stations on day 6

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	280	127	1015	265	78	272	1214	454	395	361	878	667	247	153	137	204	798
06:00-07:00	280	127	1045	266	79	272	1216	461	400	363	905	671	253	155	140	205	871
07:00-08:00	283	128	1094	270	81	277	1232	462	401	378	916	671	257	161	145	210	924
08:00-09:00	284	131	1098	272	81	279	1239	467	412	383	967	678	258	164	147	211	953
9:00-10:00	289	134	1117	276	82	281	1247	471	413	392	982	706	258	172	152	212	966
10:00-11:00	297	138	1126	277	84	285	1259	545	416	395	990	708	259	177	153	212	973
11:00-12:00	298	139	1133	284	85	290	1280	545	416	400	991	711	273	184	157	222	1011
12:00-13:00	307	140	1135	285	88	294	1287	559	417	412	999	731	282	188	158	231	1035
13:00-14:00	307	141	1145	296	88	299	1340	601	419	414	1014	734	292	190	162	239	1037
14:00-15:00	314	145	1153	297	89	303	1348	607	431	421	1015	735	302	208	163	239	1050
15:00-16:00	319	146	1157	304	91	304	1354	612	435	422	1017	759	302	222	165	241	1054
16:00-17:00	324	148	1180	305	92	324	1458	648	443	422	1026	765	302	233	182	252	1070
17:00-18:00	349	150	1195	318	94	339	1480	651	457	425	1029	789	309	238	187	253	1073
18:00-19:00	362	154	1228	323	96	342	1492	652	459	435	1049	793	313	245	193	273	1088
19:00-20:00	377	155	1229	328	100	352	1517	663	459	467	1052	796	317	249	195	274	1088
20:00-21:00	379	157	1238	328	106	359	1520	670	460	485	1054	799	318	250	196	275	1099
21:00-22:00	379	159	1244	335	106	360	1568	674	463	495	1066	815	323	258	201	276	1101
22:00-23:00	387	160	1260	338	115	371	1604	682	468	506	1083	829	324	259	205	280	1109
23:00-00:00	387	164	1260	339	118	373	1610	684	469	506	1106	851	326	259	206	285	1121
00:00-00:59	393	166	1263	341	118	383	1619	686	470	510	1107	871	330	263	207	288	1141

Table 37 : Passenger volumes for 17 stations on day 7

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	395	169	1278	347	118	403	1649	712	473	519	1113	887	333	264	208	291	1154
06:00-07:00	395	169	1293	353	119	403	1652	713	475	520	1117	888	340	265	209	292	1172
07:00-08:00	401	170	1296	354	120	418	1665	717	477	524	1117	891	342	271	213	294	1186
08:00-09:00	411	172	1326	356	122	420	1669	723	492	524	1121	927	344	272	215	294	1191
9:00-10:00	411	176	1331	358	123	421	1683	737	493	533	1121	958	357	273	215	304	1197
10:00-11:00	412	179	1331	361	124	427	1688	747	493	534	1126	961	364	274	215	307	1198
11:00-12:00	416	181	1351	369	125	437	1703	760	493	543	1146	968	367	274	217	313	1209
12:00-13:00	417	183	1352	371	126	437	1713	770	495	547	1156	969	370	275	218	314	1213
13:00-14:00	423	183	1357	371	130	443	1730	775	495	549	1161	985	375	276	223	315	1225
14:00-15:00	423	185	1362	375	130	449	1760	783	496	560	1163	992	378	277	224	317	1226
15:00-16:00	425	192	1364	377	131	460	1771	786	498	560	1165	995	397	294	228	319	1230
16:00-17:00	435	198	1376	388	133	466	1772	787	500	569	1166	1003	405	295	230	323	1232
17:00-18:00	441	199	1378	394	133	467	1774	790	501	580	1166	1024	414	296	232	327	1238
18:00-19:00	441	206	1378	398	133	468	1790	794	503	588	1186	1026	419	302	234	329	1241
19:00-20:00	447	206	1378	399	134	469	1796	808	503	593	1196	1027	419	308	237	329	1247
20:00-21:00	448	207	1405	401	135	480	1815	812	508	625	1200	1028	421	308	240	334	1257
21:00-22:00	448	220	1426	404	135	480	1818	812	512	636	1212	1040	424	315	241	335	1259
22:00-23:00	460	220	1434	405	136	481	1830	812	514	647	1250	1055	424	317	245	336	1271
23:00-00:00	463	220	1436	405	136	487	1839	813	518	650	1257	1065	425	317	247	338	1277
00:00-00:59	467	221	1437	406	137	498	1845	814	520	667	1272	1075	426	320	247	340	1289

Table 38 : Passenger volumes for 17 stations on day 8

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	469	224	1443	408	138	505	1849	827	522	732	1274	1079	429	322	258	340	1291
06:00-07:00	469	224	1446	408	139	505	1849	827	524	748	1301	1084	442	322	259	343	1301
07:00-08:00	470	227	1500	408	141	506	1849	828	525	751	1311	1087	442	324	260	346	1302
08:00-09:00	479	228	1508	410	142	508	1857	835	525	774	1357	1093	444	327	270	346	1303
9:00-10:00	480	229	1518	411	142	514	1862	839	526	779	1364	1095	445	329	270	347	1313
10:00-11:00	480	229	1523	413	143	514	1864	844	529	788	1378	1108	449	331	273	350	1342
11:00-12:00	482	233	1529	425	144	520	1868	846	531	824	1391	1112	449	333	274	353	1342
12:00-13:00	483	233	1536	427	145	524	1872	847	532	829	1392	1113	454	334	276	357	1346
13:00-14:00	485	239	1541	430	145	533	1904	850	539	831	1400	1115	457	337	277	357	1346
14:00-15:00	485	240	1544	433	145	534	1907	850	542	834	1406	1115	461	339	278	358	1348
15:00-16:00	487	246	1557	434	145	539	1927	852	554	857	1412	1119	461	342	279	358	1352
16:00-17:00	489	248	1559	437	146	539	1927	858	558	878	1417	1127	462	345	279	359	1358
17:00-18:00	489	254	1559	438	147	545	1931	867	559	881	1427	1144	462	349	279	367	1360
18:00-19:00	492	256	1570	446	147	553	1933	871	561	909	1429	1145	466	349	285	369	1360
19:00-20:00	493	263	1588	447	149	558	1934	876	561	912	1434	1154	467	349	286	372	1375
20:00-21:00	493	268	1598	456	151	565	1957	876	565	938	1446	1154	470	355	295	375	1382
21:00-22:00	494	268	1606	465	152	575	1957	877	566	949	1477	1156	472	358	297	380	1383
22:00-23:00	496	270	1625	468	152	583	1967	880	570	977	1490	1160	472	363	298	381	1385
23:00-00:00	497	272	1626	470	153	588	1969	881	576	989	1495	1161	473	367	303	381	1387
00:00-00:59	497	278	1633	475	153	590	1971	884	584	991	1514	1164	483	367	304	385	1391

Table 39 : Passenger volumes for 17 stations on day 9

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	499	280	1636	484	153	597	1978	884	585	991	1522	1166	487	368	305	387	1392
06:00-07:00	501	290	1636	486	154	601	1987	884	588	993	1529	1168	490	369	306	388	1393
07:00-08:00	507	297	1645	490	154	605	1991	885	588	997	1551	1169	491	370	306	390	1396
08:00-09:00	509	303	1652	502	155	608	1991	890	592	1017	1554	1170	494	371	308	393	1396
9:00-10:00	510	307	1661	502	156	611	2000	893	594	1027	1557	1176	499	372	309	394	1400
10:00-11:00	511	309	1667	504	156	611	2026	895	599	1039	1572	1176	500	372	315	394	1402
11:00-12:00	516	319	1672	510	157	613	2032	907	600	1052	1588	1179	505	376	318	397	1419
12:00-13:00	517	322	1674	515	160	614	2033	908	613	1057	1596	1183	519	377	318	398	1421
13:00-14:00	517	323	1681	522	160	621	2034	909	614	1059	1602	1184	521	379	319	398	1438
14:00-15:00	517	325	1695	522	163	621	2039	911	626	1062	1637	1191	534	384	320	399	1445
15:00-16:00	519	326	1713	526	163	623	2040	915	634	1073	1638	1191	536	387	327	399	1459
16:00-17:00	520	333	1718	528	167	624	2056	921	652	1078	1645	1193	538	388	327	400	1472
17:00-18:00	524	341	1728	533	168	633	2066	926	657	1137	1663	1195	542	389	328	403	1475
18:00-19:00	525	345	1729	546	171	636	2070	931	658	1162	1665	1197	543	391	330	406	1479
19:00-20:00	526	346	1750	553	172	637	2080	933	662	1208	1669	1206	544	391	333	410	1487
20:00-21:00	537	351	1757	557	174	638	2092	938	663	1264	1669	1208	545	391	333	411	1488
21:00-22:00	538	353	1769	558	174	638	2094	940	667	1337	1675	1209	546	396	334	412	1494
22:00-23:00	539	354	1771	559	174	639	2096	940	669	1341	1679	1216	546	404	337	412	1513
23:00-00:00	540	363	1788	568	174	640	2097	946	673	1370	1694	1218	548	407	338	417	1524
00:00-00:59	544	370	1813	568	177	646	2114	946	673	1384	1707	1219	549	408	343	418	1527

Table 40 : Passenger volumes for 17 stations on day 10

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	544	383	1826	568	177	648	2138	953	674	1388	1711	1227	549	408	343	422	1528
06:00-07:00	547	384	1834	578	178	662	2142	958	686	1394	1714	1236	554	409	344	422	1528
07:00-08:00	548	391	1847	579	178	663	2152	958	686	1400	1725	1236	556	410	348	423	1540
08:00-09:00	550	394	1849	581	180	663	2156	966	688	1407	1738	1241	557	414	350	426	1544
9:00-10:00	551	403	1861	582	180	666	2183	968	691	1459	1763	1242	559	414	350	438	1545
10:00-11:00	552	406	1889	586	181	667	2189	970	706	1460	1768	1253	568	415	351	439	1550
11:00-12:00	555	411	1893	587	181	667	2189	978	708	1462	1784	1257	571	418	355	440	1554
12:00-13:00	556	413	1914	588	183	667	2191	980	709	1473	1785	1260	571	418	356	440	1558
13:00-14:00	557	425	1917	590	186	668	2230	984	717	1484	1789	1264	572	419	356	440	1561
14:00-15:00	560	428	1919	591	186	671	2231	986	719	1537	1800	1265	580	422	358	441	1563
15:00-16:00	571	429	1923	592	187	674	2232	987	725	1657	1878	1265	580	422	362	441	1564
16:00-17:00	571	431	1925	594	188	674	2234	987	726	1675	1893	1268	580	423	364	443	1568
17:00-18:00	573	437	1926	602	188	675	2236	988	736	1678	1898	1277	584	424	368	454	1569
18:00-19:00	573	440	1937	603	189	676	2237	993	737	1746	1944	1280	586	425	370	454	1576
19:00-20:00	579	441	1939	603	189	676	2239	996	744	1796	1992	1282	594	425	372	455	1578
20:00-21:00	580	443	1940	610	190	681	2246	996	747	1805	2009	1283	599	427	373	458	1582
21:00-22:00	581	443	1941	618	192	682	2253	1000	748	1819	2015	1285	601	427	375	459	1585
22:00-23:00	583	444	1955	618	193	682	2259	1007	751	1839	2062	1303	602	428	377	465	1586
23:00-00:00	585	446	1958	622	195	683	2275	1008	753	1902	2077	1317	603	431	377	465	1588
00:00-00:59	586	448	1959	623	195	693	2275	1009	757	1967	2093	1332	603	432	382	465	1593

Table 41 : Passenger volumes for 17 stations on day 11

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	588	448	1966	625	198	694	2280	1013	764	2010	2096	1338	606	432	382	470	1594
06:00-07:00	591	449	1974	630	198	699	2286	1017	764	2014	2099	1340	609	434	385	474	1599
07:00-08:00	604	450	1977	633	201	700	2288	1018	767	2034	2124	1349	610	438	386	475	1604
08:00-09:00	606	463	1984	635	201	702	2303	1029	773	2058	2126	1352	611	441	387	475	1609
9:00-10:00	606	464	2027	637	203	702	2312	1035	781	2072	2133	1354	615	442	389	477	1615
10:00-11:00	610	470	2028	641	203	708	2330	1036	781	2080	2147	1358	622	444	389	487	1619
11:00-12:00	614	470	2030	642	204	712	2352	1040	790	2120	2148	1379	623	447	396	488	1619
12:00-13:00	622	482	2061	643	204	716	2358	1040	792	2130	2154	1381	624	451	397	492	1636
13:00-14:00	623	483	2070	646	206	719	2363	1050	793	2150	2160	1385	625	453	404	493	1637
14:00-15:00	632	483	2074	647	206	722	2372	1058	793	2178	2173	1396	629	455	410	493	1639
15:00-16:00	634	492	2084	649	207	723	2376	1058	796	2203	2215	1412	629	456	417	494	1649
16:00-17:00	643	493	2084	649	210	723	2378	1075	796	2225	2216	1423	630	457	419	499	1652
17:00-18:00	643	496	2085	651	211	728	2402	1077	807	2249	2228	1423	631	458	420	501	1666
18:00-19:00	643	497	2096	666	211	730	2419	1090	807	2264	2242	1460	631	458	421	502	1671
19:00-20:00	649	500	2120	668	212	733	2429	1093	811	2279	2253	1469	632	459	424	505	1675
20:00-21:00	654	506	2129	673	212	734	2430	1099	813	2426	2288	1472	632	461	425	507	1683
21:00-22:00	658	511	2143	678	213	739	2442	1108	817	2447	2307	1475	633	462	425	507	1706
22:00-23:00	671	511	2151	684	214	745	2446	1114	818	2475	2333	1480	635	464	426	508	1720
23:00-00:00	671	519	2157	700	215	748	2447	1117	822	2484	2333	1480	637	464	427	516	1723
00:00-00:59	673	527	2163	704	216	755	2461	1118	825	2484	2362	1483	637	465	432	517	1724

Table 42 : Passenger volumes for 17 stations on day 12

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	674	529	2169	706	221	755	2476	1119	827	2486	2386	1488	642	466	436	517	1728
06:00-07:00	684	540	2170	708	222	758	2485	1119	830	2523	2389	1492	645	467	437	520	1731
07:00-08:00	685	547	2172	709	224	760	2497	1119	835	2532	2416	1499	650	469	438	521	1732
08:00-09:00	694	550	2174	721	225	763	2520	1127	846	2553	2419	1509	651	470	442	525	1740
9:00-10:00	705	551	2176	722	227	773	2527	1133	852	2559	2460	1515	653	472	446	530	1747
10:00-11:00	707	553	2176	743	232	774	2567	1138	852	2601	2481	1520	657	474	446	530	1747
11:00-12:00	715	556	2177	749	235	775	2571	1140	860	2666	2540	1524	658	475	453	532	1750
12:00-13:00	720	569	2182	751	235	778	2579	1159	874	2720	2544	1533	668	477	454	532	1753
13:00-14:00	726	571	2183	752	238	780	2583	1160	880	2730	2552	1535	668	478	456	534	1766
14:00-15:00	727	583	2194	755	242	786	2583	1160	880	2750	2565	1536	671	480	456	537	1772
15:00-16:00	728	595	2220	762	250	792	2595	1160	882	2779	2578	1541	671	481	458	546	1824
16:00-17:00	731	595	2238	772	254	792	2596	1160	886	2804	2584	1552	680	482	466	547	1836
17:00-18:00	745	604	2243	780	257	799	2598	1164	896	2813	2593	1568	686	483	476	547	1837
18:00-19:00	768	611	2245	782	259	804	2602	1168	901	2823	2593	1570	704	484	476	547	1838
19:00-20:00	769	628	2260	783	262	819	2629	1169	907	2862	2595	1571	711	489	478	547	1840
20:00-21:00	778	628	2278	791	263	854	2632	1171	910	2871	2597	1614	715	492	480	557	1847
21:00-22:00	794	630	2278	792	264	859	2635	1186	916	2936	2600	1616	718	497	503	560	1896
22:00-23:00	810	630	2281	797	273	875	2642	1195	923	2946	2623	1620	723	499	508	565	1904
23:00-00:00	822	631	2289	814	279	875	2659	1197	925	3017	2646	1621	723	504	513	566	1905
00:00-00:59	827	633	2298	820	289	894	2660	1211	926	3094	2670	1622	731	505	515	572	1911

Table 43 : Passenger volumes for 17 stations on day 13

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	834	664	2301	834	290	902	2673	1229	928	3137	2670	1632	734	506	515	574	1920
06:00-07:00	850	671	2308	838	291	906	2686	1230	935	3175	2720	1635	746	506	527	575	1928
07:00-08:00	879	675	2333	847	292	913	2693	1247	935	3188	2748	1639	761	506	530	576	1935
08:00-09:00	894	683	2361	848	299	919	2703	1251	939	3189	2803	1647	764	508	531	576	1995
9:00-10:00	896	691	2379	850	299	928	2704	1255	945	3226	2877	1658	769	509	535	581	2003
10:00-11:00	909	699	2384	858	305	929	2781	1265	949	3250	2881	1690	786	510	541	595	2013
11:00-12:00	913	700	2395	858	307	929	2812	1274	971	3256	2905	1691	809	514	549	597	2019
12:00-13:00	919	708	2402	861	312	947	2882	1276	975	3256	2915	1740	809	521	563	602	2038
13:00-14:00	923	715	2405	863	314	948	2899	1283	984	3303	2948	1779	828	522	574	605	2040
14:00-15:00	932	726	2413	867	316	953	2905	1286	985	3433	2983	1783	832	522	595	627	2056
15:00-16:00	940	730	2416	869	319	959	2906	1299	990	3471	2995	1790	847	526	603	642	2073
16:00-17:00	953	741	2421	872	321	960	2921	1308	991	3555	3002	1824	880	526	608	649	2078
17:00-18:00	959	744	2430	874	325	977	2983	1311	1023	3590	3012	1860	882	534	628	669	2088
18:00-19:00	974	754	2433	876	333	979	3002	1363	1042	3608	3102	1887	886	550	643	673	2152
19:00-20:00	976	760	2448	876	334	983	3035	1387	1043	3627	3129	1969	912	554	659	678	2163
20:00-21:00	982	769	2455	882	335	988	3104	1397	1055	3639	3131	1972	955	559	665	692	2184
21:00-22:00	985	774	2460	894	339	997	3142	1409	1062	3653	3150	1991	981	561	671	710	2217
22:00-23:00	985	783	2471	907	340	1014	3166	1411	1070	3664	3151	2034	984	572	676	719	2219
23:00-00:00	999	784	2472	914	342	1036	3188	1423	1120	3678	3203	2232	990	574	679	723	2269
00:00-00:59	1000	784	2482	915	342	1042	3202	1426	1142	3735	3218	2442	990	583	693	750	2297

Table 44 : Passenger volumes for 17 stations on day 14

Station name	Evka3	Üniversite	Bornova	Bölge	Sanayi	Stadyum	Halkapınar	Hilal	Basmane	Çankaya	Konak	Üçyol	İzmirspor	Hatay	Goztepe	Poligon	F.altay
Time interval :																	
05:00-06:00	1006	793	2485	947	343	1099	3219	1430	1346	3753	3340	2552	1015	591	711	763	2371
06:00-07:00	1007	812	2493	978	348	1106	3226	1433	1395	3757	3348	2585	1040	593	717	773	2372
07:00-08:00	1016	821	2498	1016	386	1108	3276	1437	1409	3777	3369	2591	1043	598	719	781	2391
08:00-09:00	1017	827	2505	1034	411	1132	3309	1524	1444	3779	3435	2650	1056	605	727	791	2395
9:00-10:00	1035	845	2533	1045	421	1146	3384	1530	1457	3797	3451	2706	1062	619	737	810	2432
10:00-11:00	1041	887	2550	1048	424	1152	3468	1572	1485	3832	3468	2789	1145	632	752	817	2575
11:00-12:00	1049	895	2568	1085	434	1174	3471	1588	1488	3909	3474	2838	1167	660	767	828	2595
12:00-13:00	1081	903	2573	1086	451	1266	3481	1661	1492	3914	3491	3123	1243	666	779	879	2612
13:00-14:00	1088	904	2587	1094	461	1474	3482	1682	1499	4068	3505	3205	1276	673	812	881	2640
14:00-15:00	1102	904	2591	1116	477	1517	3559	1801	1502	4136	3543	3261	1278	763	817	934	2662
15:00-16:00	1154	969	2600	1153	697	1563	3578	1835	1505	5288	3565	3328	1314	767	830	956	2671
16:00-17:00	1155	983	2606	1198	702	1563	3626	1863	1509	5363	3740	3437	1319	780	833	964	2677
17:00-18:00	1156	1029	2739	1213	759	1569	3674	1909	1518	5472	3797	3438	1394	791	839	981	2703
18:00-19:00	1158	1064	2760	1244	767	1573	3691	1912	1520	5829	3891	3492	1425	797	841	1009	2813
19:00-20:00	1180	1661	2772	1287	778	1587	3732	2011	1529	5932	3925	3580	1443	812	863	1019	2834
20:00-21:00	1182	1837	2781	1289	788	1615	3771	2029	1581	5983	4085	3625	1447	851	900	1024	2924
21:00-22:00	1204	1842	2804	1292	793	1629	3801	2059	1584	5985	4112	3675	1485	854	914	1053	3007
22:00-23:00	1223	1899	2809	1410	809	1649	3823	2131	1624	6287	4240	3690	1565	863	915	1085	3130
23:00-00:00	1239	2055	2834	1471	816	1831	3946	2197	1674	6397	4307	3854	1571	870	938	1103	3212
00:00-00:59	1241	2071	2899	1478	837	1832	4871	2198	1709	6789	4389	3945	1637	901	944	1134	3361