ANALYSIS OF PEDESTRIAN BEHAVIOUR ATTRIBUTES IN RAIL TRANSIT TERMINAL BASED ON PEDESTRIAN SPATIAL INTERACTION

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by

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LIST OF ABBREVIATIONS

RTT	Rail transit terminal
KLSS	Kuala Lumpur Sentral Station
MN	Normal walking male
ML	Male walking while carrying luggage
MG	Male walking while using gadget
FN	Normal walking female
FL	Female walking while carrying luggage
FG	Female walking while using gadget
LRT	Light rail transit
MTR	Mass transit railway
TOD	Transit Oriented Development
LOS	Level of services
HCM	Highway Capacity Manual
KTM	Keretapi Tanah Melayu
ERL	Express Rail Link
MRT	Mass Rapid Transit
KL	Kuala Lumpur
SPSS	Statistical Product and Service Solutions
Q1	First quartile
Q2	Second quartile
Q3	Third quartile
ANOVA	Analysis of variance
LD	Lowest distance
HD	Highest distance

NOP	Number of pedestrians
IQR	Interquartile range

ANALISIS CIRI-CIRI TINGKAH LAKU PEJALAN KAKI DI TERMINAL TRANSIT KERETAPI BERDASARKAN INTERAKSI RUANG PEJALAN KAKI

ABSTRAK

Memahami dinamik orang ramai adalah asas untuk merancang dan mengurus aliran pejalan kaki di terminal rel transit (RTT). Dalam sumbangan ini, analisis berkomputer telah dijalankan dan memberi tumpuan kepada ciri-ciri tingkah laku pejalan kaki di RTT untuk pelbagai aktiviti semasa berjalan berdasarkan interaksi ruang. Kajian ini dijalankan di RTT terbesar di Malaysia yang terletak Kuala Lumpur. Objektif kajian ini adalah untuk menentukan ciri-ciri pejalan kaki secara empirikal berdasarkan interaksi ruang dan memformulasi domain persepsi pejalan kaki di RTT. Sejumlah 359 orang pejalan kaki telah dipilih dari 26 rakaman video berdurasi 10 minit. Pejalan kaki yang telah dipilih dibahagikan kepada dua kategori, (1) jantina; (2) aktiviti lain semasa bejalan kaki (membawa bagasi dan menggunakan peranti pintar terutamanya telefon pintar). Empat ciri-ciri tingkah laku pejalan kaki dikaji secara empirikal seperti halaju, jarak psikologi, halaju sudut dan sudut mengelak dengan lanjutan hubungan ketumpatan dan perumusan domain persepsi pejalan kaki. Dapatan kajian menunjukkan pejalan kaki wanita yang membawa bagasi merekodkan halaju paling rendah,1.27 m/s diikuti lelaki membawa bagasi (1.36 m/s), wanita dan lelaki menggunakan peranti pintar (1.37 m/s). Selain itu, untuk jarak psikologi, pejalan kaki lelaki yang menggunakan peranti pintar merekodkan jarak paling jauh iaitu 3.72 m dan lelaki membawa bagasi merekodkan jarak paling dekat iaitu 3.12 m. Apabila diklasifikasikan mengikut zon jarak yang dicadangkan oleh Hall,1966, 54% daripada pejalan kaki yang dipilih berada dalam 'social distance' (1.20 - 3.60 m) dan 46% berada dalam 'public distance' (3.60 - 7.60 m). Halaju sudut pejalan kaki menunjukkan pejalan kaki lelaki yang membawa bagasi merekodkan halaju sudut tertinggi iaitu 2.18 rad./s dan pejalan kaki wanita tanpa sebarang aktiviti lain merekodkan halaju sudut terendah iaitu 0.96 rad./s. Ciri-ciri terakhir iaitu sudut mengelak menunjukkan pejalan kaki lelaki yang membawa bagasi merekodkan sudut mengelak tertinggi iaitu 49.94° dan pejalan kaki wanita tanpa sebarang aktiviti lain merekodkan sudut mengelak terendah iaitu 21.98°. Akhir sekali, formulasi domain persepsi pejalan kaki berdasarkan ciri-ciri tingkah laku pejakan kaki dijalankan untuk menggambarkan interksi pejalan kaki di RTT. Melalui pemahaman ciri-ciri tingkah laku pejalan kaki di dalam RTT di Malaysia membolehkan prancang infrastruktur dan pembuat dasar untuk meramal tingkah laku pejalan kaki dan menyusun stategik untuk memastikan kelancaran aliran pejalan kaki.

ANALYSIS OF PEDESTRIAN BEHAVIOUR ATTRIBUTES IN RAIL TRANSIT TERMINAL BASED ON PEDESTRIAN SPATIAL INTERACTION

ABSTRACT

Understanding the dynamics of a crowd is fundamental in planning and managing pedestrians' flow of large public buildings and urban environments. In this study, computational analysis was conducted to investigate pedestrian behaviour attributes in Rail Transit Terminal (RTT) by considering different pedestrian activities while walking based on spatial interaction. The study was piloted at the largest RTT in Kuala Lumpur. The objectives were to empirically determine pedestrian behaviour attributes based on spatial interaction and formulate pedestrian perception domain concerning Malaysian pedestrian in RTT. A total of 359 numbers of pedestrian (NOP) were chosen from 26 recorded videos. The chosen pedestrian was divided into two categories, (1) gender; (2) secondary activities while walking (carrying luggage and using gadget specifically smartphone while walking). Four pedestrians' behaviour attributes were investigated empirically, namely walking velocity, psychological distance, angular velocity and angle of avoidance, with the extension of density relation and formulation of pedestrian perception domain. From the findings, female pedestrians who walk while carrying luggage recorded the lowest average walking velocity, 1.27 m/s followed by males with luggage (1.36 m/s), female and male using gadget while walking (1.37 m/s). Meanwhile, for the pedestrian psychological distance, males using gadget while walking recorded the highest with 3.72 m, and males with luggage recorded the lowest distance with 3.12. When classified according to distance zone proposed by Hall, 1966, 54% of pedestrian average psychological distance falls in the social distance (1.20 – 3.60 m) and 46% fall in public distance (3.60 – 7.60 m). This

indicates that chosen pedestrians were individual pedestrian that has no relation with other pedestrians (stranger) around them. For the pedestrian angular velocity, where males with luggage recorded the highest velocity (2.18 rad./s) and females who walk without any activity recorded the lowest velocity (0.96 rad./s). The final attribute, the pedestrian angle of avoidance, male with luggage recorded the highest (49.94^{o}) and female without any secondary activity while walking recorded the lowest (21.98^{o}). Last, the formulation of pedestrian perception domain from obtained pedestrian behaviour attributes was conducted to represent pedestrian interaction in RTT. It is believed that different pedestrian activities contributed to different behaviour attributes in RTT. Through the understanding of pedestrian, behaviour attributes in RTT at Malaysia allow the infrastructure planner and policymakers to predict future walking behaviour and plan the strategic alternative for a continuation of smooth pedestrian movement.

CHAPTER 1

INTRODUCTION

1.1 Rail Transit Terminal

The rail transit system is considered one of the best choices for metropolitans to solve ground transportation problems in terms of congestion and efficiency. As the national capital of Malaysia, Kuala Lumpur will continue to experience strong population growth as it is a centre of economic growth with a high human development index. Thus, most of the population preferred rail transportations than road transportations due to critical traffic congestion on the road, especially during peak hours.

Across the world, there are nearly 650 transit lines served by more than 11,000 stations where Tokyo is the busiest transit system with 3.46 billion trips annually followed by Moscow, Shanghai, Beijing, Seoul and New York City (Richarz, 2018). Malaysia as a developing country, specifically in Kuala Lumpur there was about 12 rail lines with more than 20 rail transit terminal (RTT) available. According to statistics produced by Land Public Transport Commission or SPAD, Malaysia, for the year 2017, in Kuala Lumpur itself, an estimated 1.1 million people are traveling by trains and buses every day (Pillay, 2017).

Transportation nodes, terminal, and station experiencing massive passenger flow especially during peak hours, weekends and holidays. During weekends and holidays, unnecessary congestion usually occurred. It influences other pedestrian movement and reduces station performance due to confused non-familiar commuters. Therefore, in transiting large passenger flows, RTT is an important public building that attracts the crowd not only for the local population but also for people around the country. Being able to attract massive pedestrian movement brings the agencies to study pedestrian behaviour in addressing the issue of security.

Pedestrian behaviour has a huge relation to its environment. The crowded environment at RTT limits the space available around the pedestrian body. Pedestrian behaviour in relation to spatial interaction is an important study to portray pedestrian behaviour in different pedestrian flow density. It is expected that pedestrian behaviour attributes such as walking velocity and psychological distance decrease as the flow density increases due to restriction space available. According to that, a better understanding of pedestrian behaviour in relation to spatial interaction help authorities in improving the contingency plan in RTT.

1.1.1 Pedestrian Behaviour Attributes

Pedestrian behaviour attributes such as walking velocity, psychological distance, angular velocity and angle of avoidance are the important attributes that can be empirically analysed. Study pedestrian behaviour attributes and its relationship with flow density is a crucial measure to predict how pedestrian react with its surrounding when there are changes in flow density.

Pedestrian walking velocity was studied in various places that attract crowds such as airport terminal, bus terminal, shopping mall, and transit terminal. Pedestrian walking velocity is affected by the density, other pedestrians, location and type of walking facilities. A sudden change in pedestrian behaviour during trains arrival and departure makes it crucial to study pedestrian walking velocity and its relation to density in RTT.

Urbanization leads to an increase in the use of transit stations to make consideration of pedestrian psychological distance important in designing pedestrian facilities. Pedestrian psychological distance defines pedestrian behaviour towards other pedestrians in available space. Generally, individual characteristics, surrounding factors, and psychological factors influence pedestrian psychological distance.

The rail transit system is considered one of the best choices for metropolitans to solve ground transportation problems in terms of congestion and efficiency. The current trend shows there is an exponential increase in rail traffic passenger volume, causing more attention must be paid towards crowd safety in RTT through the understanding of pedestrian behaviour. Considering pedestrian behaviour attributes such as angular velocity and angle of avoidance help in understanding pedestrian collision avoidance. In higher density, the pedestrian was expected to avoid collision with other pedestrians more compare to low density.

Several pedestrian activities were usually seen in large passenger flow such as walking while carrying luggage or using a gadget. By considering several pedestrian activities at RTT like walking while carrying luggage and walking while using gadgets into this study, a better understanding of pedestrian behaviour in RTT is witnessed. The different behaviour during walking contributed to different pedestrian activities that need to be studied through their overall interaction with respect to space used. Thus, study pedestrian behaviour through their spatial interaction is crucial to determine pedestrian behaviour with different pedestrian activities.

1.1.2 Pedestrian Spatial Interaction

Pedestrian spatial interaction referring to an area surrounded human bodies that played an important role in determining pedestrian behaviour. Other names used to represent pedestrian spatial interaction are interpersonal distance, personal distance, proxemics distance, safety buffer, and territory. Being address as a virtual boundary between pedestrians, some researchers described pedestrian spatial interaction as the shape of a soap bubble or circular, an egg, an elliptical and a fan. It is believed that other factors such as culture, gender, age, and personality do affect pedestrian spatial interaction. During peak hours, a higher number of crowds were expected to flood in the RTT concourse area causing pedestrians to behave differently.

RTT as an important facility that attracts the crowd and promotes the use of public transportation especially rail services making the study of pedestrian behaviour attributes with consideration of spatial interaction crucial for planning smooth pedestrian flow and designing proper walking facilities in the RTT. Therefore, this study is carried out to empirically investigate pedestrian behaviour attributes in RTT for formulating pedestrian perception domain that represents Malaysia pedestrians.

1.2 Problem Statement

The largest rail transit terminal in Malaysia, namely Kuala Lumpur Sentral Station (KLSS) was originally designed to serve only 100,000 commuters daily (Nair, 2017). However, the current estimated number of commuters is increasing up to double its original design causing a study on the dynamics of pedestrian crowd behaviour is becoming necessary to provide smooth pedestrian movement and improve emergency response-ability. According to Zanariah et al. (2014), along the area of RTT in Malaysia, there were still lacking in overall and detailed consideration of pedestrian behaviour studies such as walking velocity, psychological distance, angular velocity and angle of avoidance. Therefore, it is important to determine the fundamental of pedestrian behaviour attributes with respect to the pedestrian in RTT.

The massive pedestrian movement was expected at the concourse area during peak hours in RTT as commuters' transit from their origin to their destination lead to low transfer efficiency. Besides, the variation of pedestrian activities while walking in RTT affected the overall pedestrians' movement and contribute to low transfer efficiency. Thus, understanding pedestrian behaviour in relation to spatial interaction with the consideration of pedestrian secondary activity while walking will prevent unnecessary congestion and increase transfer efficiency.

1.3 Objective

The objectives of this study are divided into two:

1. To determine pedestrian behaviour attributes in RTT (as listed below) with respect to different pedestrian activities while walking.
    i. Walking velocity.
    ii. Psychological distance.
    iii. Angular velocity
    iv. Angle of avoidance.
2. To formulate pedestrian perception domain that represent pedestrian at RTT in Malaysia using the above attributes. Pedestrian perception domain is important in modelling and simulation work.

1.4 Scope of Study

KLSS was chosen as a study area since it is Malaysia's largest transit hub that connects almost all rail transportations available in Kuala Lumpur. Besides, it is reported that the KLSS needs to cater up to 200,000 commuters daily where it already exceeded its original design with 100,000 commuters daily. This study is carried out based on field observation and video recording at KLSS Level 1 concourse area. The videos were recorded during peak hours (7.00 am to 9.00 am, 12.00 pm to 2.00 pm and 5.00 pm to 7.00 pm) in three sessions per day for three consecutive days during school holidays from 28/11/2017 to 30/11/2017. Since the video footage was taken during school holiday it represents the public high volume of usage during the holiday.

Pedestrian was chosen at random from collected video footage for analysis purposes. Since the concourse area is a big open space with an approximation area of 1,710 m^2, it is impossible to track pedestrian trajectories in the whole area. Therefore, a small space with an approximation area of 50 m^2 was selected as a predetermine measuring trap. The trap considered in this study was chosen to avoid the kiosk area so there will be no influence on the walking behaviour.

This study attempts to empirically investigate pedestrian behaviour attributes: walking velocity, psychological distance, angular velocity and angle of avoidance; and formulate pedestrian perception domain particularly in rail transit terminal. This study focuses on empirical analysis of walking pedestrian with respect to different pedestrian activities: normal walking, walking while carrying luggage and walking while using gadget particularly smartphones.

The pedestrians walking in the predetermine trap are selected from the video footage for analysis purposes by considering predetermined conditions: pedestrian walk individually without others companion, pedestrian must continue walking without stopping and sudden turning, pedestrian continue walking in the measurement trap and not just start walking in the trap, pedestrian must walk without any additional support such as wheelchair, shoulder crutch or cane and pedestrian must fall in either one of these six activities: normal walking male (MN), male walking while carrying luggage (ML), male walking while using gadget (MG), normal walking female (FN), female walking while carrying luggage (FL) or female walking while using gadget (FG).

1.5 Significance of Study

This study aims to help in increasing pedestrian securities in term of convenience, space structure and equipment layout of the transit terminal by empirically determine pedestrian behaviour attributes in rail transit terminal. Despite the increasing number of commuters, it is impossible to reconstruct the structure to cater to the commuters. The possible way is to plan a pedestrian stream and relocate the temporary structure. Therefore, the most appropriate approach is through the evaluation of pedestrian behaviour attributes and the outcome is used in planning pedestrian movement in the existing facilities and designing proper walking facilities in the future.

Few studies in developing cities have investigated the effect of different pedestrian activities during locomotion on pedestrian behaviour. However, there were several studies related to pedestrian walking while carrying luggage and currently no study related to the pedestrian walking while using gadget particularly smartphones in transit terminal. Therefore, this study aims to empirically evaluate the effect of different pedestrian activities on pedestrian behaviour attributes particularly in the rail transit terminal. Since the rail transit terminal is a place that attracts travelers, gadget likes smartphones have become unavoidable materials, causing their behaviour will help in a better understanding of crowd behaviour.

Besides, the evaluation of different pedestrian activities while walking provides a better understanding of walking velocity, psychological distance, angle of vision, angular velocity and angle of avoidance. Walking conditions in RTT differ substantially from those outsides because of the higher densities of people and a wider range of walking purposes. This empirical analysis of specific behavior might offer a better solution to the strategic approach for the traffic engineer in designing walking infrastructure. Furthermore, it can be used as a basic guideline for the planner, designer, and policymaker in strategizing the design of a sustainable transit-pedestrian oriented development and also improve the built environment for the pedestrian in the RTT.

1.6 Chapter Outline

This dissertation is organized into five chapters incorporate with references and appendix. Chapter 1 provides an introduction of the study, which discusses the general background of pedestrian behaviour attributes in RTT with consideration of spatial interaction. Chapter 1 also includes the problem statement, objectives of study, scopes, and limitations.

Chapter 2 presents literature related to pedestrian behaviour attributes in RTT. This chapter focuses on issues of existing RTT, pedestrian behaviour attributes, pedestrian walking velocity, psychological distance, angle of vision, angular velocity, angle of avoidance, flow density and perception domain.

Chapter 3 elucidates the methodology applied in achieving the main objectives of this study. The step by step process of data gathering at Kuala Lumpur Sentral Station (KLSS), converting raw data to analytical data and the criteria of the chosen pedestrian are explained. Moreover, this chapter also discusses the methodology of an empirical investigation on pedestrian walking velocity, psychological distance, angular velocity, angle of avoidance and density in RTT using mathematical equations to formulate the pedestrian perception domain.

Chapter 4 discusses the result using descriptive analysis and inferential analysis to investigate pedestrian walking velocity, psychological distance, angular velocity and angle of avoidance with respect to two categories (gender category and six variables category). Moreover, the result from pedestrian behaviour attributes is used in formulating pedestrian perception domain with consideration of pedestrian density is performed.

Chapter 5 summarises the key finding of this study. At the same time, the recommendations for future study are also discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Rail Transit Terminal (RTT)

Across the world, there are nearly 650 transit lines served by more than 11,000 stations. According to Florida (2018), transit is a key component of modern urban infrastructure that drives innovation and productivity, extends the boundaries of cities' rail area, creating opportunities for denser development around suburban transit and contributes for less-stressful commutes.

Tokyo is the busiest transit system with 3.46 billion trips annually followed by Moscow, Shanghai, Beijing, Seoul, and New York City. Tokyo with the capital's rail operators handling 13 billion passenger trips annually able to manage smooth commuters' movement along concourses and platform although commuters packed shoulder-to-shoulder (Richarz, 2018). Besides Tokyo, an estimated 9 million commuters took train across Russia's capital each day make Moscow's metro system one of the busiest mass transit systems in Europe. With such a huge crowd, brightly coloured ticket halls and exit areas were used to help commuters navigate efficiently (Abadi, 2018; Lo, 2018; Kuzmichyonok, 2018).

According to Cheng and Yang (2012), several incidents occurred in rail systems worldwide such as a serious explosion incident in Lubyanka Station, Moscow in March 2010 which caused more than 41 people dead and 60 people injured.

and a passenger trampling in Dongdan Station, Beijing in July 2011 caused by an escalator malfunction that leads to 11 people injured. Unexpected incidents may lead to a chaotic situation that needs proper crowd management.

According to Cheng and Yang (2012), several incidents occurred in rail systems worldwide where unexpected incidents may lead to a chaotic situation that needs proper crowd management.

Study on the dynamics of pedestrian's crowd behaviour is necessary in order to improve emergency response-ability and preventing such incidents. However, the study on the dynamics of pedestrian's crowd behaviour at RTT in Malaysia is not being focused (Zanariah et al., 2014). Providing the best RTT facilities from engineer and planner points of view is not the assurance of smooth pedestrian movement without the knowledge of pedestrian behaviour attributes such as pedestrian walking velocity, psychological distance, angular velocity, angle of avoidance and flow density.

2.1.1 Rail Transit Terminal in Malaysia

Rail transportation is one of the transportation services available in Malaysia with its early function to transport raw material such as tin from mining town at Taiping to Kuala Sepetang (Port Weld) back in 1885 (Nordin et al., 2017). As time goes by, rail transportation services evolved rapidly especially in Kuala Lumpur and its surrounding areas. Keretapi Tanah Melayu (KTM) Komuter was introduced as Kuala Lumpur first rail system followed by light rapid transit (LRT), monorail and mass rapid transit (MRT). Until now railway network that primarily serves Klang Valley and Kuala Lumpur consist of 11 fully operated rail lines estimated total ridership of 1.1 million daily on trains and buses with 99.7% service reliability (Pillay, 2017).

Masjid Jamek light rail transit (LRT) station that connects three rail lines is an example of RTT in Malaysia. According to Zakwan et al. (2016) deterioration in station performance was expected during weekends in Masjid Jamek LRT station due to non-familiar commuters which cause unnecessary congestion that influences other pedestrian movements. Masjid Jamek LRT station is a RTT surrounded by major land uses such as commercial building and business makes pedestrian movement massively generated brings the agencies to study pedestrian behaviour to address the issue of security, convenience, facilities utilization, space structure and equipment layout of transit station (Bohari et al., 2016).

Kuala Lumpur Sentral (KL Sentral) refers to the entire 72 acres (≈ 290,000 m^2) of development built based on Transit Oriented Development (TOD) consist of transportation hub (Kuala Lumpur Sentral Station (KLSS)), hotels, office towers, condominiums and shopping malls (Abdullah and Mazlan, 2016). As Malaysia's largest RTT, KLSS has long passed its maximum capacity with original design to cater up to 100,000 commuters daily by 2020. The estimated increasing number to 200,000 commuters daily aligned with the opening of mass rapid transit (MRT) Phase 2 leads to overcrowding (Nair, 2017). A natural way to alleviate transit crowding is by expending capacity, but it is time-consuming, expensive and businesses located near the transit route often oppose it (Palma et al., 2017).

Prasarana Malaysia Berhad project Kuala Lumpur population reach 10 million by 2020 and targeted 40% public transport modal share by 2030. Increase population in Kuala Lumpur lead to crowded transit stations. Sukor at el. (2018) mention that the facilities provided in RTT were limited, thus, the study on pedestrian behaviour is important for future planning and facilities design to cater increase in demand. Through RTT, various transportation network was connected under the same building and enhanced connectivity which promotes the use of public transport. Therefore, the study on pedestrian behaviour attributes such as walking velocity, psychological distance, angular velocity, angle of avoidance and flow density in RTT is crucial, especially in Malaysia.

2.2 Pedestrian Behaviour Attributes

Public buildings such as transportation nodes, terminal, and stations experiencing massive pedestrian movement. The study of pedestrian behaviour such as walking velocity, psychological distance, angular velocity, angle of avoidance and flow density is needed to accumulate different situation in such area which attracts high numbers of pedestrians to produce an effective and efficient design of any pedestrian facilities (Sukhadia et al., 2016). Serious congestion problems and pose threats to pedestrian safety in the high-density crowd make it crucial to understand the crowd dynamic and pedestrian behaviour (Wang et al., 2015). However, the information about pedestrian behaviour in high-density crowd dynamic was very little.

Pedestrian walking velocity is the most studied pedestrian behaviour in RTT as described in **sub-chapter 2.3**. Bohari et al. (2016) studied pedestrian walking velocity between male and female pedestrian and found that male has a higher average walking velocity compare to female. Besides, pedestrian behaviour attributes such as pedestrian psychological distance were studied by many researchers and used Hall, 1966 distance zone as a benchmark (see **sub-chapter 2.4**). Gorrini et al. (2014) studied pedestrian psychological distance during locomotion and compare the result with the personal distance proposed by Hall (1966).

On the other hand, pedestrian angular velocity and angle of avoidance are two pedestrian behaviour attributes that rarely studied by researchers. As described in **sub-chapter 2.6** and **2.7**, it is crucial to study pedestrian angular velocity and angle of avoidance, especially in RTT due to the close relation with pedestrian collision avoidance behaviour. Song et al. (2017) studied pedestrian angular velocity in unidirectional and bidirectional flow and found a higher value of body rotation during bidirectional flow compare to unidirectional flow. Besides, studied on the pedestrian angle of avoidance by Imanishi & Sano (2014) found that pedestrian with higher walking velocity needs a bigger angle of avoidance to bypass the obstacle.

Pedestrian behaviour attributes also being focused in other public buildings such as airport terminal and bus terminal. Public buildings were distinguished by its pedestrian behaviour attributes such as walking velocity and density where pedestrian behave according to their walking purpose and environments (Ali et al., 2018; Liu et al., 2018). Big variety of services offered in the airports related to the preparation of passenger for their air trip and their free time inside the terminal lead to the urgencies to study pedestrian behaviour attributes especially passenger flow (Kalakou et al., 2015).

2.2.1 Secondary Activities while Walking

Secondary activities while walking such as carrying luggage, using gadget, using a walking stick or in a wheelchair and groups were commonly seen in RTT. Pedestrian used transit stations for various reasons and were not only used by the working community but also traveller, student, housewife, elderly, etc. Most common secondary activities spotted in KLSS were walking while carrying luggage and walking while using gadget. Therefore, considering secondary activities while walking such as carrying luggage and using gadget provides precious information on overall pedestrian behaviour in RTT.

Secondary activity while walking such as walking while carrying luggage are often found in RTT but the impact of luggage on pedestrian walking behaviour has not been systematically investigated (Huang et al., 2019). Studies conducted found that walking while carrying luggage from small handbags to big suitcases at the outdoor environment and indoor RTT facilities such as stairs do contribute to different pedestrian behaviour (Gupta et al., 2017; Patra et al., 2017). In a big city like Guangzhou where most of the train station was connected to an underground shopping mall makes many pedestrians carried shopping bags or luggage not only affected self-behaviour but also affected other pedestrians nearby (Zhao and Ling, 2016). Considering pedestrian walking while carrying luggage behaviour attributes in designing pedestrian facilities can improve traffic efficiency (Huang et al., 2019).

On the other hand, secondary activity while walking such as walking while using gadget particularly smartphone have become a social issue since there was an annual increasing trend in the number of people accident related to smartphone used while walking (Yoshiki et al., 2017). According to Sharp (2015), walking while using smartphones grows annoyance in the mass transit railway (MTR) commuters. The commuters might be paying less attention to their safety and as well as the safety of other passengers. This has raised concern among the authorities. Using a smartphone while walking makes pedestrians inattentive to hazards and increases the risk of accidents and possible casualties in railway stations (Haga et al., 2015). German has employed a new way to address the danger of distracted walking especially pedestrian walking while using a smartphone by the embedded traffic light in the pavement in response to an increase in pedestrian traffic accidents such as being hit by tram (Phillips, 2017). Thus, with such effect, the study on pedestrian behaviour attributes with respect to walk while using gadget may provide practical information to improve the safe use of gadget while walking (Lim at el., 2017).

2.2.2 Spatial Interaction

Pedestrian spatial interaction comes in many names as listed by Sommer (2017) in **Table 2.1**. The interpersonal distance was defined by social psychology which refers to the amount of favourite space between organisms and their conspecifics. Meanwhile, peripersonal space was defined by cognitive neuroscience which refers to the area surrounding the body where stimuli are coded in a multisensory and motorway for immediate action. Personal space originated in ethology which refers to the emotionally tinged zone around the human body that people feel is “their space". Besides, proxemics refers to the space used by humans in relation to culture was introduced by Edward Hall, the cultural anthropologist. In Highway Capacity Manual (HCM), safety buffer refers to protective buffer surrounding the body to protect their integrity through defensive or avoidance actions. Meanwhile, territory refers to a fixed geographical space marked and defended by an organism and used for life-sustaining activities that were usually involved in a large area that not used in describing area surrounded the human body.

Effect of culture, gender, age, personality and situations towards pedestrian spatial interaction was investigated and the concept was applied in designing offices, stores, banks, and mass rapid transit (Sommer, 2017). Besides, pedestrian spatial interaction had been described using analogies to a soap bubble, snail shell, and aura around the human body, but the dimensions were not fixed and vary according to internal state, age, culture and context (Sommer, 2017). Pedestrian spatial distribution played an important role in pedestrian flow processes that may improve pedestrian traffic efficiency or caused crowding effect in pedestrian facilities (Liu, 2016). Pedestrian spatial interaction was interpreted in terms of psychological distance and used proxemics as a benchmark in this study.

Table 2.1 Spatial interaction glossary (Sommer, 2017)

Glossary (Sommer, 2017)	Description
Interpersonal distance	The amount of favourite space between organisms and their conspecifics.
Peripersonal space	The area surrounding the body where stimuli are coded in a multisensory and motor way for the purpose of immediate action.
Personal space	The emotionally tinged zone around the human body that people feel is "their space."
Proxemics	A term introduced by Edward Hall for the study of spatial relationships; Hall identified four interaction zones: intimate, personal, social, and public distance.
Safety buffer	Protective buffer surrounding the body to protect their integrity through defensive or avoidance actions.
Territory	A fixed geographical space marked and defended by an organism and used for life-sustaining activities.

2.3 Pedestrian Walking Velocity

Understanding pedestrian flow characteristic at RTT such as walking velocity on horizontal and vertical movement facilities play an important role for pedestrian changing and evacuating process (Patra et al., 2017). The unsafe pedestrian movement caused by a sudden change in pedestrian behaviour during trains arrival and departure makes it important to study on walking velocity and its relation to density (Shah et al, 2015).

Table 2.2 shows the list of pedestrian walking velocity obtained from various facilities in RTT by previous studies. Sukor et al. (2018) studied pedestrian walking velocity on stairway in RTT found that walking down the stair recorded higher walking velocity compare to going up. Meanwhile, Patra et al. (2017) also studied pedestrian walking velocity on a stairway in RTT found that males recorded higher walking velocity compare to females. Shah et al. (2015) studied the effect of stairway width on pedestrian walking velocity found that a wider stairway allows the pedestrian to walk faster compare to a narrow stairway. Besides, Zhao & Ling (2016); Zhao et al. (2014) studied pedestrian walking velocity on a walkway in RTT found that secondary activity (carrying luggage), type of shoes and companion do contribute to the reduction of walking velocity.

Table 2.2 List of pedestrian walking velocity at RTT from previous study.

Author	RTT		Walking velocity (m/s)
Sukor et al., (2018)	KLCC LRT station, Malaysia	Stairway	
		Ascending	0.81
		Descending	0.97
		Escalator	
		Ascending	0.76
		Descending	0.79
Patra et al., (2017)	Secunderabad Railway station, India.		
		Stairway	
		Male	0.756
		Female	0.590
Bohari et al., (2016)	Masjid Jamek LRT station, Malaysia.		
		Straight path concourse	
		Male	0.54 ~ 1.55
		Female	0.46 ~ 1.46
Zhao and Ling, (2016)	Guangzhou Metro Line 1, China.		
		Walkway	
		Male	1.14 ~ 1.40
		Female	1.05 ~ 1.35
		Luggage	1.01 ~ 1.13
		Shoes	
		Flat	1.10
		High-heeled	1.07
		Slippers	1.16
		Accompany	1.10
		Single	1.11
Shah et al., (2015)	Transit station Mumbai, India.		
		Stairway	
		Wide (2.65 m)	0.49 (1.99 p/m^2)
		Narrow (2.15 m)	0.47 (1.57 p/m^2)
Zhao et al., (2014)	Guangzhou Metro, China.		
		Age	
		0 ~ 15	1.00
		16 ~ 30	1.14
		31 ~ 60	1.10
		≥ 61	1.02
		Shoes	
		High heels	1.07
		Flats	1.08
		Slippers	1.11

According to Rastogi et al. (2011) walking facilities, age, gender, gadget, carrying luggage while walking and with companion were some factors that influence pedestrian walking speed. According to Zhao and Ling (2016), the relation between walking velocity and personal information such as age, gender, luggage, shoes and companion in Guangzhou metro station was analysed and found that the size of luggage was most obvious followed by the type of shoes. All listed studies in **Table 2.2** found that male pedestrian has a higher walking speed compared to female pedestrian. Other factors affected pedestrian walking velocity in RTT found from previously studied were a ground gradient, size of luggage, type of shoes and walking in a group.

Pedestrian walking velocity was also being studied in other indoor and outdoor pedestrian facilities as listed in **Table 2.3**. Shams-E-Rabbi & Hossain (2018); Vanumu et al. (2017); Gupta et al. (2017); Sukhadia et al. (2016) studied pedestrian walking velocity at outdoor walkway found that gender, gradian, group size, secondary activity (carrying luggage), event of the day (i.e. public holiday and special event day) effect pedestrian walking velocity. Furthermore, Ali et al. (2018) studied pedestrian walking velocity in bus terminal found that gender and secondary activity (carrying luggage) do affect pedestrian walking velocity.

Although most studies considered walking while carrying luggage as a common secondary activity, however, there was no study found on pedestrian walking while using gadget. Duke & Montag (2017) mention that gadget such as a smartphone has changed the way of communicating, navigating, working, and entertaining ourselves but there is no study on the effect of walking while using gadget particularly at rail transit terminal.

Table 2.3 List of pedestrian walking velocity in other places from previous study.

Author	Place		Walking velocity (m/s)
Shams-E-Rabbi and Hossain, 2018	Walkway in Khulna, Bangladesh.	Gender	
		Male	0.91
		Female	0.78
Vanumu et al., 2017	Walkway in Indian Institute of Technology Delhi, India.	Group size	
		1	1.85
		2	1.66
		3	1.52
		4	1.41
		≥ 5	1.28
Gupta et al., 2017	Walkway in Dharamshala, India.	Uphill	
		Male	1.02
		Female	0.91
		Without luggage	0.96
		With luggage	1.01
Sukhadia et al., 2016	Corridor in Vadodara, India.	Event day	
		Male	0.92
		Female	0.85
		Normal day	
		Male	1.12
		Female	1.00
Ali et al., 2018	Bus terminal area, Malaysia.	Without luggage	
		Male	1.20
		Female	1.16
		With luggage	
		Male	1.15
		Female	1.05
Liu et al., 2018	Chengdu Shuangliu International Airport, China.	Terminal piers	1.13

2.4 Pedestrians Psychological Distance

Psychological distance is a cognitive separation between the self and other instances such as persons, events or times (Baltatescu, 2014). The concept of psychological distance was put forward by Bullough in 1912 as principles of aesthetics and it evolved from time to time with great changes from the principle of aesthetics to measuring social attitudes and social relations (Li & Chen, 2019). Being address as pedestrian spatial interaction, pedestrian psychological distance focuses more on the interaction of individual pedestrian with other pedestrians around them. Psychological distance was also referred to as interpersonal distance (Layden, 2018; Cartuad et al., 2018; Bandini et al., 2017), personal space (Braga et al., 2016; Gorrini et al, 2014; Chugo et al., 2013), spatial behaviour (Liu et al., 2016; Guo, 2014) and proxemic distance (Hall, 1966).

General studies on pedestrian psychological distance across the world found that individual characteristic (i.e., ethnic, culture, age, gender and physical appearances), surrounding factors (i.e., familiarity, density, time of day, climate and temperature) and psychological factors (i.e., individualism level and loneliness) influence pedestrian psychological distance (Layden et al, 2018; Sorokowska et al, 2017; Dridi, 2015; Vieira and Marsh, 2014; Hall, 1966). Layden et al. (2018) found that individual pedestrian psychological distance towards stranger was 3.28 m and male pedestrian tend to prefer a larger distance than female pedestrian. Meanwhile, Vieira & Marsh (2014) found that the preferred psychological distance from 46 students obtained from experimental works was between 0.42 m to 1.58 m. Sorokowska et al. (2017) studied the preferred pedestrian psychological distance through a questionnaire involving 8,943 participants from 42 different countries. Malaysia was ranked the 12th for furthers psychological distance with 1.05 m to 1.16 m. Besides, Ali et al. (2018) studied the pedestrian psychological distance at the bus terminal area in Kuala Lumpur, Malaysia. They found that pedestrian psychological distance between male (1.37 m) was higher compared to female (1.10 m).

According to Braga et al. (2016) safety is a fundamental issue where it is very important to consider human psychological distance in designing pedestrian facilities. A large number of people used transit station every day as a result of urbanism make designing pedestrian facilities with the consideration of pedestrian psychological distance provides more comfortable walking spaces (Tang et al., 2012). The pedestrian psychological distance was discussed in general and no specific study focuses on pedestrian psychological distance in RTT. Interaction of individual pedestrian with other pedestrian expected to increase as the number of commuters in KLSS increases and contribute to limited space available that may lead to inconvenience walking environments. Providing comfortable walking space not only depends on the pedestrian facilities but also the smooth movement of pedestrian flow especially during peak hours. Therefore, due to the concern on safety issues related to a high number of pedestrians in public transport transit, it is important to study pedestrian behaviour attributes especially psychological distance (Ali et al., 2018).

2.4.1 Proxemic Distance

Hall (1966) was one of the earliest researchers studied on pedestrian psychological distance and referred to as "proxemic distance" by proposing four distance zones as described in **Table 2.4**. The study conducted by Hall (1966) on the proxemic distance was involving mainly natives of the northeaster seaboard of the United State. The distance zone was set as a benchmark in this study where the psychological distance was categorized based on the distance zone in **sub-chapter 4.4.3**. Although Hall (1966) distance zone is an old reference, it is still being used by other recent researchers as a benchmark. From the literature conducted, there are no other recent finding that systematically classify the psychological distance.

A few researchers that used Hall (1966) distance zone as a benchmark in their research work, like Gorrini et al. (2014) applied the general distance zone theories in collecting the dynamic of psychological distance during movement and compare it with personal distance proposed by Hall (1966). Meanwhile, investigation on traveller engagement with the local people conducted by Setiyana et al. (2017) and used Hall (1966) distance zone to interpret the proximity level. Besides, the study on the global comparison of preferred psychological distance conducted by Sorokowska et al. (2017) used Hall (1966) distance zone to classify the preferred distance according to intimate distance, personal distance, and social distance. Hall (1966) stated that the human sense of space and distance is not constant, it's the perception of space is dynamic because it is related to action "what can be done in a given space rather than what is seen by passive viewing".

Table 2.4 Distance zone

Distance zone (Hall, 1966)	Description
Intimate distance (0 to 0.45 m)	Distance between love-making couples (with physical contact and sensory input).
Personal distance (0.45 to 1.20 m)	Distance between close friends (with only physical contact) and relatives.
Social distance (1.20 to 3.60 m)	Distance represents the distance between promoter and client (with no physical contact and maintain normal voice level).
Public distance (3.60 to 7.60 m)	Distance represent the conventional interaction between pedestrians in public space (need amplifier to communicate in this distance zone).

2.5 Angle of Vision

It is found that pedestrian angle of vision was cone-shape rather than a semicircle (180º) and seldom react to obstacle located more the 45º from walking direction but only react with obstacle directly ahead (Kitazawa & Fujiyama, 2010). Besides, the study on pedestrian self-evasive action considers the binocular vision of 120º as the angle of vision (Gotoh et al., 2012). Meanwhile, according to Widmaier et al. (2008) human maximum horizontal field of view approximately 200º with two eyes, 120º which makes up the binocular field of view and two 40º fields of view seen by one eye as illustrated in **Figure 2.1**. They added that binocular vision gives human ability to detect objects in enhanced, provide stereopsis view (vertical field of view) to gives precise perception to depth. The binocular vision occurred when neurons receiving input from two eyes converge onto common cells in the primary visual cortex and it is common to human and many other mammals (Başgöze et al., 2018).

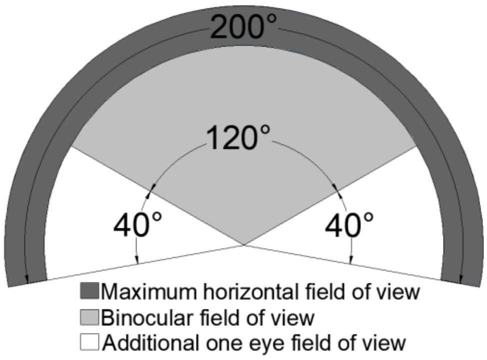

Figure 2.1 Human field of views.

Introducing individual visual field views in pedestrian movement is important due to the important role of vision in the motion of pedestrians (Qin et al., 2018). Pedestrian's field of view is defined by an angle and distance were considering that pedestrian is looking into their desired direction of motion and the angle defines how much the pedestrian able to see on either side of the imaginary line of sight (Porter et al., 2018). Since it is impossible to empirically measure the pedestrian angle of vision based on field observation, adopting from previous research is the most appropriate solution to determine the pedestrian angle of vision.

2.6 Pedestrians Angular Velocity

Parisi et al. (2016) defined angular velocity as the rate of change of angular position of a rotating body where it is used to measure the curvature of the trajectory due to the lateral swaying with expected oscillatory behaviour. When the unidirectional