ANALYSIS AND SIMULATION OF PEDESTRIAN WALKING CHARACTERISTIC AT KUALA LUMPUR CITY CENTRE UNDERGROUND TRAIN STATION

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By

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I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

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Date :

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(Signature of Examiner)

Name of Examiner :

Date :

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Last but not least, I would also like to take this opportunity to express my appreciation to my family members, friend and my course-mate, who gave me mentally support whenever I faced any difficulty during the research process.

ABSTRAK

Bilangan penumpang yang menggunakan sistem kereta api di Kuala Lumpur semakin meningkat dari tahun ke tahun dan stesen kereta api yang sedia ada pada masa kini telah semakin sesak. Dengan peningkatan permintaaan ruang dalam stesen, keupayan satu stesen untuk mengendalikan jumlah penumpang yang besar ini sering disoalkan. Kajian mengenai ciri-ciri pejalan kaki di dalam stesen kereta api bukan sahaja dapat membantu untuk memahami trafik pejalan kaki di dalam satu stesen tetapi juga dapat membantu semasa mereka bentuk stesen yang bakal dibina. Semua yang dinyatakan di atas boleh dicapai kerana infomasi dapat diberi kepada pereka untuk mereka satu kawasan yang sesuai bagi pejalan kaki dengan ciri-ciri yang didapati dari kajian. Dalam kajian ini, data telah dikumpul melalui rakaman video dari televisyen litar tertutup yang disediakan oleh pihak Prasarana Berhad Malaysia. Rakaman video ini telah merakan aktiviti pejalan kaki semasa berjalan di dalam satu ruang legar yang terletak di dalam stesen transit aliran ringan di Pusat Bandaraya Kuala Lumpur pada 29 Januari 2015. Data yang diekstrak telah digunakan untuk mendapat kelajuan pejalan kaki berjalan dan juga perkadaran perjalan kaki di setiap laluan dan hala. Dari segi kelajuan berjalan, pejalan kaki berjalan lebih cepat ke arah koridor berbanding dengan ke arah pusat beli belah. Analisis juga menunjukkan bahawa pejalan kaki melencong ke tengah ruang lebar dan juga jalan di sisi kiri. Situasi ini mungkin disebabkan cara memandu yang diamalkan oleh warganegara Malaysia. Semua dapatan dari kajian ini termasuk dapatan yang akan bakal dibincang dalam disertasi ini amat berguna untuk memahami ciri-ciri pejalan kaki berjalan di dalam satu ruang yang terbatas di stesen kereta api. Semua hasilan dari kajian ini juga dapat digunakan untuk kajian ciri-ciri pejalan kaki berjalan pada masa hadapat dan juga dapat memberi data yang penting untuk reka bentuk stesen kereta api yang bakal dibina.

ABSTRACT

The ridership of rail-transit system in Kuala Lumpur is increasing from year to year and the existing stations are getting more and more crowded as well. With the increasing space demand of the station, the ability of a station to handle such huge volume of pedestrians may be questioned. Study of the pedestrian walking characteristic in a train station may not only helps to reveal the current pedestrian traffic but may also help in future station design. These are achievable because it provides information for the designer to design an area that suit with current local pedestrian walking characteristic. In this study, data were collected through a closed-circuit television's footage provided by Prasarana Berhad Malaysia. This video footage had recorded the pedestrian walking activities in a concourse area inside the Kuala Lumpur City Centre underground light rail train station on 29 January 2015. The extracted data were analysed to determine the pedestrian walking speed and proportion of pedestrian in each path and direction. In term of walking speed, the analysed results showed the pedestrian walked faster toward corridor than walked toward shopping complex. The analysed results also showed that pedestrian tends to in the middle of the concourse area and the pedestrian also tends to walk on the left side of their path, which might probably be influenced by the Malaysian driving style. These finding, included the finding that explained in this study soon are useful to understand the pedestrian walking behaviour in a confined area inside a train station. These findings also can help for future pedestrian walking behaviour study and provide important data for future facilities design.

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LIST OF ABBREVIATIONS

Location of points

LA - **L**eft (**A**)

LB - **L**eft (**B**)

LC - **L**eft (**C**)

RA - **R**ight (**A**)

RB - **R**ight (**B**)

RC - **R**ight (**C**)

RD - **R**ight (**D**)

Form used

No. - Number

Unit

Ppm - **P**edestrian **p**er **m**inute

Pph - **P**edestrian **p**er **h**our

Name

K.T.M.B. **K**eretapi **T**anah **M**elayu **B**erhad

K.L.C.C. **K**uala **L**umpur **C**ity **C**enter

TVM **T**icket **V**ending **M**achine

NOMENCLATURES

v	Velocity, or referred as pedestrian walking speed

CHAPTER 1

INTRODUCTION

1.1. Background

Malaysia began a transition towards industrial sector since 1970s and has driven the economics of Malaysia to a higher point. According to the World Bank, Malaysia almost achieved an annual GDP growth rate of 5 to 11percent every year and the rapid growth of Malaysia's economic had allowed Malaysia to be economically prosperous (John and Drabble, 2001). Like the other countries, the economic prosperity has given benefits to Malaysia's transportation sector, especially on rail networks. Despite Kuala Lumpur is not the first city in Malaysia to have rail transport system but after decades of development, Kuala Lumpur is now a city featured with the most modern and the most number of rail stations in Malaysia. In parallel to this rapid development, the population of Kuala Lumpur is experiencing a sharp rose since 1970 as more rural citizen had been migrated to cities for a better job. Today, based on statistics from the Department of Statistics Malaysia, Kuala Lumpur was making up of 1.79 million population for 243 sq. km (Federal Territory of Kuala Lumpur, n.d.). As the densest and the most populated city, huge demand of transportation services is needed to be supplied.

In 1995, the rail-based transit system in Kuala Lumpur had started with the K.T.M.B. Komuter system (Bachok et al., 2004). One year later, Kuala Lumpur's first LRT (Light Rail Transit) line stated to operate, providing services from Ampang to Jalan Sultan Ismail. In 1998, another line of LRT was opened and connected more destinations for the citizens, providing more services to the citizens in Kuala Lumpur. By the end of 2014, these two LRT lines had provided more than 145million of ridership. (Ministry of Transport Malaysia, 2014). Such high amount of ridership denoted that the light rail transit services are widely used by the citizens. The information from Ministry of Transport Malaysia (2014) also showed that the ridership of light rail transit is increasing from year to year. Hence, it is reasonable to forecast that the ridership of the light rail transit will keep increasing in the future.

The increase of ridership wasn't solely contributed by the existing LRT lines but also was contributed by the new LRT line or so-called LRT3 that begin constructed since second quarter of year 2016 (Project Timeline, n.d.) and the MRT line that begin constructed since 8 July 2011 (The MRT Sungai Buloh-Kajang Line, n.d.). The LRT3 serves 26 stations and expected to benefit 74,000 commuters daily while the MRT served by 31 stations is expected to benefit 500,000 commuters daily. The ridership of existing transit line will increase because part of the new transit lines will be connected and share the stations from the existing line that give the train passengers more options and transit by using the train services.

The efforts such as the initialling of park and ride program have been taken by the government of Malaysia as well as rail operator to encourage citizens to travel by using public transport (Bernama, 2016). Some park and ride facilities such as Kelana Jaya Station was found that to have high occupancy rate during weekday and most of the people who parker at the station were travelling for work purpose (Kadar Hamsa et al., 2014). With more and more park and ride facilities are being constructed at train stations, it is undeniable that the ridership will be increased as people will park and commute to work by train. However, without any understanding and upgrading the services at the existing rail stations, the capacity of the stations will remain the same and there is a probability for the station will become congested in the future.

Figure 1.1: The overall rail transit map in Klang Valley (Fa Lrt3 Flyers ed1, 2016)

Unfortunately, it is very difficult and almost chanceless to observe the exact circumstance of a fully crowded station. It is because this situation is very rare to happen. The worst case is when the emergency evacuation is needed at the train station during the peak hours where the volume of pedestrian and train passenger are high. In order to understand and predict the worst-case scenario in the future, the simulation at the train station is needed.

1.2. Problem Statement

It is undeniable that the transportation system in Kuala Lumpur is expanding towards the nearby suburban area. More stations and transit lines will be provided at the suburban area. This will allow the residents who live in suburban areas to have chances to travel by rail transit system. The increment of the population in and nearby to Kuala Lumpur area also promote the ridership of light rail transit system (Land Public Transport Commission, 2011).

The increment of the pedestrian in a station will undoubtfully increase the space demand of a station and made the existing un-upgraded station to be more crowded. The crowded station made the pedestrian feel uncomfortable because pedestrian will have to stand closely to each other and eventually demote the quality of service of the station (Campanella et al., 2013). The uncomfortable feeling will demote the willingness of pedestrians to take the public transport and may consider switching their mode of transport to car (Transit Development Corporation et al., 2007). Hence, as one of an importance parameter that would affect the mode of transport of people to travel, poor quality of service should be avoided and station should be upgraded if the quality of service is getting poorer. In order to determine the necessarily to upgrade a station, questions regard the ability and capacity of a station to handle such huge number of pedestrians in the future while maintaining the quality of service may need to be answered.

A review may be necessary to be done to determine the adequacy of station layout design to favour a smooth pedestrians' walking activities. Layout design such as the width of the exit walkway and the facilities inside the station, which become obstacle could probably affect the level of service of a station. As it is impractical, time-consuming as well as costly to have a live drill in a busy station, a suitable method must be found to serve this purpose. A simulation shall be a good solution to forecast the walking activities.

1.3. Objective

The objectives of this study are as listed as below

1. To determine the pedestrian walking speeds at the pedestrian corridor in the underground train station.
2. To identify the pedestrian walking paths at the pedestrian corridor in the underground train station.
3. To obtain the density of pedestrian in studied area by simulate the pedestrian walking activities at the pedestrian corridor using Viswalk.

The main focus of this dissertation is to determine the walking speed of the pedestrians and to simulate the pedestrian walking activities in the underground LRT station. This study is useful and meaningful as it can help to understand the pedestrian walking speed in an underground station. Besides, the simulation that simulates pedestrians walking in the underground station can help to understand and to foresee the future atmospheres of the station. Such simulation also helps to determine the efficiency of evacuation of the station and also can help to determine the need to upgrade the station facilities.

Furthermore, this study can help in the design of station in the future. An ideal station design should not only able to cater the amount of rider while providing conformable to the rider who are using the station but also to be economical in term of capital and maintenance cost. A balance between cost and user friendly aspect should be achieved. In this way, the station can be said as designed to be cost-effective, futureproof and the best and adequacy facilities can be provided to the rider. The information gathers in this study can be used for another station design.

1.4. Scope of Work

The main focus of this dissertation is to study the pedestrian walking speed in an underground train station under normal circumstance only. The walking speed in this study will not be categorised according to gender and age. However, walking speed of children will not be recorded as well despite they were guided or following their parents.

The normal circumstance in this dissertation refers to pedestrians who walk normally and completed their trips in the area of study. The pedestrians who involved with other activities such as turn to the ticket selling machines or stop for a long time in the area of study will not be recorded. The pedestrian who have difficult in walking such as pedestrian who travel using a wheelchair will not be included as well.

Despite there are so many stations in Kuala Lumpur, only one station that located in Kuala Lumpur City Centre area was selected in this study. This station is one of the stations from Kelana Jaya Line. The main reason for selecting this station is because of its huge number of pedestrian inside the station compared to the other underground station in Kuala Lumpur. Figure 1.2. highlighted the selected station for this study.

In this study, pedestrian walking activities in the unpaid concourse area only were observed and recorded. The pedestrians come from paid concourse area were not included in this study. The data collection focused on the pedestrians walking activities during peak hour time. Peak hour times were referred to morning, afternoon and evening peak hour.

1.5. Dissertation Outline

This thesis consists of five chapters. The first chapter consists of the introduction. This chapter provides an introduction to the topic of this dissertation inclusive of background study, problem statement, objectives and the scope of study. The second chapter is the literature review and focused on the previous studies and works as well as founding. The third chapter is the methodology which will explain the method used and how this dissertation was done. The forth chapter is the data analysis. In this chapter, the collected data were analysed and then were presented in this chapter. Simulation results were shown in this chapter as well and the results were compared with the actual collected data. The last chapter which is conclusion that describe the summary of the finding in this study as well as provide suggestion for future study on pedestrian walking characteristic.

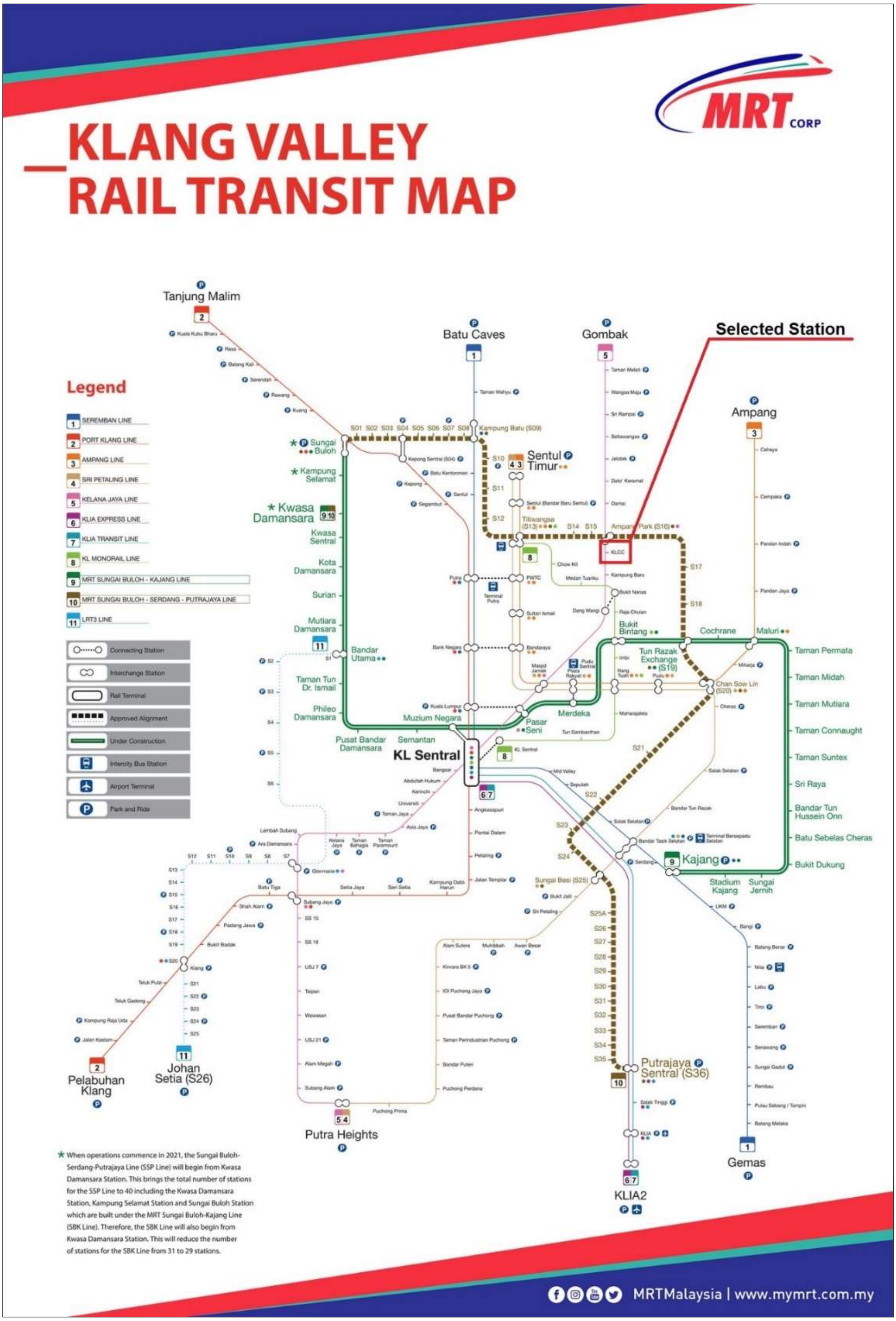

Figure 1.2: The overall existing rail transit map in the Klang Valley (MYMRT, n.d.)

CHAPTER 2

LITERATURE REVIEW

2.1. Overview

The previous studies about the pedestrian walking speed, walking behaviour and simulation model were explained in this chapter. The previous results on verification and validation process were also described in this chapter in order to get a better understanding of the upcoming task in the next chapter.

2.2. Pedestrian walking speed

Pedestrian walking speed is defined as the rate of motion in distance per unit time and it is a parameter that describes how fast a pedestrian walk to complete a unit length of trip. Usually, the units of walking speed are centimetre/second, meter/second or meter/minutes. (Rao and Mathew, 2007) Walking speed is a very important parameter that will be used in a simulation work. The equation of walking speed is defined as equation 2.1.

$$v(m/s) = \frac{distance(meter)}{time(second)} \qquad (2.1)$$

Goh et al. (2012) have studied the pedestrian walking speed in Kuala Lumpur. In his study, the pedestrian walking speed at non-signalised crosswalk in Kuala Lumpur is found to be 1.39m/s while at signalised crosswalk is 1.31m/s. The same study also concluded that Malaysian walking speed is different and is slightly higher than the pedestrian walking speed in other nation.

Rahman et al. (2012) and Rahman et al. (2013) were involved in the pedestrian study in Dhaka, Bangladesh. In both studies, the pedestrian movement at the sideway at three different locations was observed and free flow means walking speed was calculated. The pedestrian free flow mean walking speed is found to be 1.15m/s. Table 2.1 below shows the pedestrian walking speed observed by Rahman et al. (2012)

Table 2.1: Studied pedestrians walking speed (Rahman et al., 2012)

	Pedestrian walking speed (m/s)		
	Minimum	Maximum	Average
Commissioner's Market Sidewalk	0.59	1.90	1.10
Kazi Nazrul Islam Avenue	0.68	2.03	1.20
Mirpur Road	0.72	1.76	1.17
		Mean	1.15

The previous study related with the pedestrian walking speed are not limited to Asia country only. Finnis and Walton (2008) had observed the pedestrian walking speed in 4 different cities in New Zealand with difference terrain conditions. Their study had found that New Zealanders walk at a mean speed of 88.08m/min (equivalent to 1.47m/s) at flat location. If the pedestrians walk with purposes, their speed was found to be increased to 82.30m/min (equivalent to 1.37m/s).

In addition, Lagervall and Samuelsson (2014) studied the pedestrians walking speed at two different pedestrian flows in a Sweden train station and found that the mean walking speed was 1.33m/s during low flow and 1.25m/s during high flow. In fact, prior to this finding, it had proven that flow has a close interrelationship with walking speed and density of the pedestrian area.

Hu (2011) had done a study in Huaqian Road station, an urban rail transit station in Shenzhen, China. Pedestrians were found to walk at a speed of 1.34m/s at the free flow area while the walking speed had reduced to 1.11m/s in congested area. This finding complies with the theory of speed-density relationship as speed reduced with the increases of density.

2.2.1. Pedestrian walking speed in confined passageway

Passageways, walkway and corridor in buildings are considered as confined walkway as well as the space is usually designed for pedestrians and always with the limited width. Most of the facilities in a station are built in a confined area and hence, confined walkway always be the focus point of most of the study.

Chen et al. (2011) found that pedestrians walk at a mean speed of 1.356m/s at level passageway in their study. Pedestrians walk faster in level passageway than staircase is mainly because of the stairways' step riser and the tread will cause restraint of pedestrian walkability.

Ye et al. (2012) did a study about pedestrian walking speed at a 4.4m passageway in People's Square Station as well. However, in this study pedestrians were divided into 22 groups and the mean walking speed of these 22 groups was not mentioned. Hence, the speed was manually calculated and speed of 1.308m/s was obtained. Table 2.2 shown is the walking speed found by Ye et al. (2012).

Table 2.2: Pedestrian walking speed of all 22 groups (Ye et al., 2012)

		Luggage loading condition									
		None		Small		Medium		Large		Trolley Bag	
Age	Gender	M	F	M	F	M	F	M	F	M	F
	Young	1.51	1.40	1.36	1.36	1.39	1.33	1.31	1.20	1.39	1.28
	Middle	1.39	1.32	1.36	1.29	1.30	1.25	1.25	1.15	1.35	1.26
	Older	1.14	1.14	No data							
Cumulative walking speed = 28.78m/s (not obtainable in the study) Mean walking speed = 1.308m/s (not obtainable in the study)											

Zhang et al. (2009) found that pedestrians walk at a speed of 1.33m/s in a passageway in their study. In the platform, pedestrians tend to walk faster at a speed of 1.62m/s if they realise that subway vehicle has arrived on the platform. If there is no subway vehicle, pedestrian walk at a speed of 1.49m/s only.

Lam and Cheung (2000) have a more comprehensive study on pedestrian speed and flow at walking facilities in Hong Kong. In this study, pedestrian walking speed indoor walkway in commercial areas with an effective width of 6.3m and indoor walkways in shopping areas with an effective width of 5.4m were observed. The result was summarized in Table 2.3. Meanwhile, study of walking activities in MRT and KCR stations by Lam and Cheung (2000) also revealed that pedestrians walk at different speed at different facilities and was presented in Table 2.4.

Table 2.3: Walking speed in indoor walkways (Lam and Cheung, 2000)

	Walking speed in indoor walkways			
	Free flow speed		Mean speed	
	m/min	m/s	m/min	m/s
Commercial area	58.95	0.983	54.89	0.915
Shopping area	47.93	0.799	43.42	0.724

Table 2.4: Walking speed in different walking facilities (Lam and Cheung, 2000)

	Free-flow walking speed			
	Mass Transit Railway (MRT)		Kowloon-Canton Railway(KCT)	
	m/min	m/s	m/min	m/s
Passageway	82.26	1.37	79.45	1.32
Platform	74.75	1.25	76.38	1.27
Concourse (Straight ahead movement)	76.94	1.28	77.45	1.29
Concourse (turning movement)	78.13	1.30	76.99	1.28

2.2.2. Pedestrian walking speed in staircase

Staircase is one of a confined walkway. Kretz et al. (2008) observed the pedestrian walking speed on stairs in difference scenarios. The study found that the pedestrian intended to walk at a speed of 0.427m/s to 0.502m/s on stair. The fastest speed was walked by pedestrian who walks without being obstructed by anyone and the slowest speed was walked by pedestrian in high density situation as were presented in Table 2.5.

Table 2.5: The walking speed in stair (Kretz et al., 2008)

Category A	Individual who walks without influenced by anyone
Category B	Few people moving around the observed individual. There were small or even no visible influence from one to another.
Category C	High density situation and pedestrian was influenced by others

Slope speed (m/s)	Category A	Category B	Category C
Mean	0.517	0.468	0.439
Median	0.502	0.457	0.427
Minimum	0.27	0.16	0.43
Maximum	1.55	1.40	0.52

Pedestrian walking speed in stair also studied by Jiten et al. (2016) in India. In this study, the relationship between stair width and the pedestrian walking speed were investigated. In this study, it is found that pedestrians walked faster with the increases of stairway width. However, beyond 2.5m of width, pedestrian start to walk slower. The finding is shown in Table 2.6

Table 2.6: The walking speed in stair (Jiten et al, 2016)

Station	Clear width	Mean walking speed	
	(m)	(m/min)	(m/s)
Mumbai Suburban-Dadar Station, India	2.67	30.49	0.508
	2.15	28.25	0.471
Vadodara intercity Station, India	3.68	37.46	0.624
	2.45	38.09	0.635
	2.26	17.96	0.299
	2.14	33.70	0.562

The pedestrian's walking speed on the stairs in Vadodara railway station, India was also studied by Shah et al. (2013b). In his study, pedestrian's walking speed upstairs and downstairs was observed. It is found that pedestrians walk downstream faster than upstream, at overall speed of 0.460m/s versus 0.442m/s. This results were presenting for all genders, ages and loading conditions.

Meanwhile, Chen et al. (2011) examined the pedestrian walking speed at two train stations, namely People Square Station and Zhong-Shan Park Station in China. The free flow speed at different walking facilities for these stations was shown in table 2.7. It was found that pedestrian walked faster in level passageway than in stairway. Pedestrians walk faster during downstairs than upstairs is mostly because of pedestrians need to consume more energy than when they walk downstairs. (Chen et al., 2011) In facts, the energy cost of walking in slope is higher than in level terrain while energy cost of walking at a positive slope or upstairs is a lot higher than walk at a negative slope. (Virtanen, 2013; Minetti et al., 2002).

Table 2.7: The characteristic parameters of pedestrian flow (Chen et al., 2011)

	Free-flow speed		Capacity (p/min/m)	Critical Density (p/m^2)	Optimal Density (p/m^2)
	m/min	m/s			
Level passageway	81.37	1.356	70	0.3	1.53
Ascending stairway	37.72	0.629	73	0.5	3.20
Descending stairway	46.25	0.771	68	0.6	2.83
Two-way stairway	41.82	0.697	63	0.5	2.76

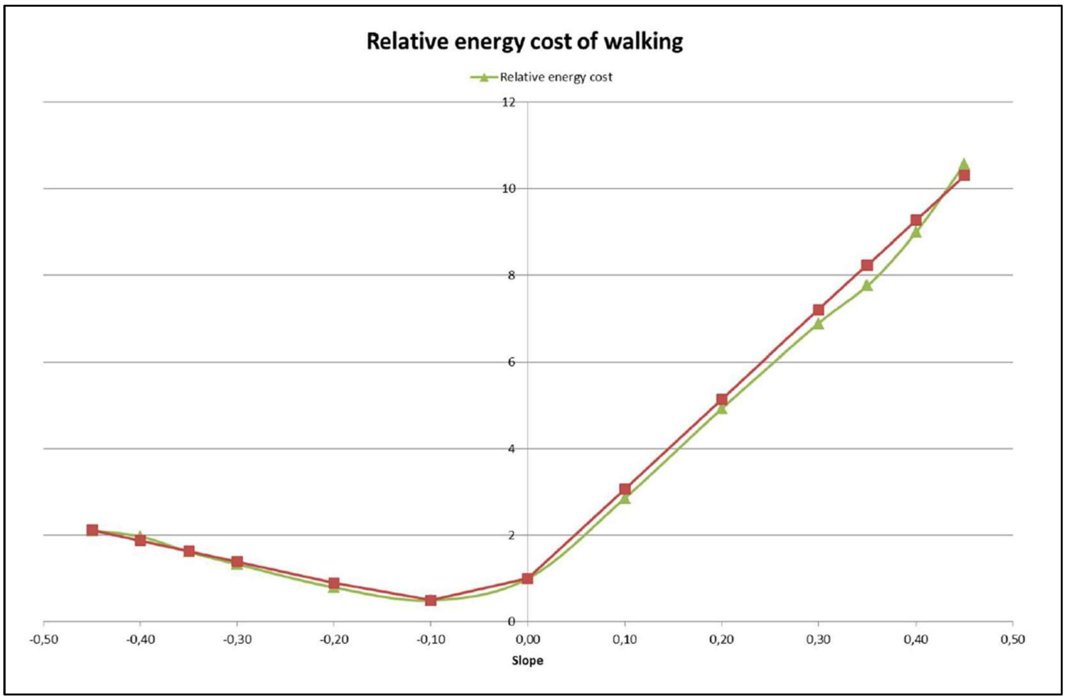

Figure 2.1: The energy cost of walking (Virtanen, 2013)

Many previous studies such as Lam and Cheung (2000), Kretz et al. (2008), Zhang et al. (2009), Xiang et al. (2009), Chen et al. (2011) and Shah et al. (2013b) were also focused on the pedestrian walking speed on the stairways. The summary of the the previous findings are shown in Table 2.8. However, the study by Lam and Chueng (2000) and Chen et al. (2011) represented the free flow speed on the stairs. From the presented table, it was found in some circumstance pedestrian walk slower when walk downward, such as Kretz et al. (2008).

Meanwhile, a study by Lam and Chueng (2000) and Zhang et al. (2009) have found the same finding which show that the pedestrian walking speed were faster while walk downward than walk upward.

Table 2.8: The walking speed in stair in difference study.

Author	Location	height	Walking speed (m/s)	
			Upward	Downward
Lam and Cheung, 2000	Stations in MRT		0.860	0.971
	Stations in KCR		0.768	0.873
Kretz et al., 2008	Dutch pavilion (Expo 2000)		0.71	0.65
Zhang et al., 2009	Fu Xing Men Transfer Hub	(1.2m)	0.71	0.68
		(2.4m)	0.71	0.90
Xiang et al., 2009	Somerset MRT, Singapore		0.453	0.689
Chen et al., 2011	People Square Station, China & Zhong-Shan Park Station, China		0.629	0.771
Shah et al., 2013b	Vadodara Railway station, India		0.442	0.460

2.2.3. Factors affect pedestrian walking speed

The mean pedestrian walking speed from difference study as well as difference country is found to be not same. This difference usually caused by several factors. (Daamen and Hoogendoorn, 2003; Bohannon and Andrews, 2011).

One of the factors is the flow and the density of pedestrian in an area as observed by Lagervall and Samuelsson (2014). Flow is a parameter that used to describe how smooth the pedestrians walk in an area and unit used for flow is pedestrian/second or pedestrian/minutes. Density is usually referring to how crowded and how many amounts of person in a designated area.

When the amount of pedestrian is less or density is low, the pedestrian can walk freely and with a higher speed. This is because of less obstacles in pedestrian walking pathway. The increase of flow is found to have penalty effect on the pedestrian walking speed as pedestrians start to have difficulty to walk at their preferred walking speed (Chen et al., 2011; Sarsam, 2013; Sarsam and Abdulameer, 2015). In term of flow, beyond the density that yields the maximum flow, any increase in term of density will start to reduce the walking speed as the ability of pedestrian to move freely is impaired because of the crowded situation (Löhner, 2010). The interrelationship between speed, density and flow are best illustrated by the Virkler and Elayadath (1994) founding as shown in figure 2.2.

Age also influence the walking speed of pedestrian as elder usually walk slower than others. (Rahman et al. 2012; Shah et al. 2013a; Goh, 2012). In Ye et al. (2012) study found that gender has less influence on speed for the elder. Despite elders are walking slower, it was found that the walking speed of elder is improving at a rate of 0.013m/s per year for the past 23 years (Peel et al, 2012) and it was believed that the improved healthcare and survival rate had contributed to this improvement

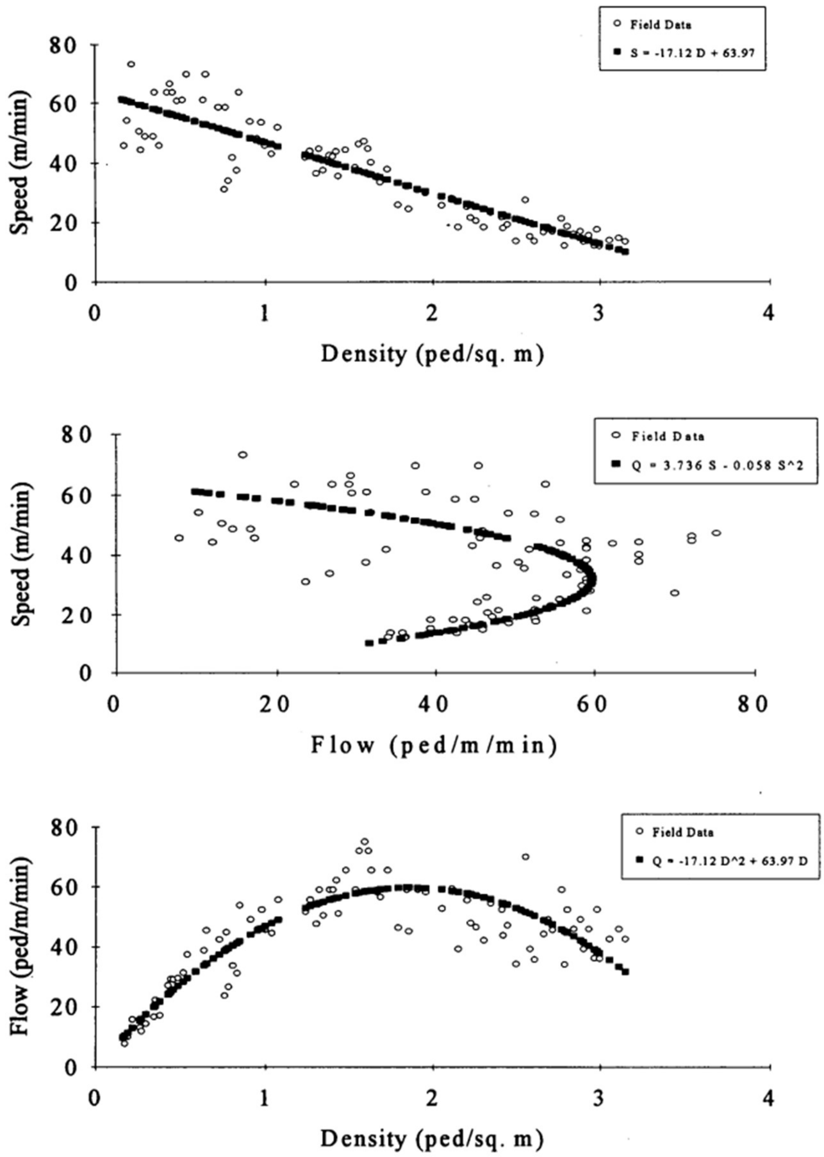

Figure 2.2: The relationship between speed, flow and density

(Virkler and Elayadath, 1994)

In term of gender, a study of walking speed by Shah et al. (2013b) had found that male walk 17% faster than female, which indicates that gender is one of a factor that will influence the mean pedestrian walking speed. This was supported by Hermant (2011) and Zhang et al. (2009) observation. The study finding of Hermant (2011) is shown in Figure 2.3.

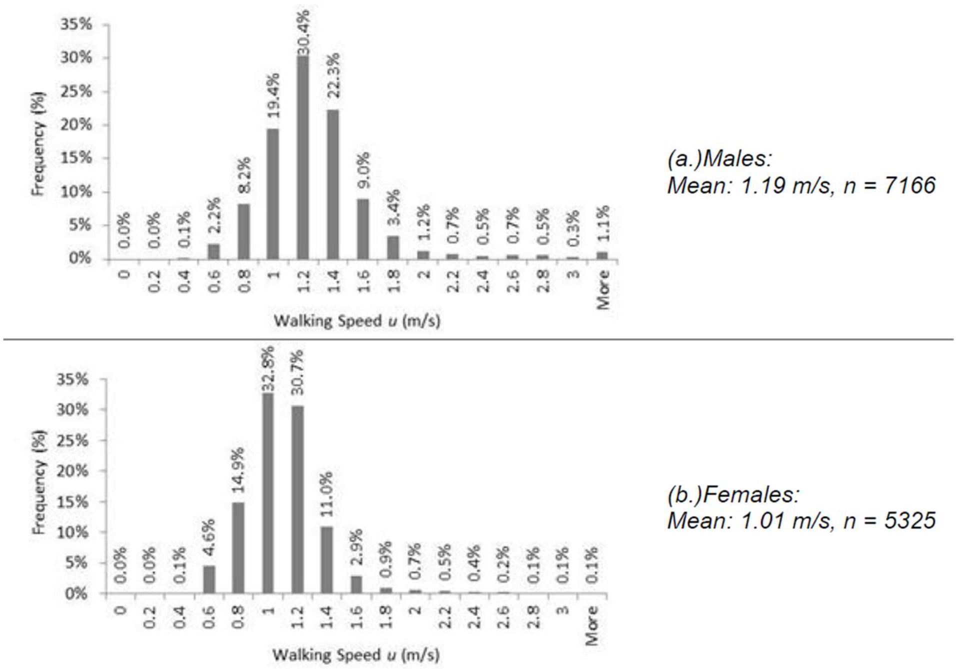

Figure 2.3: The walking speed between male and female (Hermant, 2011)

Zhang et al. (2009) compared the walking speed between gender in different facilities such as at walk way, platform, stair and inclined area. The result showed that male walk faster than female in almost all facilities observed. This is most likely due to the physical condition of males such as leg length, height and other indicators giving advantages to male to walk faster.

In a train station, a pedestrian may carry luggage when travel or bag to work. The study also had found that pedestrian with luggage will walk slower than pedestrian without luggage. (Ye et al., 2012; Hermant 2011; Shah et al., 2013b; Lagervall and Samuelsson, 2014). Ye.et al. (2012) summarize the impact of luggage size to pedestrian walking speed in his study and the impact was presented in Figure 2.4. 100% represents that pedestrian walk at normal speed.

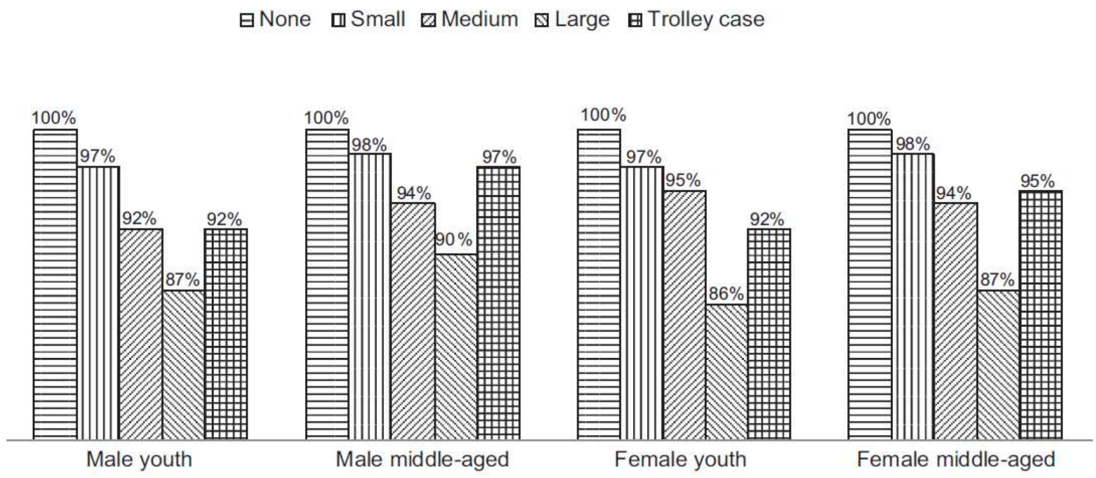

Figure 2.4: The impact of luggage bag size to pedestrian walking (Ye.et al., 2012)

Beside factors of the physical condition of the pedestrian as explained above, Jetthumrong and Ladavichitkul (2016) found that the presence of door or exit will affect the pedestrian walking speed as well. From their study, they found that pedestrian changes their speed at 0 to 0.5m before a door except for a very small door. Pedestrian will change their speed 0.5m to 2.0 meter before a 40cm width door.

In fact, beside the mentioned factor on above, there are a lot of factors that influence the pedestrian walking speed. As summarized by Buchmuller (2006), the main factors are the physical conditions of pedestrians, travel purpose, environmental conditions and walkways attributed.

2.3. Pedestrian walking behaviour

Human as a thinkable organism has their own walking style and walking behaviour. Despite human has their own thinking and walk differently, it's well known that a pedestrian will always be based on their ease of movement and the surrounding condition (Zhang and Han ,2011).

Ease of movement or the pedestrian walkability is related to the interaction between each pedestrian. When pedestrians walk, they will always have interaction with the others pedestrians and that incurred interaction will always influence the behaviour and the direction of a pedestrian move.

Zhang and Han (2011) believed that during the interaction between each pedestrian, there are three main effects that will occur which are follow effect, deterrent effect and rejection effect. Figure 2.5 illustrates the effects of the mentioned three types of effects. These effects are often being investigated as well.

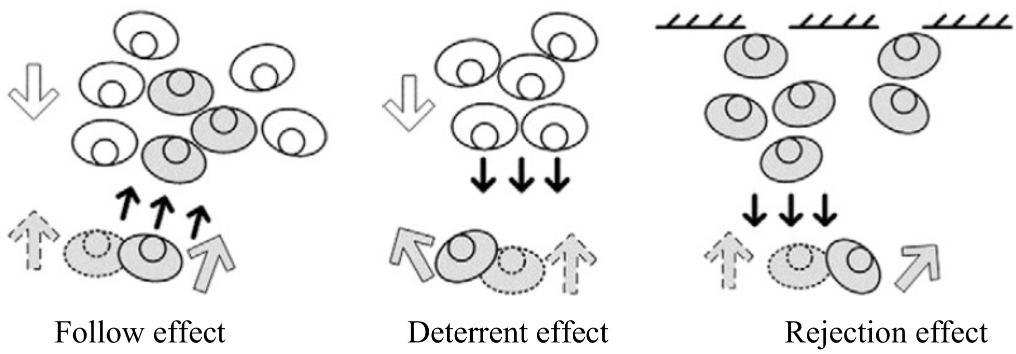

Figure 2.5: The main three types of effects that will occur during interaction between pedestrian (Zhang and Han, 2011)

Follow effect is usually performed when a pedestrian follows another pedestrian who in front of them. Followers are most likely to match their speed with the pedestrian or leader who they following (Rio et al. 2014).

The deterrent effect is triggered when a pedestrian moved away to avoid collision with pedestrian from opposite direction. Study from Moussaid et al. (2009) explained well about this effect, which clearly showed that pedestrians tend to avoid the standing pedestrian. The observed trajectories are showed in Figure 2.6 where red dot and blue dot represent the standing pedestrian and moving pedestrian respectively.

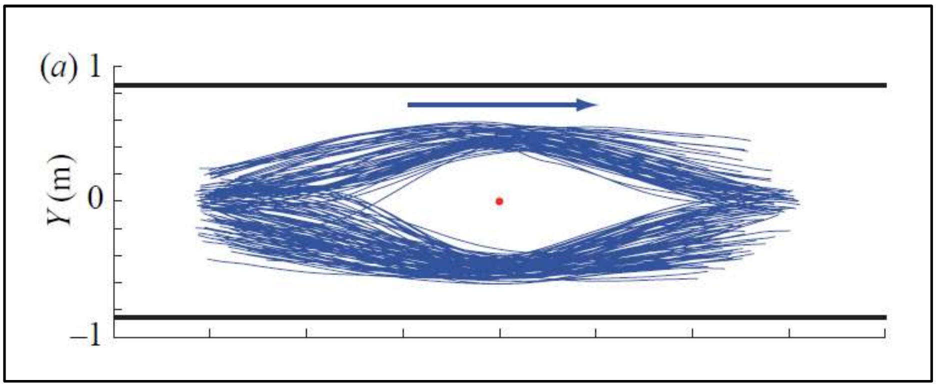

Figure 2.6: The observed trajectories of pedestrian (Moussaid et al. 2009)

The third effect which is rejection effect is trigger when pedestrians changed their direction of decision after their path had been hindered by other pedestrians. This effect can be explained by one of the Heliövaara et al. (2012) finding. In the study, the pedestrian is found to choose another exit which is further away the nearest exit is occupied by other pedestrians.

As suggested by Löhner (2010), a pedestrian may not only try to avoid collision with other pedestrians but also try to avoid collision with the surrounding and built environment such walls. Moussaid et al. (2009) realised that pedestrian has repulsion force to wall at approximate 30cm from the wall border.

Ma et al. (2010) study also found that pedestrian keeps a distance of about 0.4m from the wall and has the tendency to walk away from far when they are close to the wall. The reason of pedestrians tends to keep a distance from the wall is mainly because of they will feel uncomfortable and worry about getting hurt by touching the wall (Helbing and Molnar, 1995).

2.3.1. Pedestrian walking behaviour in crowded environment

Pedestrian walks differently in a crowded environment, to prevent collision with another pedestrian and to have comfort walking speed (Helbing and Molnar, 1998). Because of interaction between each pedestrian, the will to avoid collision and tend to walk comfortable, pedestrians usually choose to turn their walking direction. Figure 2.7 show the trajectories of pedestrian and it clearly showed that pedestrian does not walk straight to get to their destination.

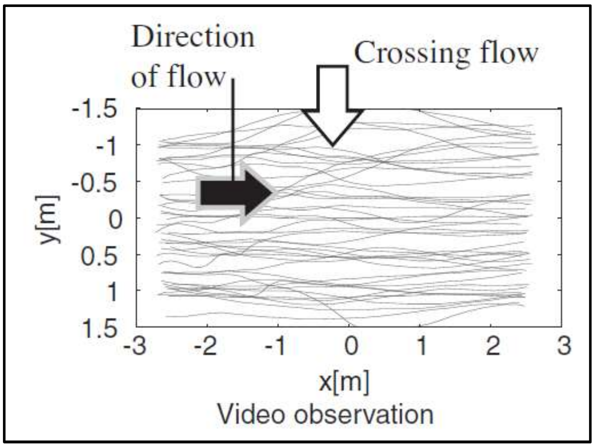

Figure 2.7: Trajectories of pedestrian showed pedestrians does not always move in a straight line in crowded situation (Asano et al., 2010)

To minimised collision and to reduce interaction effect with another pedestrian who come from difference direction, pedestrian tends to follow the pedestrian who in front of them (Teknomo, 2006). Consequently, lanes of pedestrian traffic flow are formed. This phenomenon or so called bidirectional traffic flow actually helps to improve the pedestrian traffic efficiency. Figure 2.8 show the traffic efficiency of a mixed lane and lane-like segregation traffic flow. From the figure, it is clearly proven that a lane-like segregation traffic flow allows pedestrian to move faster and more efficient.

Moussaid et al. (2009) who studied the pedestrian walking direction realised that pedestrians are most likely walk at the right side of the walkway in bidirectional flow. The same traffic flow was found by Kretz et al. (2006) as well, where the right-hand traffic formed nine times in nice experiment, indicated that none left-hand traffic flow was formed.

However, Moussaid et al. (2009) believed that the direction where a pedestrian chooses to avoid collision is not related to the direction of car traffic while Kretz et al. (2006) would want to check the correlation between car traffic rule and pedestrian walking behaviour in the country with left-hand traffic before any comment.

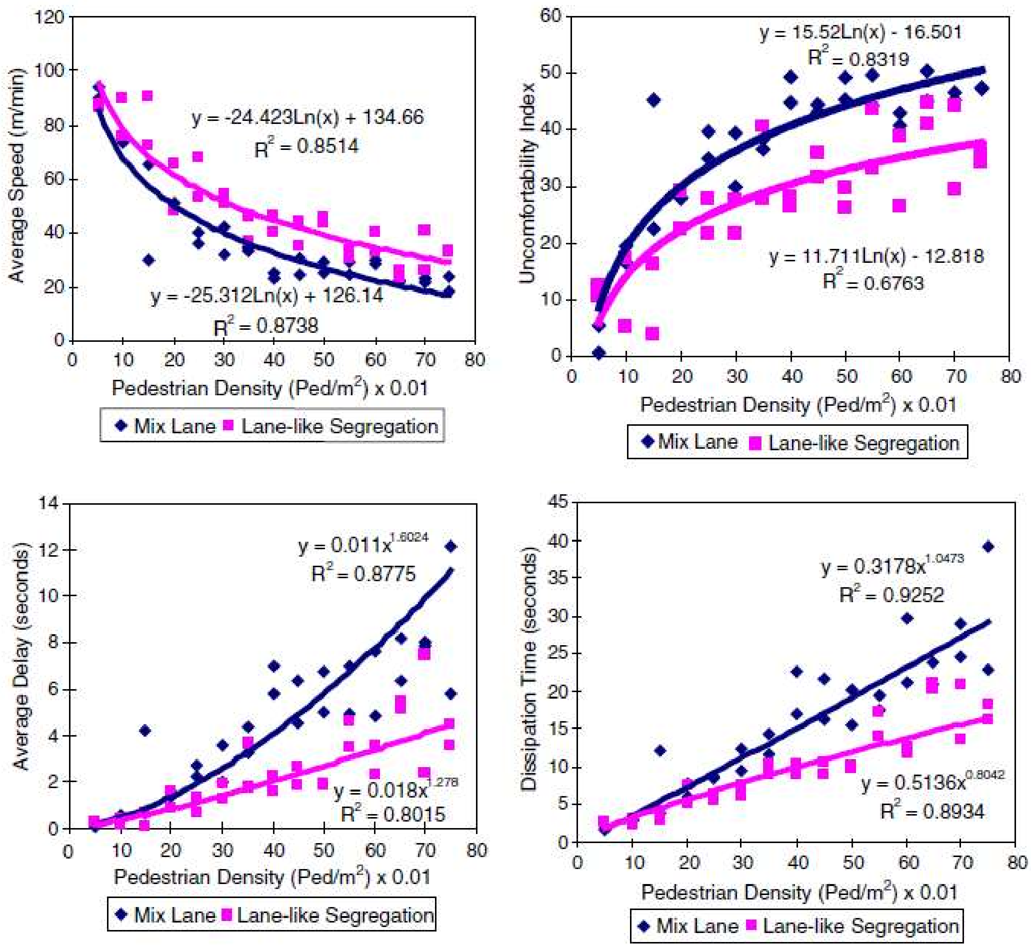

Figure 2.8: Comparison of pedestrian traffic flow efficiency in mix lane and lane-like segregation condition (Teknomo, 2006)