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Research Article / Araştırma Makalesi

# DETERMINATION MINIBUSES STOP DELAY IN ISTANBUL

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**ABSTRACT**

Although reduction of car use with the help of public transportation systems is desired, frequently stopping of minibuses and buses to board and alight passengers, affects negatively traffic flow especially when a lane is not assigned only for public transportation. The lost time, which is named as dwell time in the literature, caused by passenger boarding and alighting consists of three durations. First duration is required to stop the vehicle, second duration, defined as stop delay, is required for passenger boarding and alighting as well as doors' opening, third duration is required for the acceleration of the vehicle. Stop delays of minibuses are examined within this study. The amount of minibus stopping for passenger boarding and alighting, durations of each of these stopping and the number of boarding and alighting passengers were observed on two selected minibus routes in İstanbul. It is found that stop delay changes at peak hours and with the presence of stairs at the entrance of minibus. Additionally, it is determined that stop delay is not constant for analyzed routes. Three mathematical models are formed for minibus stop delay where the number of boarding and alighting passengers is used as independent variable. The dead time is calculated as 1.69 sec and stop delay changes 2.13 sec per passenger.
**Keywords:** Stop delay, public transportation, minibus route.

## 1. INTRODUCTION

Today, while increasing of private car usage is negatively affecting the traffic, public transportation systems help to solve this problem. Encouragement of using the public transportation systems is important as well as the development of these systems. Transportation of more people with less private cars can be provided with urban public transportation systems, which leads to a reduction of traffic jam.

Public transportation systems have some negative effects on the traffic as well as positive effects. Stoppings of the public transportation vehicles at stops and stations for the purpose of boarding and alighting passengers are one of these negative effects. The lost time in passenger boarding and alighting consists of three parts, such as; the duration needed to stop the vehicles, the duration needed for passenger boarding and alighting as well as doors' opening and the duration needed for the acceleration of the vehicle. Despite the fact that buses only stop at

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designated stations, minibuses stop not at stations only, nonetheless randomly and frequently. The number of these stoppings is directly correlated with travel time. These stoppings do not only affect traffic flow negatively but also cause additional environmental pollution.

The stop delay is affected by multiple factors. Some of these factors are vehicle features, crowdedness, location, stopping point, weather conditions, passenger and driver features. In this study, the effects of peak hour as an indicator of crowdedness, location and vehicle features are evaluated in Istanbul. In addition, a mathematical model is developed for the relationship between the stop delay and the number of passengers who boarded and alighted.

In the scope of this study, minibuses' passengers stop delay had been examined at two minibus routes in İstanbul. These two minibus routes are selected in different regions in order to determine location effect. At each route observations are realized at minibuses with and without stairs to analyze the effect of vehicle features. Moreover, observations are done during peak and off-peak hours separately to calculate crowdedness effect on stop delay. Among the observed situations in this context, variations of durations of passenger boarding and alighting are examined.

## 2. STUDIES RELATED TO DWELL TIME AND STOP DELAY

Dwell time is considered as the total time of the bus spent for serving its passengers when it stops [1]. In Figure 1, the process of movement for a public transportation vehicle to perform passenger boarding and alighting is shown, dwell time is described as the time elapses between $T_1$-$T_4$.

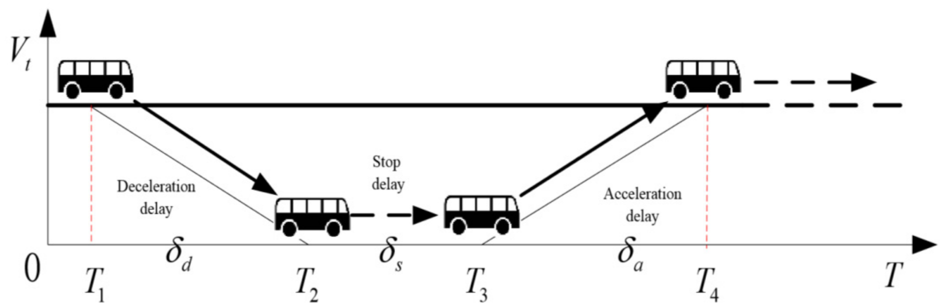


**Figure 1.** The Whole Process of Bus Stop [2]

Here, $T_1$-$T_4$ is dwell time in a bus stop, $\delta_d$ is deceleration delay at a bus stop, $\delta_s$ is stop delay at a bus stop, and $\delta_a$ is acceleration delay at a bus stop [2]. Considering the fact that dwell time covers 26% of the total travel time of the buses, it is important to understand the factors, which are affecting to this duration [3]. Determination of the variables that affect dwell time is crucial for its optimization by public transport operators. There are five main factors affecting dwell time; boarding and alighting passenger demands, stop area, fare payment process, vehicle features and inner-vehicle circulation [4].

Conducted studies on bus passenger boarding and alighting are usually area based and purposive due to the fact that data collection procedure is relatively expensive and long. Kraft and Bergen are reported that bus passenger alighting duration 2 s plus 4.5 s for each boarding passengers when the payment is performed in-vehicle, and 1.5 s plus 1.9 s for each boarding passenger when the payment performed out-vehicle in 1974 [5]. On the other hand, in the study which performance of travel time on public transportation are investigated by Levinson in 1983, bus dwell time is defined as 5 s plus 2.75 s for each boarding or alighting passenger [6]. Guenthner and Sinha reported that bus dwell time described as 10-20 s plus for each stop plus 3-5 s for each boarding or alighting passenger in 1983 [7]. Guenthner and Hamat reported that models may remain weakly, when considering many factors are influencing dwell time (fare payment type, with and without staired, number of doors etc.) and with the addition of limited number of routes examined. The relationship between passenger boarding alighting duration with control of passenger mass and fare payment type structures was examined in 1988 [8]. Lin and Wilson are reported that the model of dwell time is presented as an equation, which contains boarding, alighting and standee passengers in 1992. Later on, this equation is additionally adapted to light rail systems [9]. Bertini and El-Geneidy are indicated that dwell time model, which is developed one-way as in buses at morning peak time, is analyzed while estimating the number of stops and the numbers of boarding and alighting passengers in 2004 [10-11]. Some studies on dwell time in the world are shown in Table 1.

**Table 1.** Selected Studies on Dwell Time [12]

| Location | Types of Vehicles | Dead Time (s) | Alighting (s/pax) | Boarding Time (s/pax) |
|---|---|---|---|---|
| Michigan, USA | 1-door buses | 2.25 | 1.81 | 5.66 |
| London and Exeter, UK | 1 and 2-door buses | 2.38-8.26 | 0.99-2.94 | 2.74-8.87 |
| Tehran, Iran | 2 and 3-door buses | 12 | 0.99-1.04 | 1.64-2.00 |
| Portland, USA | Buses | 5.14 | 1.7 | 3.48 |
| New Jersey, USA | Buses | 1.32-5.99 | 1.93-4.63 | 4.65-6.91 |
| Santiago, Chile | 2,3 and 4-door buses, metro | Metro: 3.24<br>Buses:8.04-9.32 | Metro: 0.70<br>Buses:1.39-3.32 | Metro: 1.13<br>Buses:2.05-6.04 |

## 3. FIELD STUDY

Three methods are available to estimate the bus dwell time. These are field study, ordinary value and calculation method. Field study method gives more accurate results about an available bus route [13]. In the study, initially, in minibuses, the durations of each stopping for passenger boarding and alighting, in other word stop delay, are recorded. The distribution of these delays is observed with the help of plotted histograms and descriptive statistics are given. Secondly, the effects of "crowdedness", "location" and "vehicle feature (presence of stairs at the entrance)" on stop delay are analyzed with hypothesis testing. The data, the duration of each stopping, are divided into two groups to determine the effect of each variable. In order to observe the effect of crowdedness on stop delay, the data are grouped as "peak hour" and "off-peak hour" data. By determining the effect of location, the data are separated according to observed routes, such as Bağcılar-Bakırköy and Beşiktaş-Sarıyer. The effect of the presence of the stairs at the entrance on stop delay is realized by grouping the data according to vehicles having stairs and no stairs. At the last stage, stop delay is modelled according to the number of passengers boarding and alighting with the help of regression analysis.

The study is conducted on two minibus routes, which are Bağcılar-Bakırköy and Beşiktaş-Sarıyer. At each of these routes, observations are made four times in peak hour and four times in off-peak hour, which both sum up to eight times by moving from the first until the last stations of the routes. The observations are performed in August and September 2015. The observations are recorded via video capturing; subsequently, number of stopping, stop delay, number of passengers in first station, the number of boarding-alighting passengers and the number of passengers in last station were written down by analyzing the recordings.

### 3.1. The Average of Stop Delay

Despite the fact that there are many studies about bus stop delay in the literature, the dwell time of minibus, which is a paratransit system, is not studied until so far. The averages number of stoppings of minibuses are calculated as 19 and 28 for Bağcılar-Bakırköy and Beşiktaş-Bakırköy minibus routes correspondingly. These numbers are 16 and 33 for buses that have exactly same route. On the other hand, when number of stopping is almost constant for buses during peak and off-peak hours, it is about 50% higher on minibus routes during peak hours when compared with off-peak hours.

Total stop delay of observed two minibus routes comprise 7% of travel time during peak hour, 5% of travel time during off-peak hour. This rate is moderately low compared to buses because of the inequality of number of passenger carried by two modes (bus and minibus) per trip.

On Bağcılar-Bakırköy minibus route for peak and off-peak hours, average travel time decreased from 34 min 23 s to 20 min 52 s, average number of passenger decreased from 42 to 21 passengers, number of stopping decreased from 24 to 14, and average stop delay decreased from 6.2 s to 4.4 s.

On Beşiktaş-Sarıyer minibus route during peak and off-peak hours average travel time decreased from 55 min to 44 min 40 s, average number of passenger decreased from 81 to 53 passengers, number of stopping decreased from 32 to 24, average stop delay decreased from 7.3s to 5.6 s. When peak hours data are compared with off-peak hours data it is seen that total travel time, average number of passenger, number of stopping, average stop delay decreased and average travel speed increased per trip.

In Table 2, on the observed two minibuses route, the average of travel times, the number of boarding and alighting passengers, the number of stoppings to board and alight passengers, the average time which is lost in each stops are shown. In Figure 2, the histogram of the stop delay is given.

**Table 2.** Observed Two Minibuses Routes' Data

| Route | Crowdedness | Route Length (km) | Average Travel Time | Average Number of Board. & Alight. Pass. | Average Number of Stopping | Averag e Stop Delay (s) |
|---|---|---|---|---|---|---|
| Bağcılar-Bakırköy | Peak | 6.7 | 34 min 23 s | 42 | 24 | 6.2 |
| | Off-peak | 6.7 | 20 min 52 s | 21 | 14 | 4.4 |
| Beşiktaş-Sarıyer | Peak | 18.0 | 55 min | 81 | 32 | 7.3 |
| | Off-peak | 18.0 | 44 min 40 s | 53 | 24 | 5.6 |

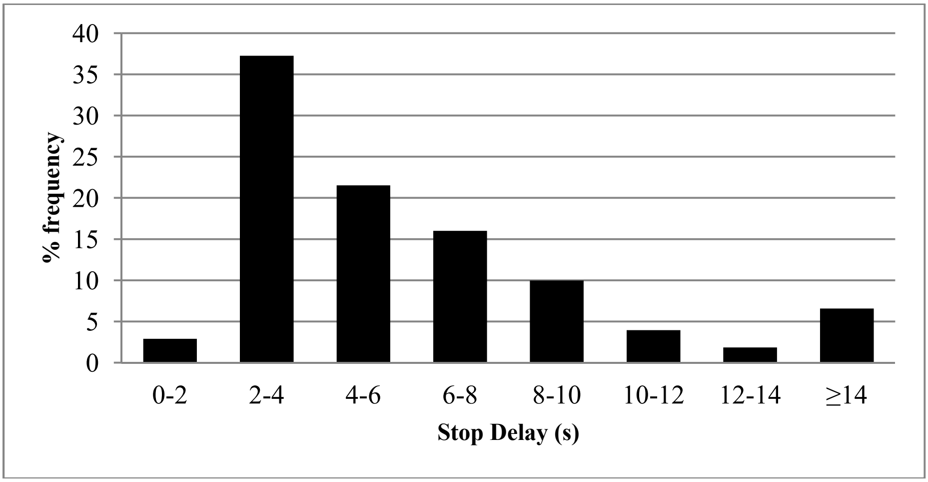


**Figure 2.** Histogram of the Stop Delay

### 3.2. The Efficiency of Crowdedness in Stop Delay

In peak hours, the average of minibus stop delay is 6.82 s, its standard deviation is 5 s; in off-peak hours, the average of stop delay is 5.14s, its standard deviation is 3.83 s. The stop delays during peak and off-peak hours are compared statistically with the help of hypothesis t-test in order to determine crowdedness effect. Calculated t-value is 3.69, while t-critical at 10% level of significance is 1.65, which leads us to the rejection of null hypothesis. It is concluded that stop delays change during peak hours compared to off-peak hours. In Figure 3, the histograms of the stop delay for peak and off-peak hours are presented.

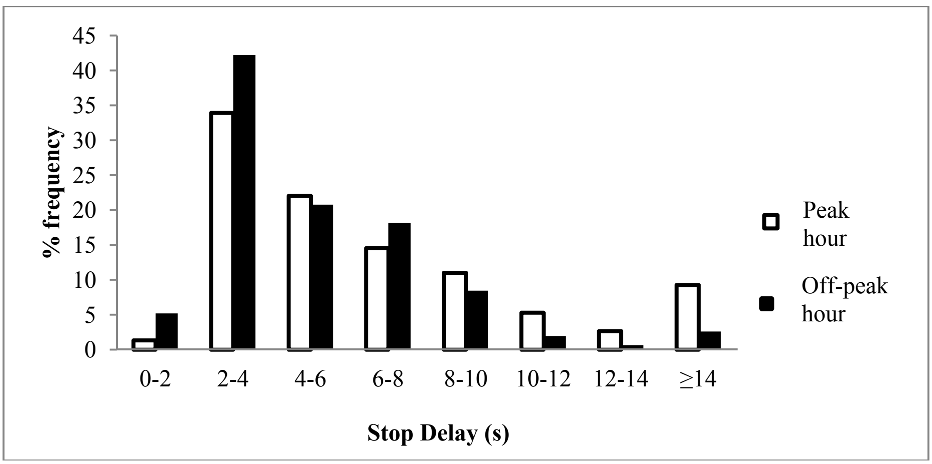


**Figure 3.** Histogram of the Stop Delay for Peak and Off-Peak Hours

### 3.3. The Efficiency of Location in Stop Delay

The average stop delay on Bağcılar-Bakırköy minibus route is calculated as 5.51 s while it is equal to 6.57 s on Beşiktaş-Sarıyer minibus route. Their standard deviations are 3.31 s and 5.31 s respectively on Bağcılar-Bakırköy and Beşiktaş-Sarıyer routes. When calculated t-test statistic of two minibus routes which is equal to -2.39 is compared with t-critical at 10% level of significance (-1.65), it is determined that stop delay changes according to routes statistically. Histograms of the stop delay on Bağcılar Bakırköy and Beşiktaş-Sarıyer minibus routes are shown in Figure 4.

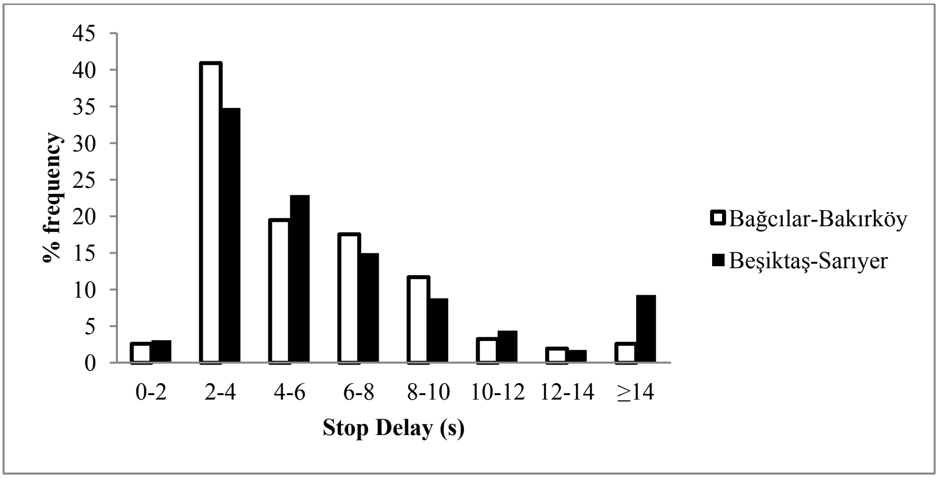


**Figure 4.** Histogram of the Stop Delay on Bağcılar-Bakırköy and Beşiktaş-Sarıyer Minibus Routes

### 3.4. The Efficiency of Minibuses With and Without Staired in Stop Delay

It is calculated that in the minibuses with staired, the average of stop delay is 7.20 s, the standard deviation is 5.11 s; on the other hand, in the minibuses without staired, the average of stop delay is 5.12 s, with 1.49 s standard deviation. Hypothesis t-test is applied for minibuses with and without staired in order to analyze the statistical difference. As calculated t-statistic (4.46) is greater than t-critical value (1.65), it is concluded that the presence of stairs at the entrance effects stop delay. In Figure 5, the histograms of stop delay for minibuses with and without staired are presented.

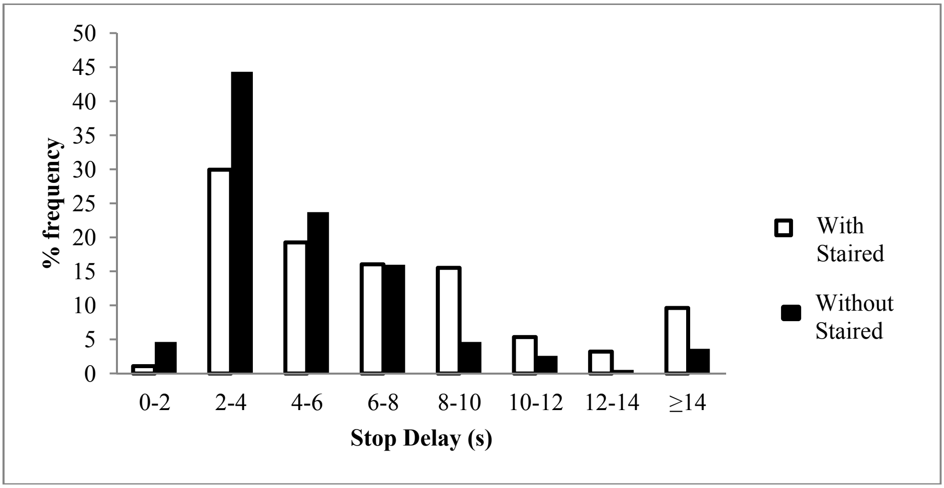


**Figure 5.** The Histogram of the Stop Delay For Minibuses With and Without Staired

### 3.5. The Efficiency of Total Number of Boarding and Alighting Passenger in Stop Delay

Relationships between stop delay and number of boarding and alighting passengers on Bağcılar-Bakırköy and Beşiktaş-Sarıyer minibus routes are shown Figure 6 and 7 respectively. This relationship is given in Figure 8 for aggregated data of both minibus routes.

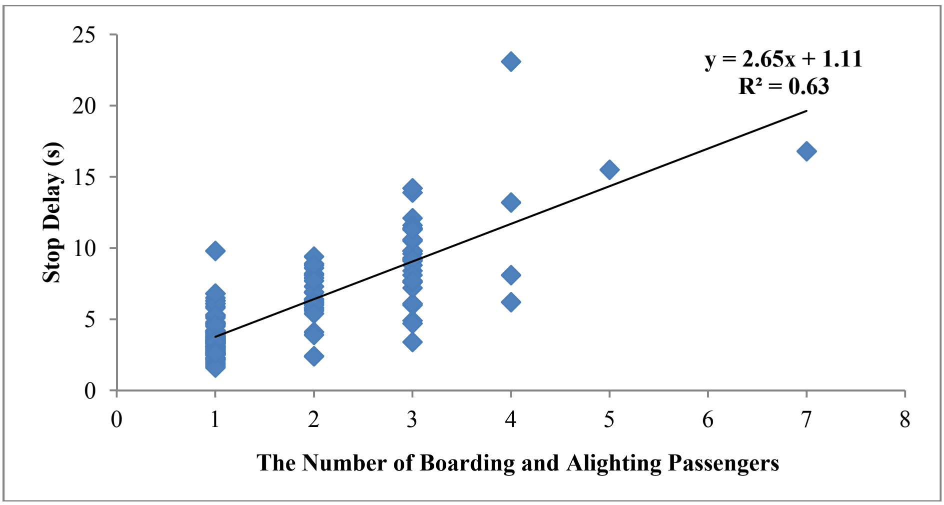


**Figure 6.** Relationship between Stop Delay and Number of Boarding and Alighting Passenger on Bağcılar-Bakırköy Minibus Route

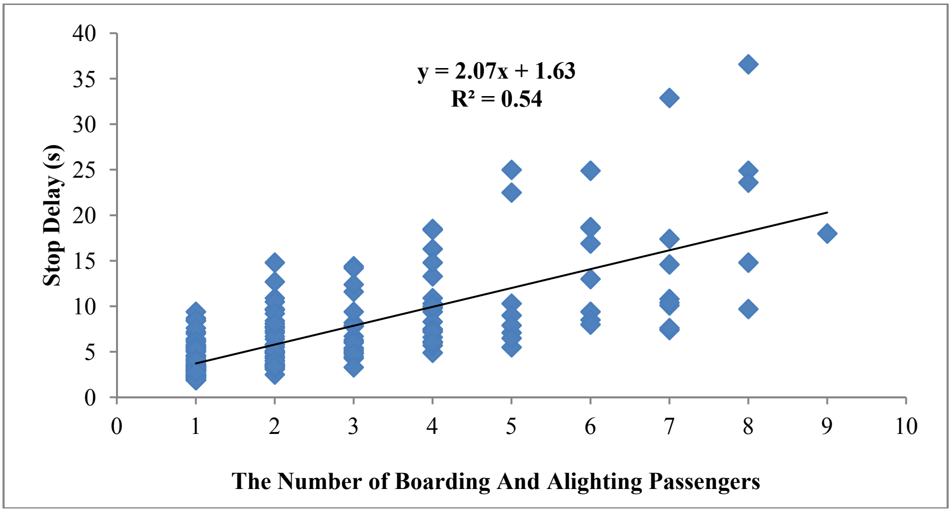


**Figure 7.** Relationship between Stop Delay and Number of Boarding and Alighting Passenger on Beşiktaş-Sarıyer Minibus Route

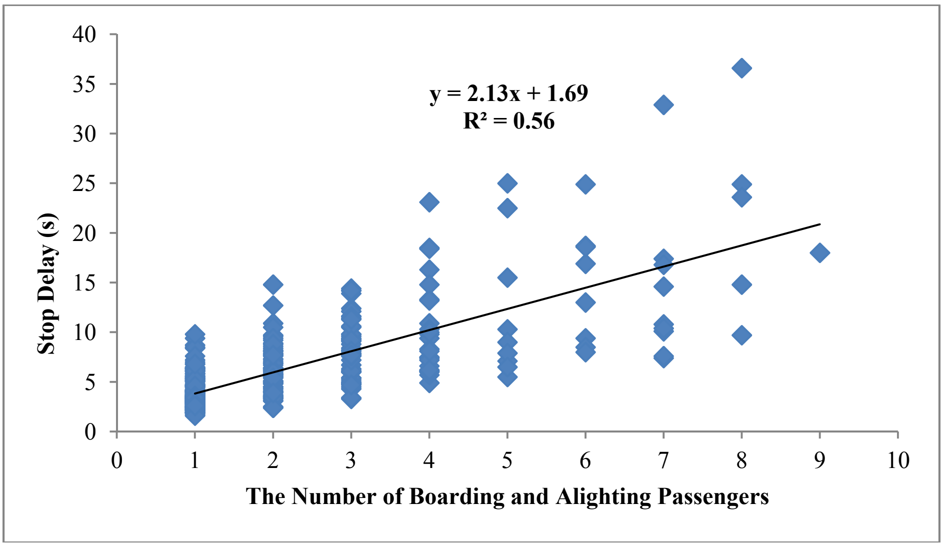


**Figure 8.** Relationship between Stop Delay and Number of Boarding and Alighting Passenger on Both Minibus Routes

## 4. CONCLUSION

The efficiencies of "crowdedness", "location", "with and without staired" in stop delay are studied on two minibus routes in İstanbul, and it is concluded that these three variables affect the stop delay.

It is observed that the stop delay increases with crowdedness; it is 4.4 s when average number of passengers is 21, and 6.2 s when average number of passengers is 42 on Bağcılar-Bakırköy route. Similar increase is observed on Beşiktaş-Sarıyer route, while it is 5.6 s with 53 passengers and 7.3 s with 81 passengers in average.

It is determined that the stop delay is not constant for observed two minibus routes when peak and off-peak hours data are compared separately.

It is concluded that the presence of the stairs at the entrance increases stop delay dramatically. 40% increase (from 5.12 s to 7.20 s) is observed for staired minibuses. Moreover, the standard deviation similarly increases in the case of stairs.

Relation between stop delay and number of boarding and alighting passengers on Bağcılar-Bakırköy and Beşiktaş-Sarıyer minibus routes are modelled with linear regression method. It is found that dead time is 1.69 s and delay stop increases 2.13 s per passenger. The explained variation by the model is determined as 0.56.

In addition to these three analyzed variables, the effects of "weather conditions", "road condition", "number of standee" on the stop delay can be studied in further studies. It is possible to develop a powerful model for İstanbul minibus lines by increasing the sample size. Bus and minibus lines having the same route can be compared in terms of average travel time, average number of boarding and alighting passengers and average stop delay to determine the strengths and weaknesses of these two transportation modes.

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