Investigating the Factors Affecting Bus Dwell Time, Case Study: Ardabil, Iran

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Abstract

Bus dwell time, especially in developing countries like Iran, is one of the most important factors to improve the total bus travel time, because of the high usage rate of public transportation on daily travels. This study aims to investigate the factors that affect bus dwell time, in Ardabil, Iran. The investigation was conducted among 1,267 buses, at 66 bus stops, while 20 of them are located in Central Business District (CBD) and 46 in Non-CBD. The results of data analysis showed that average bus dwell time is higher in CBD compared to Non-CBD (32.3 sec and 17.2 sec, respectively) and passengers which pay their fare with cash lead to increase the bus dwell time 2.09 and 2.22 sec/pass in CBD and Non-CBD, respectively. Two different multi regression models were estimated for two districts with regard to specified variables such as the number of boarding and alighting passengers through each door, the bus floor status, the number of passengers which used cash to pay the fare, the bus congestion and the stop congestion.

Keywords – Dwell time, Boarding, Alighting, Central/Non-Central Business District,

1. Introduction

Many countries have been facing with traffic congestion challenges because of increasing population and car ownership; correspondingly, encouraging people to use public transportation rather than private car can lead to decrease the congestion and its related problems. Travel time is one of the most important components of choosing a public transportation mode, and time saving, one of the most crucial parameters of public transportation quality, is often claimed to be the greatest benefit of transportation systems. Hence improving the travel time of public transportation systems will improve their usage dramatically.

The bus travel time consists of two components such as running time and dwell time. Dwell time is believed to cumulate from 26% to 50% of the total travel time of buses[1, 2], therefore variation of dwell time can largely affect the accuracy of travel time prediction. Hence, understanding the nature of dwell time and contribution factors would help to improve the reliability of public transportation systems.

The aim of this study is to investigate and evaluate the factors that affect bus dwell time in Ardabil, Iran and estimate bus dwell time models with regard to specified factors. These factors are related to the properties of buses, number of passengers and operating conditions.

2. Literature Review

The Transit Capacity and Quality of Service Manual [3], defined the bus dwell time as the duration of time of the transit vehicle stopped for serving passengers. It includes the total passenger boarding and alighting times and the time needed for the bus to open and close doors. As the door opening and closing times are generally constant, for a specific bus, the number of boarding and alighting at bus stops are likely the most significant factor causing dwell time variation. The factors contributing to dwell time are the bus floor status, the in-bus congestion level, the fare collection method, the time of the travel, the bus stop crowdedness or the weather conditions[1, 4, 5, 6].

In current practical engineering applications, more attention should be paid to evaluate the bus dwell time, because of its obvious effects on traffic flow [7], public transportation trip time [8], public transportation service reliability [9]and public transportation assignment [10]. It is likely that, dwell time is one of the most important factors should be considered to improve the performance and service quality of the urban traffic system [11].

Levinson (1983) conducted one of the earliest studies on bus dwell time estimation. He estimated the bus dwell time with respect to the number of boarding and alighting passengers and the time required for bus doors opening and closing. Guenthner and Hamat (1988) in the other study [12] investigated the relationship between the bus dwell time and bus fare collection system. Dueker et al. (2004) analyzed determinants of dwell time such as passenger activity, lift operations, bus floor status, time of day and route type. He[13] found that the lift operation would increase the bus dwell time significantly although its occurrence is rare. Tirachini (2013) studied the influence of different payment methods, the existence of steps at doors, the age of passengers and the possible friction between users boarding, alighting and standing in dwell time. Fletcher and El-Geneidy (2013) attempted to determine the influence of crowding and fare payment on dwell time. The crowding significantly increased dwell time after approximately 60% of bus capacity was surpassed.

3. Data Collection

The dwell time of 1,267 buses have been investigated during July and August, 2016 in Ardabil, Iran. Data were gathered at 33 different locations while 10 of them are located in CBD and 23 in Non-CBD, as shown in Figure 1. At each location, there are two bus stops at each direction.

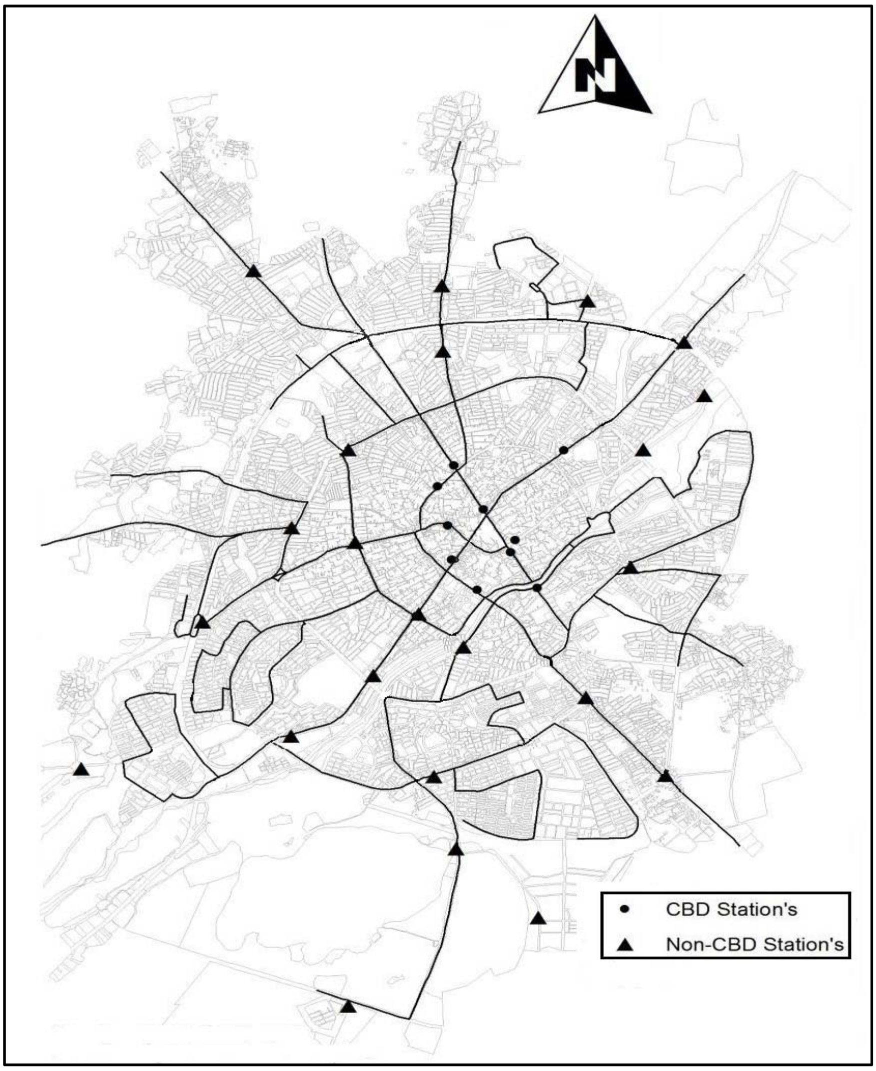

Figure 1: The locations of bus stops where data were gathered

Ardabil is one of the developing cities in Iran which needs several improvements in its public transportation systems. Traditionally because of the cheap oil price, people were accustomed to use private care or taxi for their daily trips; however, in the last few years, with tremendous increase of oil price in Iran and subsequently increase in taxi fares, people get more intensive to use alternative public transportation modes like buses, which are cheaper than taxies.

All the buses in Ardabil have two doors and divide the bus into two separate parts, such that front half of the bus belongs to men and back half of the bus belongs to women. So men using the front door for their boarding/alighting and women using the back door for their boarding/alighting. Passengers are free to pay the fare by electronic cards or by cash. The Electronic card machine is available in both front and back door. In order to encourage passengers to use electronic payment method, the cash fare is 30% more expensive than card fare. Men pay their fare while they board and women pay while they alight additionally if a woman wants to pay cash after alighted, she must go to the front door to pay the fare to the driver.

The dwell time data were collected manually by observers equipped with stop watch, who were recorded the bus dwell time, the number of boarding and alighting passengers, their fare payment methods, the bus floor status, the in-bus congestion level and the number of waiting passengers at stop before bus arrival. Since Ardabil's bus systems operated by private operators, sometimes especially in CBD, buses wait more than usual to pick up more passengers. In this case, the time at which the door would have been closed under normal circumstances was estimated and the extra waited time of bus had noted separately.

4. Data Analysis

The variables that affect bus dwell time are determined as the number of boarding and alighting passengers through each door, the fare payment method, the in-bus congestion level, the bus floor status and the number of waiting passengers at bus stops.

The bus dwell time is considered as the time that a bus stops to serve passengers. The number of men and women which board and alight from front and rear doors (respectively) are determined as initial independent variables. In order to evaluate the effects of bus congestion on operating condition, the congestion of each bus is recorded by using two levels such as; all of seats are taken and almost half of the aisle occupied by standees, while near side of the doors for boarding and alighting are empty (congestion level 1); more than half of the aisle and especially near side of the doors for boarding and alighting are almost occupied by standees (congestion level 2). In order to determine the effect of bus properties on dwell time, the bus floor height is investigated. Buses are distinguished in two types such as high floor and low floor. In the high floor buses, there are two steps at the near side of the doors. In the low floor bus, there are no steps next to the doors. In order to evaluate the effects of bus stop congestion on bus dwell time, number of existing passengers before bus arrival in each stop is analyzed.

The number of observed buses in Non-CBD and CBD are shown in Table 1. As it can be seen from Table 1, in Non-CBD almost 82% of data were gathered in high floor buses while in CBD, almost 74% of data belongs to high floor buses.

Table 1: Number of Observed Buses in CBD and Non-CBD

	Low Floor		High Floor		Total
	Congestion Level 1	Congestion Level 2	Congestion Level 1	Congestion Level 2	
Non-CBD	67	37	364	114	582
CBD	109	68	316	192	685
Total	176	105	680	306	1267

Tables 2 and 3 show the descriptive statistics of recorded data with regard to determined variables (exclude bus stop congestion) for Non-CBD and CBD, respectively. As it can be seen from Table 2, in Non-CBD almost 22% of passengers paid their fare with cash, while in CBD, given in Table 3, almost 17% of passengers paid with cash.

Table 2: Descriptive Statistics of Bus Dwell Time in Non-CBD

		Front Door (Men)		Rear Door (Women)		Payment		Total
		Boarding	Alighting	Boarding	Alighting	Cash	Card	
Low Floor	Congestion Level 1	37	43	59	68	45	162	207
	Congestion Level 2	46	60	49	52	30	177	207

High Floor	Congestion Level 1	238	229	380	305	255	1074	1152
	Congestion Level 2	133	89	134	171	117	410	527
Total		454	421	622	596	447	1646	2093

Table 3: Descriptive Statistics of Bus Dwell Time in CBD

		Front Door (Men)		Rear Door (Women)		Payment		Total
		Boarding	Alighting	Boarding	Alighting	Cash	Card	
Low Floor	Congestion Level 1	117	164	255	327	144	719	863
	Congestion Level 2	140	227	193	278	127	711	838
High Floor	Congestion Level 1	553	426	930	679	462	2126	2588
	Congestion Level 2	392	452	741	903	351	2137	2488
Total		1202	1269	2119	2187	1084	5693	6777

The statistics of dwell time data are given in Table 4 for Non-CBD and CBD separately. As it can be seen in Table 4, the mean value of bus dwell time in CBD (32.3 sec) is almost two times higher than the average dwell time in Non-CBD (17.2 sec).

Table 4: Statistics of Bus Dwell Times

Statistics	Non-CBD	CBD
Mean	17.2	32.3
Median	16.2	27.8
Sta. Dev.	8.6	18.8
Skewness	1.1	1.4
Kurtosis	1.6	2.6
Max	57.6	116.8
Min	5.2	5.2
Q_1	10.5	18.60
Q_3	21.4	40.70
IQR	10.9	22.10

In order to analyze how the considered independent variables effect bus dwell time, two multiple regression models are developed for CBD and Non-CBD, separately. With regard to the fact that if a qualitative variable has m levels, then m - 1 quantitative variables would be required, the independent variables of bus dwell time in CBD and Non-CBD are given in Table 5.

Table 5: Independent Variables in Bus Dwell Time Model

Variable	Regressor	Explanation
Number of Boarding from Front Door (Men)	X1	-
Number of Alighting from Front Door (Men)	X2	-
Number of Boarding from Rear Door (Women)	X3	-
Number of Alighting from Rear Door (Women)	X4	-
Floor status	X5	1, if high floor 0, if low floor
Number of Cash payments	X6	-
In-Bus Congestion	X7	1, if level 1 0, if level 2
Stop Congestion	X8	-

Both models are estimated with stepwise multiple regression by adding independent variables one by one with regard to their correlation with the dependent variable.

4.1. Non-CBD Bus Dwell Time Multi Regression Model

In order to estimate the bus dwell time with stepwise multiple regression, all of the independent variables are added to models one by one with regard to their correlation with the dependent variable. After the correlation coefficients of all independent variables with dependent variable are calculated, initially the independent variable that has the biggest correlation with dependent variable will be chosen and a regression model will be estimated. At the next step, the second independent variable which has the second biggest correlation with dependent variable will be added to the first chosen variable, and a new regression model with these two variables will be estimated. Adding a new variable must increase the adjusted R-square value; otherwise regression model will be stopped at this step. This procedure will continue until there is no increase on adjusted R-square. Table 6 shows the correlation matrix of bus dwell time in Non-CBD. Second column shows the correlation of each independent variable with the dependent variable. With regard to absolute values of their correlation coefficients, the order of adding variables to multiple regression model will be X6, X4, X8, X3, X2, X1, X7 and X5. Regression statistics of all eight steps are shown in Table 7.

Table 6: Correlation Matrix of Bus Dwell time in Non-CBD

	Y	X1	X2	X3	X4	X5	X6	X7	X8
Y	1.000								
X1	0.300	1.000							
X2	0.368	-0.170	1.000						
X3	0.400	-0.143	0.394	1.000					
X4	0.514	0.237	-0.114	-0.154	1.000				
X5	0.002	-0.007	-0.107	0.002	-0.034	1.000			
X6	0.619	0.272	0.199	0.114	0.508	0.021	1.000		
X7	-0.293	-0.198	-0.134	-0.058	-0.178	0.102	-0.115	1.000	
X8	0.453	-0.064	0.674	0.700	-0.041	-0.124	0.183	-0.214	1.000

At each step of multiple regression, adding a new variable, resulted to increase the adjusted R-square value, correspondingly the final regression model is estimated with the help of eight independent variables. The regression statistics of final model, are shown at Table 8.

Table 7: Regression Statistics of Non-CBD bus Dwell Time Multi Regression Model

Step 1: X6, Y		Step 2: X6, X4, Y	
Multiple R	0.619	Multiple R	0.661
R Square	0.384	R Square	0.437
Adjusted R Square	0.383	Adjusted R Square	0.435
Standard Error	6.785	Standard Error	6.490
Observations	582	Observations	582

Step 3: X6, X4, X8, Y		Step 4: X6, X4, X8, X3, Y	
Multiple R	0.766	Multiple R	0.789
R Square	0.587	R Square	0.622
Adjusted R Square	0.585	Adjusted R Square	0.620
Standard Error	5.562	Standard Error	5.325
Observations	582	Observations	582

Step 5: X6, X4, X8, X3, X2, Y	
Multiple R	0.799
R Square	0.638
Adjusted R Square	0.635
Standard Error	5.216
Observations	582

Step 6: X6, X4, X8, X3, X2, X1, Y	
Multiple R	0.826
R Square	0.682
Adjusted R Square	0.678
Standard Error	4.897
Observations	582

Step 7: X6, X4, X8, X3, X2, X1, X7, Y	
Multiple R	0.831
R Square	0.690
Adjusted R Square	0.686
Standard Error	4.836
Observations	582

Step 8: X6, X4, X8, X3, X2, X1, X7, X5, Y	
Multiple R	0.832
R Square	0.692
Adjusted R Square	0.688
Standard Error	4.823
Observations	582

Table 8: Regression Coefficients of Non-CBD Bus Dwell Time

	Coefficients	Standard Error	t Stat	P-value
Intercept	9.17	0.70	13.09	0.00
X1	1.48	0.18	8.13	0.00
X2	1.81	0.25	7.26	0.00
X3	1.89	0.18	10.33	0.00
X4	2.38	0.17	13.86	0.00
X5	1.09	0.53	2.04	0.04
X6	2.09	0.24	8.65	0.00
X7	-1.99	0.49	-4.08	0.00
X8	0.03	0.16	0.17	0.86

The final estimated model for Non-CBD bus dwell time is as Equation 1:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 \quad (1)$$

Where:
Y: Bus dwell time in Non-CBD (sec)
b_0: Intercept
$X_1, X_2, X_3, X_4, X_5, X_6, X_7$ and X_8: Independent variables as defined in Table 5
$b_1, b_2, b_3, b_4, b_5, b_6, b_7$and b_8: Regression coefficients as shown in Table 8

From the developed multi regression model, it is conducted that:

- Intercept value is equal to 9.17 sec, which represents dwell time of low floor bus when in-bus congestion level is equal to 2.
- Women boarding and alighting result in long dwell times than men. In the case of a woman passenger boarding, the dwell time is 0.41 sec higher compared to a man passenger. This increase is 0.57 sec for alighting.
- High floor buses have 1.09 sec longer dwell times than low floor buses.
- Each passenger cash payment instead of electronic card payment increases the dwell time 2.09 sec.
- With increase of in-bus congestion level from one to two, dwell time increases 1.99 sec.
- Bus stop congestion leads to increase bus dwell time extremely low (0.03 sec per passenger in bus stop).

4.2. CBD Bus Dwell Time Multi Regression Model

The whole process of estimating bus dwell time model in CBD is same with Non-CBD. First, with regard to the correlation matrix, the order of independent variables that will be added to regression model are determined. Eight independent variables are added to the model one by one. Similar to model developed for Non-CBD, adjusted R-square increases at each step correspondingly. Table 9 shows the correlation coefficients matrix of CBD bus dwell time. Second column, is the correlation of each independent variable with dependent variable. With regard to absolute values of second column, the order of adding variables will be X4, X3, X6, X2, X7, X1, X8 and X5. Regression statistics of all eight steps are shown in Table 10.

Table 9: Correlation Matrix of Bus Dwell time in CBD

	Y	X1	X2	X3	X4	X5	X6	X7	X8
Y	1.000								
X1	0.323	1.000							
X2	0.428	0.123	1.000						
X3	0.488	0.323	-0.028	1.000					
X4	0.560	-0.009	0.303	0.058	1.000				
X5	0.091	0.083	-0.096	0.094	-0.035	1.000			
X6	0.429	0.087	0.254	-0.030	0.488	0.047	1.000		
X7	-0.336	-0.108	-0.274	-0.113	-0.310	0.006	-0.199	1.000	
X8	0.307	0.344	0.052	0.535	0.167	-0.002	-0.023	-0.117	1.000

As it can be seen in Table 10, all of eight independent variables increase the adjusted R-square value in comparison to the previous step; so the final multi regression model of bus dwell time in CBD is estimated with all of eight independent variables. The final estimated model for passenger alighting service time will be as Equation 2:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 \quad (2)$$

Where:

Y: Bus dwell time in CBD (sec)

b_0: Intercept

$X_1, X_2, X_3, X_4, X_5, X_6, X_7$ and X_8: Independent variables as defined in Table 5

$b_1, b_2, b_3, b_4, b_5, b_6, b_7$and b_8: Regression coefficients as shown in Table 11

All coefficients in Table 11 and the intercept can be interpreted as below:

- Intercept value is equal to 8.65 sec, which represents dwell time of low floor bus when in-bus congestion level is equal to 2.
- Women boarding results in long dwell times than men. For a woman passenger boarding, dwell time is 1.25 sec higher compared to a man passenger.
- High floor buses have 2.84 sec longer dwell times than low floor buses.
- Each passenger cash payment instead of electronic card payment increases dwell time 2.07 sec.
- With increase the in-bus congestion level from one to two, dwell time 2.22 sec increases.

- In the case of bus stop congestion, in Table 9 the correlation of X8 and Y is positive but in Table 11 the sign of this coefficient is negative; so because of this conflict between the signs this coefficient is must be eliminated.

Table 10: Regression Statistics of CBD Bus Dwell Time Multi Regression Model

Step 1: X4, Y		Step 2: X4, X3, Y	
Multiple R	0.560	Multiple R	0.722
R Square	0.314	R Square	0.521
Adjusted R Square	0.313	Adjusted R Square	0.520
Standard Error	15.561	Standard Error	13.004
Observations	685	Observations	685
Step 3: X4, X3, X6, Y		**Step 4: X4, X3, X6, X2, Y**	
Multiple R	0.752	Multiple R	0.799
R Square	0.565	R Square	0.638
Adjusted R Square	0.563	Adjusted R Square	0.636
Standard Error	12.402	Standard Error	11.328
Observations	685	Observations	685
Step 5: X4, X3, X6, X2, X7, Y		**Step 6: X4, X3, X6, X2, X7, X1, Y**	
Multiple R	0.801	Multiple R	0.811
R Square	0.642	R Square	0.657
Adjusted R Square	0.639	Adjusted R Square	0.654
Standard Error	11.279	Standard Error	11.041
Observations	685	Observations	685
Step 7: X4, X3, X6, X2, X7, X1, X8, Y		**Step 8: X4, X3, X6, X2, X7, X1, X8, X5, Y**	
Multiple R	0.812	Multiple R	0.815
R Square	0.660	R Square	0.664
Adjusted R Square	0.656	Adjusted R Square	0.660
Standard Error	11.002	Standard Error	10.941
Observations	685	Observations	685

Table 11: Regression Coefficients of CBD Bus Dwell Time

	Coefficients	Standard Error	t Stat	P-value
Intercept	8.65	1.35	6.40	0.00
X1	1.26	0.22	5.77	0.00
X2	2.26	0.21	10.77	0.00
X3	2.51	0.15	16.72	0.00
X4	2.04	0.15	13.36	0.00
X5	2.84	0.97	2.92	0.00
X6	2.07	0.32	6.38	0.00
X7	-2.22	0.93	-2.38	0.02
X8	-0.17	0.07	-2.26	0.02

5. Conclusions

In this study two bus dwell time models for Non-CBD and CBD in Ardabil, Iran, have been developed with regard to the contribution of different variables. The dwell time models established in this study includes the number of boarding/alighting passengers through each door, bus floor status, in-bus congestion level, cash payment methods and bus stop congestion.

The results showed that the models could explain relatively high percentage of the variation of the data, based on the R-square values (0.692 and 0.664 for Non-CBD and CBD models, correspondingly). Being able to predict bus dwell time will enable operators to improve the schedule planning and overall bus reliability.

Almost 80% of observed buses, are high floor buses that have high dwell time than low floor buses. Replacement of high floor buses with low floor buses will decrease dwell time in Ardabil.

Cash payment leads 2.09 and 2.07 sec more dwell time, per passenger in Non-CBD and CBD, respectively. Especially in congested buses and when the number of boarding and alighting passengers are high, cash payments cause extremely high time wasting. Cancelation of cash payments and substituting it with electronic card payments, has quite important positive effect on bus dwell time.

In-bus congestion increase, in both districts, leads to increase the bus dwell time which is due to passenger’s friction in boarding and alighting processes. Bus stop congestion in Non-CBD results in extremely low increase (0.03 sec per passenger in bus stop) in bus dwell time, while in CBD it results in bus dwell time decrease (0.17 sec per passenger in bus stop).

References

[1] R. Fernandez, P. Zegers, G. Weber and N. Tyler, "Platform Height, Door Width and Fare Collection on Bus Dwell Time. Laboratory Evidence for Santiago de Chile," vol. No. 214, 2010.

[2] H. S. Levinson, "Analyzing Transit Travel Time Performance," *Transportation Research Record*, vol. 915, pp. 1-6, 1983.

[3] Transportation Research Board, "Transit Capacity and Quality of Service Manual," National Research Council,, Washington DC., 2013.

[4] L. Sun, A. Tirachini, K. W. Axhausen, A. Erath and D. Lee, "Models of Bus Boarding and Alighting Dynamics," *Transportation Research Part A*, vol. 69, p. 447–460, 2014.

[5] G. Fletcher and A. El-Geneidy, "The Effects of Fare Payment Types and Crowding on Dwell Time: A Fine-Grained Analysis," *Transp. Res. Rec.: J. Transp. Res. Board* , no. 2351, p. pp. 124–132., 2013.

[6] A. Tirachini, "Bus Dwell Time: The Effect of Different Fare Collection Systems, Bus Floor Level and Age of Passengers," *Transport Metrica A: Transp. Sci.*, vol. 9, p. pp. 28–49., 2013.

[7] Y. S. Qian, P. J. Shi, Q. Zeng, C. X. Ma, F. Lin, P. Sun and H. L. Wang, "A Study on the Effects of the Transit Parking Time on Traffic Flow Based on Cellular Automata Theory," *Chinese Physics B*, vol. 19, no. 4, pp. pp. 048201-5., 2010.

[8] R. L. Bertini and A. M. El-Geneidy, "Modelling Transit Trip Time Using Archived Bus Dispatch System Data," *J. Transportation Engineering, ASCE* , vol. 130, pp. pp. 56-67., 2004.

[9] A. M. El-Geneidy, J. Horning and K. J. Krizek, "Analyzing Transit Service Reliability Using Detailed Data from Automatic Vehicular Locator System," *J.*

Adv. Transpor, vol. 45, pp. pp. 66-79, 2011.

[10] H. Z. Aashtiani and H. Iravani, "Application of Dwell Time Functions in Transit Assignment Model," in *Transpor. Res. Board Natl. Res. Council, pp. 88-92.*, Washington, 2002.

[11] S. Jinxing and L. Wenquan, "Cluster Analysis of Larger-Scale Discrete Data with Application to Estimating Dwell Time of Bus Rout," *Pakistan Journal of Statistics*, vol. 29, no. 5, pp. pp. 873-886, 2013.

[12] R. P. Guenthner and K. Hamat, "Transit Dwell Time under Complex Fare Structure," *J. Transp. Eng*, vol. 114, p. pp. 279–367, 1988.

[13] K. Dueker, T. Kimpel and J. Strathman, "Determinants of bus dwell time," *Journal of Public Transportation*, vol. 7, no. 1, pp. pp. 21-40, 2004.