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TRAMWAY DWELL TIME ESTIMATION AND ANALYSIS BY USING MULTIPLE LINEAR REGRESSION METHOD

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ABSTRACT

Dwell time is a significant issue to designate the accurate arrival time and scheduling public transportation system in cities. In the literature, dwell time of bus or light rail transit was studied, but studies focusing on Tramway dwell time are rare. Tramway is one of the most common public transportation systems around the world. In this paper, the Tramway dwell time is modeled by using multiple linear regression analysis. The data are collected from the kabataş bağcılar tramway in Istanbul-Turkey. The line covers a lot of touristic allocations and important locations in the city and generally the passenger demand is very high. The number of observations from eleven stations of this line is 171. Two separate models for weekdays and weekends include wagon occupancy, platform occupancy, the number of people who are alighting and boarding, time spent by the driver and peak hours and off-peak hours on weekdays and on weekends. The results show that between the dummy variables, the platform occupancy in the high level has more influence on tramway dwell time than wagon occupancy in the high level on weekdays, but it is vice versa on weekends. Between continues variables, in both weekdays and weekends models, the time spent by the driver has the most impact on tramway dwell time. The number of passengers who are alighting on weekdays and number of passengers who are boarding on the weekends has the least effect on the tramway dwell time. In this study, by considering the results, there are some significant policies suggested for policymakers to reduce the dwell time of tramway.

1. Introductions

In this day and age, due to urban sprawl and increasing urbanization and travel demand in metropolitan cities, a well-organized public transportation system is required. One of the public transportation systems that can be used in metropolitan cities is tramway. In general, comfort and capacity of tramway is more than the bus; also access to tramway stations is more accessible than subway stations which placed underground.

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Dwell time at stops is considered as a significant portion of travel time in transportation systems. Transportation authorities use the effect of dwell time through deigning bus, level of service and designating fare. Dwell time can be studied in various ways by different approaches. A study by Zhibin Jiang (2015) focused on crowded rail transit lines in Shanghai. Micro-simulation approach was used to simulate the passengers, train delay, and network reliability. The factors which were used in this research including the number of passengers alighting and boarding the train (Jiang, Xie, Ji, & Zou, 2015). In a study by Cen Zhang (2013) in Shanghai, China, the data is collected with automatic vehicle location (AVL) and automatic passenger counters (APC) to estimate dwell time for prediction of the arrival time. Their dwell time model included the number of passengers boarding, alighting, crowding, and fare type (Zhang & Teng, 2013). Soroush RASHIDI (2014) worked on bus dwell time of bus in Auckland, New Zealand. He used decision tree approach and find out that the passenger’s boarding time is the most significant factor that has a role in dwell time of bus (Rashidi, 2014). In a study by Fazhi LI (2012) in Changzhou, China that was about the model to predict dwell time of Bus rapid transit. They used data from a Bus Rapid Transit (BRT) vehicle, the survey conducted where BRT lines were built along passenger corridors and BRT stations were enclosed like light Rails. They have stated that dwell time depends on the number of passengers boarding and alighting, platform height, door width, fare collection method, the internal layout of vehicles, and occupancy of vehicles. They used two models for BRT station. The first model was a linear model and the second is nonlinear (Li, Duan, & Yang, 2012).

In a study by Emilio Moreno González (2012), the data is gathered by a lot of observations on Line 27 of the transports municipal company in Madrid, Spain, and they use another line data for validation (line 70) (González, Romana, & Álvaro, 2012). In general, the literature is dominated by studies related to the dwell time of Buses while a limited number of papers are present for Tramway. However, studies about the dwell time of Tramway is almost non-existent, thus in this study, Tramway dwell time is modeled by using multiple linear regressions analysis.

1.2. Dwell Time

Dwell time has different definitions in the literature. One of them is the time a transit vehicle spends at a stop for allowing passengers to alight and board. This definition does not consider the time before opening the door and the time after closing the door until starting to move [6, 7]. Moreover, in some studies, in addition to the time for alighting and boarding, the time needed for opening the doors after stopping and also the time after closing the door till moving are also added to dwell time [7, 8, 9]. Obviously, knowing the dwell time allows the planner, analyst or decision maker to predict the travel time accurately. SONG Xinghao noted that accurate prediction of bus arrival time can help for upgrading the quality of Bus-arrival-time information service and intrigue extra ridership (Xinghao, Jing, Guojun, & Qichong, 2013).

2. *Data collection*

The data used in this research is obtained by observation at the Kabataş Bağcılar tramway line at peak and off-peak hours on weekdays and on weekends. In this research, the dwell time assumed the time between the tramway stops until opening the doors, plus the time between opening and closing the doors, plus the time between closing the doors and starting to move. The wagon occupancy level, platform occupancy level, number of passengers who are alighting and boarding are observed at eleven stations located from Findikli station to Aksaray station as is shown in Figure 1. The observation days are on October 29, on October 31, on November 6 and on November 24 which are on weekdays at peak hours and off-peak hours and for weekends there is no peak hours. The observations are gathered from the tramway stations that tramway makes 16 runs including 176 stations and 6 of them are eliminated as outliers.

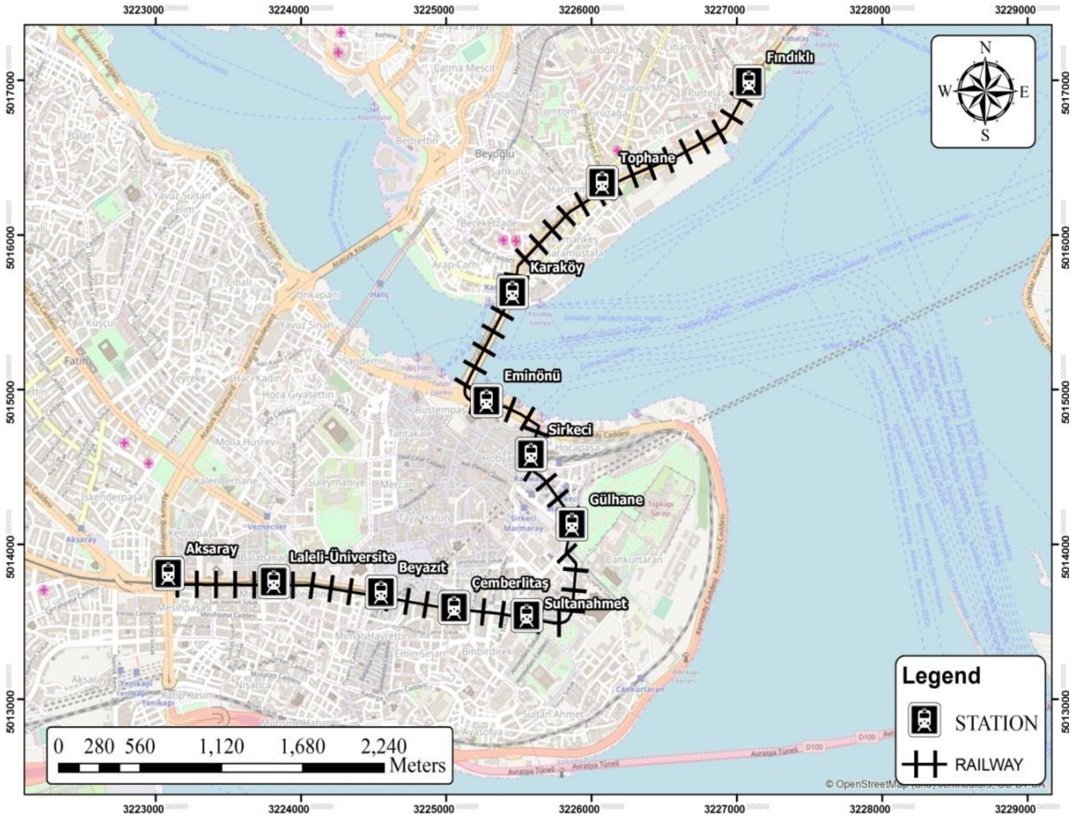

Figure 1 Eleven Stations from Fındıklı To Aksaray

3. *Data analyses*

There are eleven stations that the number and percentage of passengers alighting and boarding in each station are presented in Table 1.

Table 1 The Total Of Number Of Passengers Who Are Alighting(%) And Boarding(%) In Each Station

Station	Boarding (Passenger)	Boarding (%)	Alighting (Passenger)	Alighting (%)
Fındıklı	33	1.82	86	5.17
Tophane	73	4.02	72	4.33
Karakoy	319	17.59	152	9.15
Eminönü	177	9.76	148	8.9
Sirkeci	134	7.39	124	7.46
Gülhane	84	4.63	89	5.35
Sultanahmet	128	7.06	217	13.06
Çemberlitaş	182	10.03	210	12.64
Beyazıt	258	14.22	192	11.55
Laleli	167	9.21	224	13.48
Aksaray	259	14.28	148	8.9

As is mentioned in Table 1, slightly less than 13.48% of the passengers are alighting from Laleli station which has the highest percentage of travelers, because Istanbul University is in near this station and it can attract a lot of human beings to use it. The lowest one is close to 4.33% at Tophane station that there is no tourism or important place and it is logical that using this station is low. On the other hand, about the 17.59% of passengers are boarding at Karaköy station which is a connection station to use the ferry system that has the highest percentage as it is expected. boarding at Fındıklı station is approximately 1.82% that is the lowest one because there is not any significant or tourism place near there to use this station. The average of the number of passengers who are alighting and boarding and the average of dwell time that includes three part-time as is mentioned before in each station for the weekday at both peak hour and off-peak hour and for the weekend at the off-peak hour is stated in Table 2.

Table 2 Average of The Number of Boarding and Alighting Passengers and Dwell Time Components at Each Station According to Day And/or Time of The Observation

Station	Average											
	Board (Passenger)				Alight (Passenger)				Dwell Time (Second)			
	weekday		Weekend	Total	Weekday		Weekend	Total	Until Doors Open	Doors Stay Open	Until Start Moving	Total
	Peak Hour	Off-Peak Hour			Peak Hour	Off-Peak Hour						
Fındıklı	2.625	0.25	1.57	4.445	1.89	13.5	2.14	17.53	1.17	14.45	9.69	25.31
Tophane	5.75	1.8	3	10.55	4.75	5.75	4.6	15.1	1.19	16.31	15.45	32.95
Karaköy	30.125	6.25	7.57	43.945	9.875	6.5	6.71	23.8	1.38	19.7	4.53	25.61
Eminönü	12	9.75	9.43	31.18	6.8	10.75	9.14	26.69	1.4	18.96	4.11	24.95
Sirkeci	10.125	6	4.14	20.265	6.125	9.75	5.14	21.01	1.26	15.48	4.11	20.86
Gülhane	5.25	4.5	3	12,75	8.875	1.83	1.25	11.95	1.19	15.93	4.06	21.22
Sultanahmet	9.125	7.75	3.43	20.305	13.625	6.75	11.57	31.94	1.37	20.95	5.15	27.48
Çemberlitaş	15.625	6.25	4.57	26.445	10.75	17.5	9.4	37.65	1.17	16.54	4.12	21.82
Beyazıt	15.5	21.67	9.86	47.03	10.25	6.67	12.86	29.78	1.67	23.21	5.54	30.42
Laleli	11.125	10	5.43	26.555	18	12.5	4.28	34.78	0.97	19.21	6.79	26.96
Aksaray	14.14	18.33	15	47.47	9	14	7.43	30.43	1.33	21.95	4.84	28.11
Entire Sample	13.7	10.03	7.3	31.03	10.4	11.91	7.73	30.04	1.36	19.58	6.67	27.61

In Table 2, Fındıklı has the lowest average of the number of boarding close to 4.45 passengers and the Aksaray station has the highest one with about 48 passengers. On the other hand, Çemberlitaş has the highest average of a number of alighting close to 38 passengers and Gülhane has the lowest one with about 12 passengers. Dwell time at Tophane station is the highest average of dwell time with 32.95 seconds and the Sirkeci station has the lowest one with 20.86 seconds. There is assumed three levels of as low occupancy, medium occupancy and high occupancy. Each level of occupancy is explained in Table 3.

Table 3 Crowdedness Levels of Wagon and Platform

Level of Crowdedness in Wagon	Level of Crowdedness in Platform
Level One (Low Occupancy): When There Is No Obstacle for Alighting	Level One (Low Occupancy): When There Is No Obstacle for Alighting
Level Two (Medium Occupancy): When the Obstacle Is Medium for Alighting	Level Two (Medium Occupancy): When the Obstacle Is Medium for Alighting
Level Three (High Occupancy): When the Obstacle Is High for Alighting	Level Three (High Occupancy): When the Obstacle Is High for Alighting

The average time for each part of dwell time is designated in each level of wagon occupancy and platform occupancy on the weekday at peak hours and off-peak hours and weekend at off-peak hours in Table 4.

Table 4 Dwell Time Components Average for Each Wagon Occupancy Category, Platform Occupancy Category and Day And/or Time of The Observation

Category			Dwell Time (Second)			
			Until Doors Open	Doors Stay Open	Until Start Moving	Total
Wagon Occupancy Level	1		1.32	16.33	8.96	26.61
	2		1.59	18.9	5.54	26.03
	3		1.08	24.88	5.25	31.21
Platform Occupancy Level	1		1.41	18.21	7.28	26.9
	2		1.26	20.24	5.7	27.2
	3		1.15	26.77	4.74	32.67
Observation Day/Time	Weekday	Peak Hour	0.943	20.79	5.97	27.7
		Off Peak Hour	1.75	35.98	7.8	54.54
	Weekend		1.64	18.73	6.87	27.24

In Table 4, for wagon occupancy, the highest average of dwell time is at level 3 with 31.21 seconds and the lowest is at level 2 with 26.03 second and that is not at level 1. Because as it is seen in Table 4, average the time interval between closing the doors to start moving at level 1 is more than at level 2 which is related to the driver decision. For platform occupancy, the highest level is at level 3 with 32.67 seconds and the lowest one is at level 1 with 26.9 seconds. The highest average of dwell time is on the weekday and at off-peak hours with 54.54 seconds and the lowest one is on weekend with 27.24 seconds.

By analyzing the data, it is observed that regardless of being at peak hour or at off-peak hours when the wagon occupancy is at the low level; the platform occupancy is at the low level too. On the other hand, on weekdays at off-peak hours when the wagon occupancy is at the high level, the platform occupancy is at the low level.

The average of dwell time on weakened at off-peak hours and on the weekday at peak hours and off-peak hours for each station is stated in Table 5.

As is shown in table.5, on weekday and at off-peak hours, the highest average of dwell time is at Fındıklı station and the lowest one is at the Sirkeci station. On weekday and at peak hours the highest average of dwell time is at Beyazıt station and the lowest is at Gülhane station. On weekend and off-peak hours, the average of dwell time is the highest at Tophane station and is the lowest at Gülhane station.

Table 5 Average of Dwell Time

Stations	On Weekday and At Off-Peak Hours (Second)	On Weekday and At Peak Hours (Second)	On Weekend and Off-Peak Hours (Second)
Fındıklı	34.46	20.45	18.41
Tophane	22.43	26.04	39.93
Karaköy	19.83	26.32	20.8
Eminönü	19.49	22.4	23.13
Sirkeci	15.73	18.41	20.62
Gülhane	23.05	16.86	17.53
Sultanahmet	26.04	25.72	19.46
Çemberlitaş	16.35	20.05	20.75
Beyazıt	18.54	32.51	24.44
Laleli	17.29	28.51	23.03

Aksaray	16.72	28.05	25.02

As is shown in table.5, on weekday and at off-peak hours, the highest average of dwell time is at Fındıklı station and the lowest one is at the Sirkeci station. On weekday and at peak hours the highest average of dwell time is at Beyazıt station and the lowest is at Gülhane station. On weekend and off-peak hours, the average of dwell time is the highest at Tophane station and is the lowest at Gülhane station.

4. *Methodology*

For modeling the dwell time of Tramway, multiple linear regression analysis approaches are used to find the influence of parameters on dwell time of Tramway (Kieu, Bhaskar, & Chung, 2012). This method is used in previous studies for several of times [8, 9, 10, 11, 12, 13, 14, 15, 16, 17]. One of the first studies about using linear regression model for finding dwell time of the bus is studied by Levinson in 1983 that the alighting and boarding were used as variables to find the model (Meng & Qu, 2013). In this research, the multiple linear regression method is used for finding dwell time of tramway which is shown in Eq. (1). By using multiple linear regression approaches, two models will be made that the first one is for weekends with 63 station observations and the second one is for weekdays with 108 stations observations. Five independent variables are used in the weekend model and six variables are used in the weekday model.

Multiple Linear Regressions:

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 \quad (1)$$

Where:

Y; is a dependent variable affected by some independent variables and a constant.

B_0; is a constant which is all about the subjects which are not observed and their effect is not considered as a variable on the dwell time.

B_n: They are the coefficient of variables and if just one of the independent variables such as X_1 increases 1 unit and other independent variables are constant, Y would increase as much as B_1.

X_n; They are independent variables that are considered in the Eq. (1) that have effect on Y and their correlation with Y should be high but the correlation among each other should be low.

In the weekend model, the dwell time is assumed as the Y and the X_1 is wagon occupancy at the high level, X_2 is platform occupancy at the high level, X_3 is number of passengers who are alighting, X_4 is number of passengers who are boarding and X_5 is the time spent by driver to open the door after stopping and start to move after closing the door.

The wagon occupancy and stop occupancy data are qualitative data as it is stated in Table 3 that should be changed to be numerical one. Therefore, dummy variables are used to convert them to 0 and 1. The dwell time distribution is not normal.

Hence the Kruskal-Wallis test is used to understand the data of the two or three groups of each dummy variables are from the same population or not. when they are not from the same population, they can be separated groups and coded as zero and one. The Kruskal test results shows that for wagon occupancy in the high level, if it is at level one and level two (low and medium Occupancy) it is assumed to be equal to zero, otherwise is one. For stop occupancy, if it is at level one or level two (low and medium occupancy), it is zero; otherwise, it is equal to one. In weekday model, there are observations which are in both peak and off-peak hours, thus off-peak hour variable is considered as a dummy variable that if the observation is at the off-peak hour, it is assumed to be equal to one, otherwise zero.

Weekend Model:

There are five variables in the weekend model:

Dwell Time = B_0 + B_1 × Wagon Occupancy in The High Level + B_2 × Stop Occupancy In The High Level + B_3 × Number Of Passengers Who Are Alighting + B_4 × Number Of Passengers Who Are Boarding + B_5 × Time Spent By The Driver

Weekday Model:

There are six independent variables in the weekday model:

Dwell Time = B_0 + B_1 × Off-Peak Hour + B_2 Wagon Occupancy in The High Level + B_3 × Stop Occupancy In The High Level + B_4 × Number Of Passengers Who Are Alighting + B_5 × Number Of Passengers Who Are Boarding + B_6 × Time Spent By The Driver

By using the regression model, two models are made with the logical coefficient sign, high R^2 that is approximately 0.86 for the weekend model and about 0.62 for weekday model. Besides, the best T-Test and P-value with high correlation between dwell time and each independent variables and low correlation among the independent variables with each other are considered.

5. *Results*

Some variables such as wagon occupancy at the high level, platform occupancy at the high level, number of passengers who are alighting and boarding and time spent by the driver in the weekday model and wagon occupancy in the high level, number of passengers who are alighting and who are boarding and time spent by the driver in the weekend model are statistically significant at 90% confidence level. However, two variables are insignificant which are off-peak hour variable in weekday model, platform occupancy at the high level in weekend model. As it is shown in Table 6, the R^2 are 0.619 and 0.862 in the weekday model and weekend model respectively.

Table 6 Coefficients And T-Tests for Each Variable in The Weekend Model and The Weekday's Model

Variables	Weekday Model		Weekend (Off-Peak) Model	
	Coefficient	T-Test	Coefficient	T-Test
Intercept	15.121	9.824	13.232	10.082
Off-Peak Hour	-0.658	-0.441	-	-
Wagon Occupancy at The High Level	2.874	1.907	3.477	2.950
Platform Occupancy at The High Level	5.203	2.216	3.074	1.351
Number of Passengers Who Are Alighting	0.095	1.845	0.210	2.343
Number of Passengers Who Are Boarding	0.125	2.514	0.187	2.714
Time Spent by The Driver	1.001	11.765	1.006	18.872
R^2	0.619		0.862	
Number of Observations	108		63	

In these two models, there are two dummy variables in the weekend model and three dummy variables in weekday model and three continues variables. For comparing these variables, the dummy variables can be compared with each other which are unitless and only can be zero or one and other variables can be compared together which have the unit.

All variables except off-peak hour in weekday have coefficient with the positive sign in both models that it means they have the positive correlation with dwell time and they increase the dwell time which it is rational. The off-peak hour in the weekday model is insignificant because just 34 out of 171 observations are at off-peak hours and it has lack of variation. It has a negative correlation with the dwell time which decreases the dwell time. The wagon occupancy at the high level, because of having the bigger coefficient on the weekend model has more influence on dwell time than in the weekday model. The platform occupancy at the high level on weekend model is insignificant because it has lack of variation and just 4 out of 171 observations are at the high level. It has a less effect on the weekend model than on weekday model. The effect of platform occupancy at the high level is more than the influence of wagon occupancy at the high level in weekday model, but it is vice versa in the weekend model. The effect of the number of passengers who are alighting on weekday model is less than in the weekend model, and the impact of the number of passengers who are boarding in weekday model is less than in the weekend model. The time spent by the driver is so similar in both models because it is related to the driver effect and usually the driver acts in a similar way. Drivers sometimes wait more time to push the bottom to close the door for some passengers than the normal situation such as for elders. Between the dummy variables, the platform occupancy at the high level in weekday model and the wagon occupancy at the high level in the weekend model have the highest influence on dwell time. Between continues variables, the effect of time spent by the driver has the highest impact on dwell time than other variables in both models. The effect of the number of passengers who are alighting is less than the effect of the number of passengers who are boarding in weekday model, but it is vice versa in the weekend model. The intercept in both models is the influence of observations which are not observed or mentioned in the models on dwell time such as such as the time is spent if the passenger brings carriage or elders who board or alight slowly or disabled passengers who need more time to board or alight and some passengers who seat at the station or in the Tramway and not stand to alight or board until the doors will be open or passengers who hesitating like tourists.

Between continues variables, time spent by the driver has the highest effect on dwell time in both models. While in previous studies that are related to dwell time of the bus, it is mentioned that number of passengers who are boarding has the highest coefficient in the models [3, 5]. The other aspect of the results in previous papers about the dwell time of the bus or the light rail transit is using nonlinear regression model when the peak hour is considered as a variable in the model to get better results and when the variable is off-peak hour linear regression model is suitable for it [4, 5]. In this study, the dummy off-peak variable is used in the model and multiple linear regression methods are used and finally, the accurate results can be found by this approach.

6. *Conclusion*

In this paper, the multiple linear regression model is used to analyze and calculate the dwell time accurately and consequently the real travel time can be calculated that is conducive to make precise schedule to be used by urban planners. 171 observations are gathered from the Kabataş-Bağcılar tramway in Istanbul-Turkey which is covers 11 stations. There are some variables which have the important effect on the Tramway dwell time are considered in the models that include the number of passengers who are alighting and boarding, platform occupancy, wagon occupancy, peak hours and off-peak hours on weekdays and on weekends and time spent by the driver.

The platform occupancy at the high level has more influence on tramway dwell time than wagon occupancy at the high level on weekdays, but it is vice versa on weekends. Between continues variables, in both weekdays and weekends models, the time spent by the driver has the highest effect on Tramway dwell time. The number of passengers who are alighting in the weekday model and number of passengers who are boarding in the weekend model has the lowest impact on the dwell time. Expect the off-peak-hour variable which has a negative coefficient on weekday's model; the other variables have positive coefficients which means if they increase, the dwell time will increase and vice versa. Except the off-peak hour in weekday model and platform occupancy at the high level in the weekend model, the other variables are statistically significant at 90% confidence level.

These accurate dwell time models for tramway and having important results of their analysis can be used in planning the public transportation system to decrease the traffic in cities and make a situation to attract more passengers to use the public transportation system which is a primary aim of traffic planning engineers. For instance, policymakers can decrease the dwell time by increasing the wide and length of the platform, changing the inner design of wagon such as decreasing the number of seats to be less occupied. In addition, using the automatic button to open and close the tramway doors without driver involvement can be so efficient for reducing the dwell time of tramway. Moreover, special colored lines to indicate the place of passengers who are standing to alight or want to board can be plotted on the floor of the platform. The queue on these colored lines helps to spend less time to alight or board. In addition, the automated ticket gate can be designed that by considering the wagon occupancy, allow the passengers to pass the gate. It means when the wagon occupancy is at the high level, the ticket gate should be locked and allow the less people to pass. This helps to decreasing directly the platform occupancy and reduce the wagon occupancy and alighting and boarding time at the same time.

In the future studies, the other methods can be used in the future studies such as nonlinear regression model, fuzzy logic method, neural network method, discrete choice model to find the different levels o dwell time of tramway or other related approach. The number of observations can be more to find the better results and because of lacking study in tramway dwell time, the other study locations can be used with more variables to compare their results with the result of this paper to have more comprehensive findings for the future of transportation planning.

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