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Understanding Pedestrian Movement at Rail Transit Station Ticketing Gate

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Abstract: This study aims to assess the pedestrian movement at the ticketing gate. The study of pedestrians' speed through ticketing gates is essential for the purpose of understanding how much time that a pedestrian takes to go through a ticketing gate. The pedestrian speed through the automatic ticketing gates with various characteristics (gender, loading condition, walking condition) was identified. The data was collected at one of the rail transit station in Kuala Lumpur. The results show that the speed for all pedestrian are in the range of 30-40 m/min. The results shows that the model was fitted with only R^2 = 0.031 for peak hour and 0.024 for non-peak hour. This implies the importance of the inclusion of other factors. Based on the analysis of variance, gender has found to be the most influential factor towards pedestrian speed during non-peak hour.

Keywords: Pedestrian Movement, Rail Transit Station, Ticketing Gate

1. INTRODUCTION

High level of urbanization in a highly populated Kuala Lumpur city generates a huge amount of city commuters. Continuous growth of the city has led to the increasing demand for mobility. Thus, encouraging the development of railways infrastructure in order to ease the movement of the people, and to provide significant travel options for passengers trying to avoid roadways (Townsend et al., 2009) is needed. In Kuala Lumpur, the number of passengers traveling by rail based transportation is high due to several factors. For example, the highly connectivity of the train service and highly congested road may influence people to make the train as a major mode of transportation. Due to these reasons, the high number of passengers produces a significant number of pedestrians in the rail transit station (Liu et al., 2014). In the future, the demand for rail transit will noticeably increase; high ridership is to be expected because of the government policy to encourage ridership of the Malaysian public transportation system. Facilities have been provided and aggressive campaign has been implemented in order to reduce motorize vehicles due to many factors. For example, the city is congested with motor vehicles, the issue of oil as non-renewable energy and pollution and many more (Papadimitriou et al., 2013).

2. STATE OF ARTS

2.1. Studies on Pedestrian Speed in Closed Area at Rail Transit Station

A large proportion of pedestrians at rails transit station needs the provision of walking facilities such as proper ingress and egress gate for their safety and smooth movement (Shah et al., 2013). With the development of modern cities, the design of pedestrian facilities has become very complex. Scientific and reasonable design can ensure the safety and comfort level, as well as the pedestrian movement efficiency. On the other hand, a bad design may lead to great disasters, for instance, trampling accidents in densely populated regions (Liu et al., 2014). Previous studies by several researchers have attempted to determine several factors that are also related to this study, but have several differences such as location, variables and findings.

Pedestrians are more comfortable when walking in unidirectional flow than in a bidirectional flow (Rastogi et al., 2013). In the case of bidirectional flow, higher squeezing effect is observed towards the centre of the facility as compared to the side area. Pedestrians who are walking at the sides of the facility are mostly following their predecessors and thus walk in an orderly manner. This phenomenon suggests that pedestrians walking on sides prefer to walk in a manner that minimizes their interaction with other pedestrians (Rastogi et al., 2013). Table 1 shows a comparison of the mean speed in two different countries mainly India and China. The speed study is very informative and provides useful knowledge for research purposes since the speed is influenced by many factors. For example weather, physical condition, cultural effect and facilities that the walking activities take places (Rosenbloom, 2009).

Table 1. Comparison of pedestrian speeds at railway station in India and China

Countries	**India**	**China**
Authors	(Shah et al., 2013)	(Tang et al., 2009)
Mean speed (m/min)	38.28	43.30

2.2. Pedestrian Movement at Bottleneck Area

Bottlenecks can be seen easily in many pedestrian facilities. Bottleneck typically denominates a limited area of reduced capacity or increased demand (Zhang et al., 2014). Most typical and common example of the bottleneck for pedestrian flow is a door. At times, pedestrian facilities are encroached leading to a reduced walk through space for the pedestrians. This creates bottleneck condition with wider space available before and after the constrained location (Kretz et al., 2006). There are some observable factors in situations where pedestrians tend to slow down their step once they reach the bottleneck because perhaps they are in the process of entering smaller width of walking space. Consequently, their speed decreases as they go through the bottleneck thus affecting the level of service for that particular area (Kretz et al., 2006). Besides, pedestrian characteristics are affected by a number of attributes of pedestrian like gender and luggage condition (Shah et al., 2013).

The movement behaviors of pedestrians in the station involve various facilities such as stairways, concourse, and automatic ticketing gates. Most of the automatic ticketing gates are well-located facilities that occupy strategic spots in the station because passengers have to go through the gates before entering or exiting the station (Shah et al., 2013). Commonly, pedestrians' movement becomes slower at the automatic ticketing gates because the gates become bottleneck area for the movement of pedestrian. The design and planning approach of pedestrian walking facilities in the rail transit station must be undertaken in the context of the prevailing and future composition. Pedestrian bottleneck study has typically focused on helping planners and architects create safe, efficient and comfortable operating environments in pedestrian spaces of rail transit station. These environments nevertheless substantially share a key challenge of how to manage large volumes of people and therefore a significant of work has been concerned with understanding pedestrians' speed and evacuation events (Liu et al., 2014). Table 2 listed some studies conducted in Asia and Europe concerning the movement of pedestrian at botteleneck area and their measured variables.

Table 2. Studies related to bottleneck area and the measured variables

No	References	Location	Site	Variables
1	(Yeo et al.,2009)	Singapore City, Singapore	MRT station	Total number of pedestrian data:400 Variables 1) Age (the range of the age extracted from fare card transaction data recorded in system) 2) Gender 3) Questionnaire (to obtain the commuters' response of warning systems)
2	(Liu et al., 2014)	Hefei, China	Universitiy's playground	Total number of pedestrian data: 200 Variables: Influence of bottleneck width to; 1) Density 2) Speed
3	(Jo et al., 2014)	Chiba-ken, Japan	Full-scale compartment for experiment purposes	Total number of pedestrian data: 56 Variables: 1) Different size of corridor area 2) Flow rate (Experimental condition)
4	(Ning et al., 2010)	Nanning, China	Simulation	Variable measured: 1) Flow rate (Different size of bottleneck area in 30 runs)
6	(Kretz et al., 2006)	Duisburg, Germany	In a building at Duisburg-Essen University	Total number of pedestrian data: 94 (students) Variables: 1)Total times 2)Fluxes 3)Time gaps (10 Different bottleneck width)
7	Cek et al.2014)	Prague, Czech Republic	Full-scale room for experiment purposes	Variables: 1) Density 2) Speed 3) Flow (in front of bottleneck and at ingress and exit -2 phases)

In an emergency situation, average speed rises significantly as compared to the speed during normal condition (Jo et al., 2014). When pedestrians keep separated by a small distance when moving, they are unable to walk freely (Wu et al., 2010). The worst situation is when speed is very close to zero where step lengths are drastically reduced due to speed drop. In other words, in badly congested situation, pedestrians are forced to come almost to a stop, or otherwise, they just continue to move by letting their legs oscillate from one to the other without moving forward (Krausz et al., 2011).

With regards to the gate location, the designer also needs to take into consideration functionality requirements and space requirements while ensuring the gates do not produce major conflicting flows. Modified designs have to be established for the current situations, as well as for the future station designs (Rastogi et al., 2013). It is likely that the gates will form an active bottleneck in the station, depending on changes in local supply and demand. Supply reflects the effective capacity of the gates, depending on both the capacity of a single gate, the number of gates, and their use. Note that also secondary congestion effects may result; queues at the gates may interfere with other flows, which are either directed towards another gate or not having to pass the gates at all. These effects can have a further negative effect on the effective capacity of the gates as well as worsen traffic conditions for passengers not having to use the gates at all (Rastogi et al., 2013).

The disutility is determined as soon as a pedestrian walks into the gate area (special region near the gates). During the entire period at which the pedestrian is in this gate area, the pedestrian will determine the expected utility based on the prevailing flow conditions. When conditions change during the period of walking to a gate, a pedestrian may change his or her gate choice. It is also hypothesized that pedestrians form queues upstream of the gates, such as walking towards a specific location at the tail of the prevailing queue of the chosen gate area. Having arrived at the head of the queue, the pedestrian incurs a certain service time before passing the gate (Rastogi et al., 2013). During emergency conditions, pedestrians have sufficient opportunity to get out of the station in time. It is also interesting to note that during an emergency, the gates will open, as will special emergency doors.

Previous studies related to ticketing gate normally focus on the impact of ticketing gate on pedestrian which depend on the headway between pedestrians. However, this study attempts to understand the movement of pedestrian going through the ticketing gate in rail transit station during peak and non-peak hour for egress direction. The issue concerned in this study is related to the design of ticketing gates to enable the pedestrian movement not to be obstructed during normal situation. It is good to observe how much time a pedestrian take to go through the ticketing gate where it is crucial to understand the situation that interrupt pedestrian at ticketing gate. This is to avoid future conflict and to ease the flow in high congestion situations of pedestrian facilities (Zhang et al., 2009).

3. METHODOLOGY

3.1. The Data Collection

Data were collected at one of the rail transit station in Kuala Lumpur. The selection of the station was done because this station is one of the important stations that serve very large number of passengers daily. There are eight (8) gates available for egress direction and six (6) gates available for egress direction for both peak and non-peak hour. Data was collected for 5 days on 11th of August until the 15th of August 2014. In this study, the analysis period is on the basis of one hour for each peak and non-peak hour which are 8.00 to 9.00 am and 9.00 to 10.00 am respectively. This study involves automatic ticketing gates with fixed width of 0.53 meter and fixed length of 1.8 meters. A video observation was carried out to record the movement of pedestrian. The video was then exported to Semi-Automatic Video Analyzer (SAVA) software for further analysis. An artificial line was drawn in SAVA software to capture the speed for egress directions. The ticketing gates are design for token and contact card such as seasonal pass card or ‘Touch n Go’ card.

Figure 1. Example of automatic ticketing gates at Malaysian rail transit station

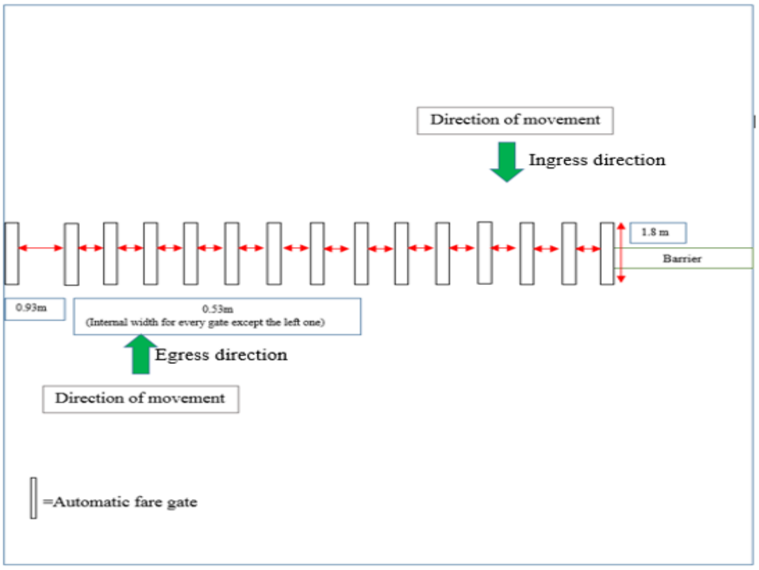

Figure 2. Sketch of study area to describe the ingress and egress direction

3.2. Description of Pedestrian Characteristics

Based on previous study, the speed of pedestrian going through a bottleneck is influence by several pedestrian characteristics such as gender and age (Townsend et al., 2009); age, gender, direction movement and luggage condition (Shah et al., 2013); speed at walkway and stairway (Wen et al., 2007) and speed with different width of bottleneck (Liao et al., 2014) . Besides that, the speed of pedestrians can also be evaluated at different facilities of rail transit station such as foyer, concourse and walkways (Hermant et al., 2010). In this study, the ticketing gate is classified as bottleneck area. Therefore, instead of generally conduct the analysis, we also introduce some variables that might have potential in influencing the speed of pedestrian at the ticketing gate. Generally, the characteristics of pedestrian were divided into three variables namely gender, walking condition and loading luggage. Their characteristics are determined as follow:

i) ***Gender:*** Identified based on male or female.
ii) ***Walking condition:*** The term rushing means the pedestrian show they are in hurry condition when going towards automatic ticketing gates.
iii) ***Loading condition:*** Identified based on pedestrians who bring luggage, bag, or backpack while walking, except for women with personal handbags.

4. DATA ANALYSIS AND DISCUSSION

4.1. Data Analysis

Table 3. Sample size of pedestrian categorized by gender, walking condition and loading condition

	Variables	**Sample Size**	
		Peak	Non-Peak
Gender	Male	1379	1051
	Female	1406	804
Luggage	No luggage	2699	1807
	With luggage	86	48
Walking Condition	Not rushing	2720	1806
	Rushing	65	49
	Total Sample	**2785**	**1855**

Table 3 shows the sample size of variables which are gender, walking condition and loading condition for peak and non-peak hour (egress direction). Samples of size 2785 were collected during peak hour and 1855 pedestrian were collected during non-peak hour. SPSS (Statistical Package for Social Science) was used to analyze the data.

4.2. Speed Analysis

Figure 3 and Figure 4 depicted the speed for all pedestrian during peak hour and non-peak hour respectively. From the analysis, we can observed some of the speed are far above the average speed range. The overall mean speed is 31.08m/min with 35.25m/min of median and 17.50 standard deviation for peak hour and 36.45m/min, 36.00m/min and 18.93 is the mean, median and standard deviation for non-peak hour respectively. The overall speed shows that pedestrian can go faster through the ticketing gate during non-peak hour.

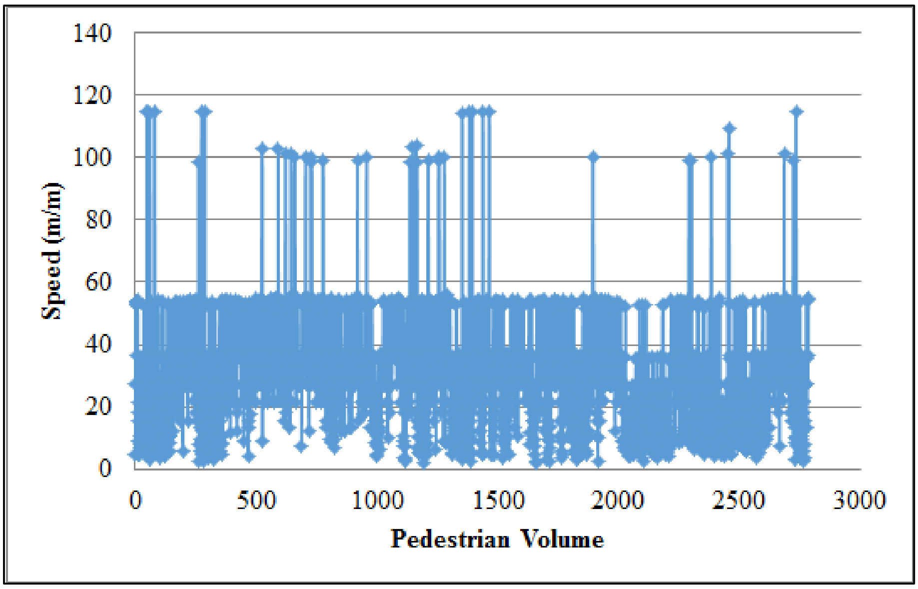

Figure 3. Speed for all pedestrian during peak hour

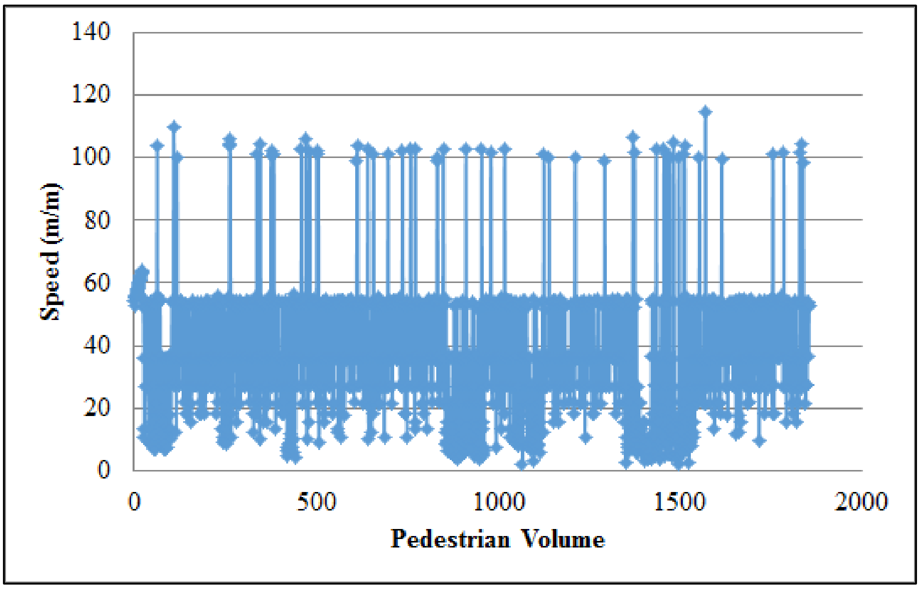

Figure 4. Speed for all pedestrian during non-peak hour

Table 4 shows the speed of pedestrian categorized by gender, whether they are carrying luggage or not as well as the walking condition; rush or not rush during peak and non-peak hour for egress direction. The mean speed during peak hour for male is 33.69 m/min and for female is 28.52 m/min. The mean speed during non-peak hour for male is 37.77 m/min and for female 34.73 m/min. The overall results shows that male pedestrian walk faster through the ticketing gate. The results are based on sample size listed in Table 1. The mean speed during peak hour for pedestrian with and without luggage is 30.72m/min and 31.09m/min. In addition, the mean speed during non-peak hour for pedestrian with luggage is 42.98 m/min and for pedestrian without luggage is 36.28 m/min. Mean speed of pedestrian is reportedly lower by 0.37m/min when they carried a luggage. 31.34m/min is the speed for pedestrian during rushing condition (peak hour). Besides, the mean speed for pedestrian in rushing condition is 36.12m/min and for pedestrian not in rushing condition is 36.46 m/min (non-peak hour). The mean speed during rushing conditon is high during peak hour but lower during non-peak hour.

Based on results, the mean speed is more than 30 m/min and less than 40 m/min. This show that most of the pedestrians' speed that passing through the automatic ticket gate for both directions is within range 30-40 m/min. It is same range with the pedestrian speed through bottleneck (stairs) at rail transit station in India (Shah et al., 2013) but slightly lower than pedestrian speed through bottleneck at rail transit station in China which is in the range of 50-60 m/min (Tang et al., 2009). These maybe due to efficiency of the gate and familiarity of pedestrian with the automatic ticketing gates. Besides, the pedestrians speed maybe influenced by many factors such as the weather, physical condition, cultural effect and facilities that the walking activities take places (Rosenbloom, 2009). Based on the observation, the speed of pedestrian may not fully depends on their physical capabilities, but also with their familiarity and alertness to the arrangement of gates. In addition, efficiency of the gate plays an important role in the pedestrian speed passing through the automatic ticketing gates because the respond of the gates may different from one type to another. In general, there are 2 ticketing options can be used which are; token and "Touch N Go" card. In some cases, even though the pedestrians show their rushing condition towards the gates, their negligence to standby and prepare their card/token may lead to slower movement at the gate area.

Table 4. Speed of pedestrian categorized by gender, carrying luggage or not and walking condition during peak hour

Variables		Peak Hour			Non-peak Hour		
		Mean Speed (m/min)	**Medium Speed (m/min)**	**Standard Deviation**	**Mean Speed (m/min)**	**Medium Speed (m/min)**	**Standard Deviation**
Gender	Male	33.69	35.81	17.99	37.77	36.10	18.51
	Female	28.52	27.11	16.62	34.73	35.9	19.35
Loading Condition	With	30.72	27.03	21.33	42.98	54.44	20.79
	Without	31.09	35.25	17.37	36.28	36.00	18.86
Walking Condition	Rushing	31.34	21.77	28.10	36.12	35.90	17.31
	Not Rushing	31.08	35.25	17.17	36.46	36.00	18.98

The observed differences of speed is discussed in terms of statistical significance. Table 5 and Table 6 summarizes the corresponding analysis of variance. Results show that *Gender * Luggage* factors is significantly affect the walking speeds of pedestrians at 5% level of significance for peak hour and non-peak hour and all other factors are not affecting the speed of the pedestrian at the ticketing gate. For non-peak hour, *gender* shows a significant effect towards the walking speed. This result shows that gender plays most an important roles regarding the speed of pedestrian. For that reason, future studies related to gates efficiency can be executed by putting attention on the speed of those variables during respective period. In this study, the priority is on female because mean speed of female is lesser than male.

Table 5. Analysis of variance for the speed data (peak hour)

Source	Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	26494.604[a]	7	3784.943	12.727	.000
Intercept	102794.085	1	102794.085	345.642	.000
Gender	781.173	1	781.173	2.627	.105
Luggage	118.254	1	118.254	.398	.528
Rushing	184.831	1	184.831	.621	.431
Gender * Luggage	1572.843	1	1572.843	5.289	.022*
Gender * Rushing	180.396	1	180.396	.607	.436
Luggage * Rushing	348.074	1	348.074	1.170	.279
Gender * Luggage * Rushing	20.577	1	20.577	.069	.793

a. R Squared = 0.031, Significant at 5% percent level of significance

Table 6. Analysis of variance for the speed data (non-peak hour)

Source	Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	16151.623[a]	7	2307.375	6.572	.000
Intercept	166642.193	1	166642.193	474.668	.000
Gender	9075.332	1	9075.332	25.850	.000*
Luggage	662.444	1	662.444	1.887	.170
Rushing	234.585	1	234.585	.668	.414
Gender * Luggage	6297.219	1	6297.219	17.937	.000*
Gender * Rushing	77.966	1	77.966	.222	.638
Luggage * Rushing	13.447	1	13.447	.038	.845
Gender * Luggage *Rushing	28.587	1	28.587	.081	.775

a. R Squared = 0.024, Significant at 5% percent level of significance

5. CONCLUSIONS AND OUTLOOK

The present study reports the understanding of pedestrian movement going through ticketing gate for egress direction. The speed analysis was carried out to determine how much time that a pedestrian need to go through ticketing gate during peak hour (higher voume of pedestrian) and non-peak hour (low volume of pedestrian). The analysis was also extended to determine whether pedestrian characteristic such as gender, loading condition and walking condition will effect the pedestrian speed at the ticketing gate. The results shows that the model was fitted with only $R^2 = 0.031$ for peak hour and 0.024 for non-peak hour. This implies the importance of the inclusion of other factors. In additon, some limitation can be observed in this study. First, the data are based on 5 different days and neglecting the trend of observation during each day might generate bias. Besides, female pedestrian usually use handbags but sometimes the size of their handbags are comparatively big which lead to confusion in distinguishing whether they carried any baggage or not. This limitation was also observed by (Rahman et al., 2006). Further study with larger sample size is useful to verify the difference in statistical analysis. Introducing simulation analysis and efficiency analysis of ticketing gate facilities with more variables should also be carried out in the near future. It is also suggested to conduct a study to determine why awareness and attention level of certain pedestrians are low in regards to the number of gates available for egress direction.

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