SIMULATION ON PASSENGER MOVEMENT FOR LRT KELANA JAYA LINE KL SENTRAL STATION USING VISSIM SOFTWARE

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Dedicated to all my beloved peoples

A IBRAHIM KUTTY & RUHANI ADEI,

MUHAMMAD AJMAL IBRAHIM & ARIFAH IBRAHIM,

& FRIENDS

Who always be there for me
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In the name of Allah S.W.T, The Most Gracious and Merciful.

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In particular, my sincere thanks are also extended to all my friends and others who have provided assistance at various occasions. Their views and tips are useful indeed. Regrettably, it is not possible to list all of them in this limited space. Thanks you. May Allah S.W.T. bless upon all of you.
Level of Service (LOS) is commonly used to assess the quality of operations of transportation facilities at the roadside. However, LOS, measures for pedestrian facilities such as waiting areas are not well developed until now. The main objective of this study is to determine the level of service of platform at KELANA JAYA LINE KL SENTRAL station, in order to identify the current operational conditions. Objectives are achieved by referring to LOS standards from Highway Capacity Manual (2000) and Transit Capacity and Quality of Service Manual (TCQSM). Furthermore, a simulation model has been carried out to analyze the Levels of Service (LOS) of the station, by the use of VISSIM 7.0. Additionally, simulation has been carried out for peak and non-peak hours and for the next five years scenario as well. Results showed that, LOS at platform was D during the peak hours, however LOS reached level E when the train arrived at the station. The probability of worse LOS levels in the future are high. Based on simulation data, access way front and the end of platform edge were identified as areas that are highly crowded. Based on three tested scenarios, simulation results indicated that station layout could handle up to 5,000 passengers per hour (boardings and alightings), while maintaining an excellent level of service. However in the case of 6,000 passengers per hour, results indicated that station were likely to become significantly crowded. Results from this study could be used as a guide by authorities and management team of the station to detect and monitor the LOS of the platform. Hence, could provide better service that matches the right level of service and provides higher passenger comfort, while using the service.
ABSTRAK

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CHAPTER 1

INTRODUCTION

1.1 Study Background

Nowadays traffic congestion reduction is widely considered as one of the most common reasons for building new transit systems. Today, the demand for rail networks across the globe is increasing, hence they are getting busier. Additionally, they became the most preferable public transportation choice by the users. To avoid congestion in traffic, railway transportation mode is the best option offered to the public, since it is ease of use. As a developing country, Malaysia depends on an urban transportation system that is effective and efficient.

As passenger distribution nodes, rail transit stations are one of the public buildings that have the highest pedestrian density. In the year in 2000, world urban population reached 2.9 billion and it is expected to increase to 5.0 billion by 2030 (Tom et al, 2006). Meanwhile, the effects of high passenger density at bus stops, rail stations, buses and trains are diverse.

On the other hand, when an area is filled with people, we will be able to see different patterns of walking behaviors, various kinds of interactions of each person and various movements that lead to different levels of comfortability and disrupt of service. For example at a train station, crowding conditions at station platform critically affect
the behavior of passengers and the dwelling time of trains, which as a result has an impact to the line capacity (William et al., 1999).

Hence, governments, operators and other agencies involved in providing service to customer should be able identify their customer needs and how they feel about the goods or services provided. Level of Service (LOS) of pedestrian can be applied to evaluate these provided services.

Level of Service (LOS) is a method by which a transportation facility's performance is evaluated. In general term, it is a quantitative measure describing operational conditions of a facility's stream and user's perception of those conditions within an area of evaluation (Klodzinski, 2001). Thus, LOS is generally used to determine the effectiveness of a facility's performance, including traffic jam in highway or signalized intersection.

By selecting a platform in a LRT station for the case study, a simulation model was established to evaluate the level of service of passenger flow and the simulation results has been analysed. The method used to determine the (LOS) for pedestrian is adapted from the Highway Capacity Manual (HCM) and Transit Capacity and Quality of Service Manual (TCQSM). Computer simulation of pedestrian movement is a useful method to help designers to understand the relation between space and human behavior.

Pedestrian simulations are used to analyze pedestrian flows, for example at airports and railway stations (Dallmeyer et al., 2012). A software for this kind of studies is often used with the focus on pedestrian density and evacuation issues.

Micro-simulation modelling allows the evaluation of potential interactions between pedestrians and vehicles. Various commercially available micro-simulation packages in the market have been used by professional software engineers around the world (e.g. VISSIM, PARAMICS, and AIMSUN). Similarities among these packages are in the ability to capture the effects of pedestrian crossing behaviour on vehicles and pedestrian travel time to be tracking.

VISSIM simulation platform was chosen to carry out this study due to its listed advantages over other platforms below. Additionally, this study has been carried out using the latest VISSIM 7.0 version. In VISSIM, a number of outputs can be obtained and transferred to Excel to be further analysed. These analysis processes include
pedestrian flows, journey time, delay time and pedestrian density. Moreover, Advantages of VISSIM are:

1. Ability to build pedestrian networks,
2. Required input and resulting output data:
   a) Input data - includes pedestrian flows, pedestrian speed and link widths.
   b) Output data - includes pedestrian flows, travel times, delay times and pedestrian density.
3. Ability to model pedestrian behaviour and interaction with vehicles,
4. Output visualisation capabilities.

In VISSIM, specific 3D images can be defined for each pedestrian group, as well as limited road markings and further 3D objects, such as street furniture. The 3D model is integral with the simulation, with the ability to select 2D or 3D for visual output and video clip recording.

1.2 Research Motivation

Based on “My Rapid Train Frequency” peak hours report, train frequency cycle average is 3 minutes. However, waiting areas cannot provide adequate space for passengers. A peak hour in train frequency may be referred to in Figure 3.25 Chapter 3, where a less minute is called a peak hour. Furthermore, inadequate space in waiting area could be seen at morning peak hours from 7.00 to 9.00 am and evening peak hours from 5.00 to 8.00pm (Figure1.1). An inadequate waiting space has tremendous negative effects on passengers, who are waiting in that area, which results in delays and time loss. Moreover, it positions rushed passengers to fight over in order to catch a train.
Apart from that, not only inadequate space causes delays and time loss for passengers, but also contributes to increased levels of discomfort that may be a health risk especially for elders and passengers with special needs.

On the other hand, high probability of increase in traffic are predicted yearly, that has similar characteristics to traffic volume in highways. Moreover, Kuala Lumpur has high level of population, that reaches 6891 citizen per square kilometers (BANCI 2010). This level makes a city more crowded and busy in all places. This research questions future implications of such problems, whereby today's platforms cannot provide an adequate space for passenger. Additionally, this research provides solutions to these issues by evaluating a simulation for future ridership of trains.

1.3 Objectives

This research aims to satisfy the following objectives:

1. To conduct a simulation of peak hours and non-peak hours using VISSIM software.

2. To identify Level of Service (LOS) of passengers at KELANA JAYA LINE KL Sentral platform.
3. To simulate future ridership in order to investigate the platform ability to load passengers for the future population.

1.4 Scope of Study

This research is established with the focus on the following scopes:

a) KELANA JAYA LINE KL Sentral platform is chosen location for this research.

b) Passenger flow during peak and non-peak hours are considered.

c) The area from the front of the access way (escalator and stairways) up to platform edge parameters are covered, with total platform width of 8.5m and length of 112.5m.

d) Data collection of the passenger volume is ranged within peaks and non-peaks hours, and they are; 7.00 to 9.00 AM and 5.00 to 8.00 PM during weekdays.

e) Train passenger capacity and coach platform entrance factors are neglected.

f) Human behaviour, and Level of Service (LOS) are addressed in literature review according to the type of simulation methodology.

g) Literature focuses on transportation systems, general theories and models on human behaviour based on relevance, with the use of VISSIM simulation only

1.5 SIGNIFICANCE OF RESEARCH

In this research a VISSIM simulation is proposed, in order to observe and analyse passenger flow during peak and non-peak hours at train stations. Hence, a comparative analysis and evaluation on the simulation is necessary to precisely capture the reality of the situation.

This research will be enable transit operators, transport planners and building designers to provide suitable walkway area to meet passenger personal space demand. This is essential in providing sufficient space for passengers that are waiting for transit services. Additionally, to prevent crowding at the platform, this could present safety hazards to the users, especially in the case of an accident.
Besides that, this research can be used as reference for future studies to further investigate this area. In order to improve the quality of service on train stations, further studies on the level of service of passenger and on other factors are essentially required.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this literature review chapter, literature study has been carried out based on previous studies and literature to get more understanding regarding the study project. The basic concept, the factor of pedestrian simulation and few other main topics have been discussed in this chapter.

As noted in chapter 1, the increase in a number of populations day by day, make the building compact and cramp or known as crowding. Transport and traffic systems led to the development of computational methods can estimate and measure the parameters required for a set of traffic conditions such as traffic simulation. This chapter contains studies related to pedestrian simulation. The first part of this chapter will focus on an overview of the simulation consists of definition and simulation models. There are discussed the model validation and measurement. Advantages and disadvantages of simulation will also be discussed.

The second part of this chapter will discuss the behaviour of the pedestrian and factor that will be affecting the pedestrian behaviour while moving. Whereas the latter part of this chapter describes the Level of Service (LOS) and crowding topics.
2.2 Pedestrian Flow Model Simulation

In recent years, transportation research community starts to more focus on the pedestrian flow at public spaces. Pedestrian flow modelling, simulation, and optimization are their main attention to solved off. As we can see, public spaces like a shopping mall, transportation hubs and etc. are always full with crowded people. Thus solving these day to day problems and optimizing the evacuation procedures need to give full attention and focus on. This topic might be able to help for the architects for design purposes to see how pedestrians move in buildings and also for transport engineers to tackle and solved the safety and transportation facilities integration problems in big hubs.

A simulation of the passenger flow can be done to analyse and to identify the main cause of the crowded situation. Numbers of simulation and method approach in both microscopic and macroscopic scales have been already put forward into the pedestrian modelling and has been carried out from the past studies from few of the researchers.

Many researchers say that the simulation method is a method increasingly popular and widely used in the fields of transportation and traffic (Rajiv et al., 2004; Syzmon et al., 2012).

The definition of simulation is difficult to describe in detail because it can be translated to mean different things depending on the particular situation (Rajiv et al., 2004). As his study showed, simulation definition means a package of computerized analysis that identifies the movement of vehicles in the road network model and network performance measured by summing together the results from the movement of the vehicle.

Other researchers did state that, simulation can be defined as "a broad collection of methods and applications to mimic the behaviour of real systems, usually on a computer with appropriate software" (Kelton et al., 2010).

Meanwhile, Syzmon (2012) defined a simulation as a "statistical sampling techniques under control". In their study, the simulation is a series of studies using a variety of computerized data input. In addition, the simulation model is described as an application that can show the actual operating system and a set of output data that can
reflect and evaluate the operating system. Their study also did state, a simulation model can be attributed to two components, namely, information about requirements or consumer travel demand, as well as information on the transport network, traffic zones such as residential areas, and public transport. In addition, they also noted that the importance of the application of simulation to design and evaluate alternative solutions to transport problems, training, traffic management and road safety analysis.

In addition, thru simulation, we can test the efficiency of our service, type of risk that will be experiencing by the users, and evaluate other things. Computer simulation is referred to as the "methods for studying a wide variety of models of real-world systems by numerical evaluation using software designed to imitate the system’s operations or characteristics, often over time" (Kelton et al., 2010).

2.2.1 Basic Concept to Carry Out Pedestrian Simulation

To understand the pedestrian flow and behaviours are the main essential point in the planning and design of walking facilities. When designing passages or way for pedestrians, engineers need to forecast pedestrian flows, plan sufficient space to placed or accommodate pedestrians and figure the effectiveness of the new walkways without causing any trouble in the future so that can avoid any reconstruction again.

To make the forecast more accurate and reliable, engineers shall know the characteristics of pedestrian flows. Thus, before starting the work, it requires effort for thorough observation and substantial data collection to understand the pattern of the pedestrian flows. To ease and make the planning process easier and to reduce the waste of time in doing same thing repeatedly, pedestrian flow models are developed for describing pedestrian behaviours and predicting pedestrian flow, and this can be done by carrying out the simulation based on the building design even though the real exact building are not build yet.
Since the 1950s, many model simulation have been developing and been studied. Other than the traffic flow, pedestrian flow simulation model also has been discovered long back. Besides, these models are vary in terms of approaches (e.g. macroscopic and microscopic, agent-based and cellular automata (CA)), application areas (e.g. pedestrian walking behaviours in normal and stressful conditions) (Bilal et al., 2012). Due to improvement, many of the software company start to produce their own simulation models such as Legion, PTV Vision VISSIM (Figure 2.1) and STEPS. But in general, these models either formulate the relationships among the characteristics of pedestrian flows such as density, walking speed and flow rate or simulate the walking behaviours of individual pedestrians. Nonetheless, whatever the types of pedestrian flow models, all of them require precise parameter calibration to suit the purposes of their applications.

2.3 Type of Behaviour Modelling

To conduct a simulation of pedestrian flow, first matter that needs to be observed is the behaviour of the movement of the pedestrian at the study area. As people move around, they tend to make a different kind of behaviour, such as there will be a passenger in normal mode, rushing mode, emergency mode and different other modes of walking
(Schadschneider et al., 2002). Thus to create a model, it should be as simplified as possible as the reality and could reflect the realistic behaviour. In pedestrian modelling, it can be done in two different scales, macroscopic or aggregate models and microscopic or disaggregate models (Bilal et al., 2012). There are many types of model simulation that been used. Each model simulation has scope and accuracy of different results. Among the simulation model created are (Bilal et al., 2012):

1) Macroscopic model
2) Microscopic model
3) Mesoscopic model

A microscopic model is capable in reflecting the basic behaviour of each of the passenger and the interaction between individuals where each of the pedestrian is figure separately and their behaviour based on the pedestrian characteristic. While in a macroscopic model, the pedestrian is studied in a crowd or group of people instead of individually as in microscopic models. It also included and considers the mass densities, flow and average velocity (Schadschneider et al., 2008). Between microscopic and macroscopic model, there is mesoscopic model studied by Teknomo and Gerilla (2008). But these studies do not obtain the expected result because this model it combines both macroscopic and microscopic character, where it consider passenger individually but in aggregates terms.

Pedestrian dynamic theories have three different level type of behaviour, Strategic level, Tactical level and Operational level (Hoogendoorn et al., 2001) (Schadschneider et al., 2008). Figure 2.2 showed firstly, at the strategic level, at this moment, the pedestrian has no clue about their direction yet. So at this pre-trip destination process, they will figure out and start to plan the route that they going to take. While at next stage, tactical level, after gather all information, the pedestrian will decide their route after considering the entire factor such as obstacle, the short way route and etc. Lastly, at the operational level, we can start to see their walking behaviour. At this point, pedestrian will start to walk to their direction with multiple behaviour, like in a speed mode, walking in the opposite direction, anticipation on obstacle, avoiding collision between other pedestrian and et cetera. Thus, in operational level, pedestrian
will act according to how their plan in the earlier stage, strategic and tactical stage as shown in Figure 2.2.

![Diagram showing strategic, tactical, and operational levels in pedestrian walking behaviour]

Figure 2.2: Different levels in pedestrian walking behaviour

2.3.1 Macroscopic Pedestrian Flow Model

Henderson (1974) first used gas kinetic equations for modelling pedestrian movement. Based on his investigations on fluid dynamic properties of pedestrian crowds, the approach has then been widely used for pedestrian flow modelling. In macroscopic model, pedestrian cannot be distinguished as one by one because it is considered in a
group of pedestrian, where the aggregates attribute to whole group like the flow, average velocity and density are been consider.

While, according to Helbing (1992), he found that fluid-dynamical are much more similar to the pedestrian flow movement. The studied has been proving that the changes in densities of the different motion type that refer to different direction of walking can be explained by these effects:

1) Tendency of pedestrian to approach their own desired speed
2) The interaction between pedestrian
3) A pedestrian who change their direction/motion from right to left.

A macroscopic model is mainly focus on the movement of pedestrian in a crowd through flow, density and speed (Fruin, 1971; Still, 2000; Daamen, 2004). The macroscopic behaviour can be conclude as when pedestrian average speed is reduced as the density increases. The flow equation,

\[ \text{Flow (Q)} = \text{Average Speed (V)} \times \text{Average Density (K)} \]  (2.1)

To count the pedestrian flow, average speed and area module need to be considered. The reciprocal of the density is called the Space Module or Area Module (M) (Teknomo, 2002).

\[ \text{Pedestrian Flow (Qp)} = \frac{\text{Average Speed (Vp)}}{\text{Area Module (M)}} \]  (2.2)

Analyses of macroscopic mostly are suited for very high density, large systems in which the behaviour of groups of units is suitable. Based on past researcher, Hughes (2002), he came out with a theory of the flow of pedestrians based on continuum modelling which flow of pedestrians as a "thinking fluid" based on well-defined hypotheses. The hypotheses that he made is to proof that the development of macroscopic model and to understand the motion of large crowd, and as foremost thru this hypothesis, area that crowd with pedestrian can be known whether it is dangerous or not and able to state the factor that lead to crushing and trampling accident.

Macroscopic model mostly are being practice and apply in building codes for pedestrian planning and design. But, however, the assumption of a linear relationship
between space and flow of macroscopic simulation is lack in several aspects. As Teknomo (2002) finding, this model is unable to give accurate results for the model. Because it is not view as individual thus we can’t analyse it thoroughly. Hence, if the interaction between the pedestrian can be controlled thru out the simulation, a more efficient pedestrian flow can be achieved with less space. These are some of the reasonable and concrete reasons of changes from macroscopic to microscopic.

2.3.2 Microscopic Pedestrian Flow Model

Microscopic pedestrian models use individual pedestrian as the elemental unit for modelling. In these models, the movement and the behaviours of individuals are controlled by rule sets or behaviour models. Based on the models, they can be classified into two models, as agent-based models and cellular automata (CA) models.

The main difference of these two types of models is that agent-based models treat walking space as a continuous while, in CA models, the movement of pedestrians are restricted on grid-like or discrete space. Social force model, a classical agent-based model developed by Helbing and Molnar (1995) simulates the collision avoidance behaviours of pedestrians. It suggests that the motion of pedestrians is subject to “social forces” which are the measures for the desire of the individuals to perform certain actions. These include acceleration of pedestrians towards their desired velocity and, the effort of pedestrians to keep a certain distance away from other pedestrians and obstacles. Due to improvement, nowadays, microscopic model have become much more feasible and useable (Bilal et al., 2012).

Microscopic models are much more accurate as these models treat each individual or pedestrian in a crowd as an individual agent occupied an area at a specific time. From this model, we could obtain all the important input regarding the behavioural inputs of the pedestrian that we analyse. In a simple explanation, factor of microscopic model are that the pedestrians are moving towards their destination by considering the interaction between the other pedestrians (Helbing et al., 2002) and (Teknomo, 2002).
Such models give a more realistic representation of pedestrian movements as compare to macroscopic simulation.

These microscopic models can be classified into four groups: Physical based models, Cellular based models, Queuing network models and Multi agent models.

2.3.3 Mesoscopic Pedestrian Flow Model

The last model is mesoscopic modelling. Mesoscopic modelling is a combination of macroscopic and microscopic model. Where, this model considers large area as macroscopic but requires more detailed modelling. Thus, the complexity in the use of microscopic models can be reduced by mesoscopic model. Thus, the complexity in the use of microscopic models can be reduced by mesoscopic model. In terms of microscopic, Barcelo J. (2010) states that mesoscopic model is more efficient than microscopic model as this model does not require a lot of detailed data. However, these model simulation results are less accurate when it used a larger area.

Hanisch et al. (2003) has come out with an idea of individual grouping to mesoscopic pedestrian flow models for the online simulation of pedestrian flow in public buildings. Instead of modelling a single pedestrian as a microscopic model, groups of pedestrians are used and every group has its own rules of behaviour. Besides that, Tolujew and Alcala (2004) also had applied this mesoscopic approach for the simulation of pedestrian traffic flows in public buildings. However, for this both studies, they could not achieve their objective as the results are less accurate.

2.4 Type of Microscopic Simulation

In this study, microscopic simulation has been chosen since this type of simulation can interact and can be analysed as individually. For microscopic simulation, there is number software that can be use. Each type of software has a different features simulation. Some examples of software that are often used are VISSIM, CORSIM and SUMO.
2.4.1 VISSIM

VISSIM software is also used to provide micro-simulation. The software is set up by PTV AG, a company based in Germany. VISSIM software able to simulate the various traffic flows, including cars, trucks, buses, trains, pedestrians and others. The advantage of this software is able to translate the model in 3D makes it an often used by designers and traffic engineers to simulate various traffic conditions and thus applicable for assessment and analysis of the quality, safety and cost. In addition, the flow of traffic, putting the vehicle, toll plazas, service stations and transport facilities can be modelled using this software (Blatnig, 2008).

Unlike CORSIM software, VISSIM is able to perform dynamic traffic assignment, using GIS layer or ortho image to define the reference input and output animation and make adjustments to the characteristics of the driver, the acceptance interval, the location, and the results (Rajeev et al., 2004).

However, this software costs, technique and knowledge of high traffic. In addition, the overall weakness is also VISSIM software program is quite difficult and complex to understand. Errors from little data or information when using this model will also affect large or error to the results of the analysis. Results of analysis using VISSIM also may vary with operational analysis of traffic signalized by HCM as VISSIM simulation and analysis using gap-acceptance theory (Rajeev et al., 2004).

2.4.2 CORSIM

CORSIM is software that is often used in microscopic traffic simulation developed by the Federal Highway Administration (FHWA) in the United States. The software is suitable for non-traffic highways and expressways. CORSIM suitable for use in a microscopic model because the software is able to model every single vehicle in traffic in turn simulates the interaction between the vehicle and the environment with care. In accordance with the main purpose of which is to reflect the CORSIM traffic situation in detail, the software is also able to simulate various network topologies, of roads or
traffic, traffic control, and the nature of vehicle movement and driver behavior itself (Blatnig, 2008).

According to Rajcev et al. (2004), low-cost software also has some disadvantages. Among them are the graphics and animation produced only a 2D version only, cannot use GIS layer or any ortho images to help define the input or output refers animation, unable to generate dynamic traffic assignment, and has had the number of nodes, links, and the number of vehicles in the simulation. In addition, there are some users who say that this software does not have a logical estimate on driver attitude when in a situation of severe traffic congestion.

2.4.3 SUMO

SUMO software or "Simulation of Urban Mobility" is a micro-simulation software is open sourced, developed in 2001. This model was developed based on the space-continuous and car-following model. The main purpose of this model is to generation networks, demand generation and simulation (Krajzewicz et al., 2012).

2.5 VISSIM Software

After went through the previous studies and literature, VISSIM software has been chosen for this project. VISSIM is a microscopic, behavior-based multi-purpose traffic simulation to analyze and optimize traffic flows (Fellendorf. et al., 2010). It offers a wide variety of urban and highway applications, integrating public and private transportation. Complex traffic conditions are visualized in high level of detail supported by realistic traffic models.

Generally, VISSIM is used for general modeling, simulation and control system design applications. VISSIM is an award winning graphical block diagram language for modeling and simulating complex dynamic systems (Hermant et al., 2010).

VISSIM is a friendly simulation software, it is because this software have visual interface that offers a simple method for constructing and simulating large-scale
complex dynamic systems, its math engine provides fast, accurate solutions for linear,
nonlinear, continuous time, discrete time, time varying and hybrid system designs.

2.5.1 Benefit of VISSIM

PTV VISSIM have been used by more than 12,000 around the world for microscopic
traffic or pedestrian simulation either by researcher, architect, engineer and others
purpose of scope of works. VISSIM is the only software that can combine all mode of
transportation and including the pedestrian, motorized traffic and bicycles into one
single simulation, which make VISSIM as the preferable software been chosen
nowadays because it is more realistic.

Option for a planning tool that can be customised to suit user needs. We can
include all the vehicle and driver properties at different level based on traffic and
pedestrian demand. PTV Vision also can connect the simulation software to other PTV
software solutions. VISSIM software can be view in 2D and 3D animation. Thus, it will
make complex and difficult traffic situation looks more understandable and looks more
interesting.

In VISSIM, a number of outputs can be obtained and transferred to Excel for
further analysis including pedestrian flows, journey times, delay times and pedestrian
density. The latter can be an important factor in assessing the level of service offered to
pedestrians (Paul et al., 2005).

Based on Paul (2005) studies, TRANSYT, AIMSUN, PARAMICS and VISSIM,
he concluded that VISSIM was the most flexible tool and was capable of:

1) Building explicit pedestrian networks as well as link widths.
2) Receiving input of specified flows or origin/destination matrices.
3) Using variable pedestrian walk speeds.
4) Providing output of pedestrian flows, travel times, delay times and pedestrian
densities.
5) Modelling some pedestrian behavior and interaction with vehicles and.
6) Visualizing outputs in either 2-D or 3D.
2.6 Pedestrian Behaviour Types at Public Spaces

Behaviour of this pedestrian crowd has been study almost four decades (Batty et al., 1997). Direct observation, photographs, and time-lapse films are the method use to evaluate the crowd behaviour. The main objective of those studies was to come out with a new level-of-service concept (Helbing, 1997) to propose a new design pedestrian facility and for the planning guideline as well. But, those studied can’t be done at the pedestrian zone or in a building because of different type design building they have and in a situation of emergency as evacuation. There are few models for route behaviour, such as, queuing models, transition matrix models, and stochastic models (Bilal et al., 2012). These models have been proposed to overcome the complexities which are slightly related to each other.

However, even though a number of simulations have been proposed, the crowds are still unable and difficult to be predict because each of the pedestrian are dealing with different type of obstruction and thus it disturb the flow. This is because, as mention by Henderson (1974), he mentions that pedestrian crowds behave similar to gases or fluids. However, a realistic gas-kinetic or fluid-dynamic theory for pedestrians must contain corrections due to their particular interactions (i.e. avoidance and deceleration manoeuvres). It meant that even though simulation has been used, the result can’t be used as a preference or guide as in real case because the flow are keep changing.

Pedestrian flow models are widely used for walking facility planning and design. Few of the studies that have been carried out are, Daamen et al., (2002) used a pedestrian flow model to assess the design of a railway station. Yuan et al. (2008) used Legion, a commercial pedestrian flow simulation software package to model the pedestrian traffic in Beijing Olympic Games 2008. (Klüpfel et al., 2007) used pedestrian flow models to simulate pedestrians at very large events such as the World Youth Day in 2005 and non-emergency exit from a football stadium. (Seer et al., 2008) established a modeling approach to estimate the effective capacities of passages including doors, stairs and meanders in railway stations for evacuation assessment.

Klüpfel (2007) has conducted a study and come out with computer models for emergency and evacuation situations. The result shown those panic modes are only
rarely can be seen. At the highest peak of emergency, such as when the pedestrian experiencing the critical anxiety to survive only then panic mode will occur such as stampede within the crowd.

When the pedestrian are in panic mode, the only thing that they tend to do is safely escape for their self without consider other people around them and it just uncontrolled situation. Thus, when this situation happens, we often can see that when the users are in panic and fear mode, they will not be looking around other than the main door to escape, and this is why other exit options like exit to be use during emergency being ignored. This “herding behaviour” usually leads to worse and dangerous overcrowding thus it makes the escape process become slower. (Klupfel, 2007) and can cause fatalities because of the selfish behaviour.

2.6.1 Normal Situation of Pedestrian Behaviour

Based from the previous studies of passenger behaviour, we can summarize the observation of normal situation of pedestrian behaviour when there are in a crowd as below: (Helbing et al., 2002).

1) Pedestrian always considers the fastest way compare to the shortest way to their destination. One of the phenomenons that can be seen is even though the route direction that the pedestrian are taking are going to the crowded places, they will still insist to walk into that direction rather than taking any detours or moving into the opposite direction. Thus, only at this moment they will consider the detour route so that they can reach their destination faster.

2) The variation of pedestrian speed in specific areas can be influenced by passenger desired speed. Pedestrians prefer to walk with their own desired speed. As we can see, that is why the flow has variety of walking speed in a one area. They chose to walk to the speed that they are comfortable with and depends on the matter for them to reach their destination in time (meeting, shopping, and etc.). Nonetheless, situation, sex and age, the time of the day, the purpose of the trip, the surrounding will affect the average speed.
3) It is a normal situation that all the pedestrian will be walking at the centre of the lane or walkway or passage or at least at the side but still keep the distance between the walls. Other than that, in a normal situation, each of the pedestrian will walk in safe distance between other pedestrian to avoid any collision or stampede.

2.6.2 Panic Situation of Passenger Behaviour

While in typical panic situation, this situation we can rarely see it, as it only happen if there is any emergency or urge for the public to leave the building at the exact time. Stampede can cause a serious injury to the crowd as the crowds will be trampled to each other and sometimes in unlucky situation it also can cause death. There is little reason why when everyone start to rush they tend to make an aggressive move as highlighted by previous researcher (Helbing et al., 2002):

1) In panic situation during the time of escape, individuals will be in nervous thus they will be in “Blind Mode” which is they will not consider the surrounding; they are just focusing on their self.

2) A person tends to walk and move extremely faster than normal speed.

3) Individuals start pushing, and interactions among people are being ignored as long as they able to out from the place.

4) Moving and passing around of a bottleneck frequently becomes in coordinated.

5) The physical interactions during the crowding can cause steel barriers to bend or brick walls tear down because of the pressure might increase up to 4,500 Newtons per meter.

6) When there are fallen or injured people, they will become as an obstacle to the others. Thus, the escape move will be slowed down. However, at this situation, barely can be seen any helpful hand been offered to the fallen or injured people.

7) People tend to show herding behaviour.

8) Alternative exits are often overlooked or not efficiently used in escape situations.
2.7 Factors Affecting Pedestrian Flow Behaviour

There are many factors affecting pedestrian flow which should be paid attention during model development and parameter calibration.

2.7.1 Mean Walking Speed

Mean walking speed is the fundamental component of pedestrian flow model and free flow speed indicates or to show the average movement speed of pedestrians when they are not hindered or been obstruct by other pedestrians or other obstacle, walking under normal condition. However, it requires extensive data collection for calibration as the walking speed is subject to many factors such as area of walking space, mood, weather and few other factors (Xu, et al. 2010). Figure 2.3 shows examples of factors which may affect walking speed.
Pedestrian walking speed determines the flow rate or capacity of a walking facility. The relationship of pedestrian flow rate and walking speed are as flowing:

\[ q = \frac{N}{t^*w} \]  

(2.3)

as

\[ v = \frac{d}{t} \text{ and } p = \frac{N}{w^*d} \]  

(2.4)

therefore,

\[ q = p^*v \]  

(2.5)
where

\[ q = \text{pedestrian flow rate} \]
\[ v = \text{average walking speed of pedestrians} \]
\[ \rho = \text{density of pedestrian in the walking facility} \]
\[ N = \text{no. of pedestrians passed through the walking facility} \]
\[ t = \text{time for a pedestrian to pass through the walking facility} \]
\[ w = \text{width of the walking facility} \]
\[ l = \text{length of the walking facility} \]

Thus, the walking speed of pedestrians is directly proportional to the pedestrian flow rate. In other words, the faster is the walking speed of pedestrians, the larger is the pedestrian flow rate or capacity of the walking facilities.

Table 2.1: Pedestrian flow rate under different circumstances

<table>
<thead>
<tr>
<th>Source</th>
<th>Max. Flow Rate (person/min/m)</th>
<th>Critical Density (person/m²)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruin (1971)</td>
<td>72</td>
<td>1.08</td>
<td>United States</td>
</tr>
<tr>
<td>Daly et al. (1991)</td>
<td>86</td>
<td></td>
<td>London Underground, UK</td>
</tr>
<tr>
<td>Lam and Cheung (1999)</td>
<td>92</td>
<td></td>
<td>Passageway in MTR Station, Hong Kong</td>
</tr>
<tr>
<td>Lam et al. (2000)</td>
<td>81.40</td>
<td>2.63</td>
<td>Outdoor Commercial Area, Hong Kong</td>
</tr>
<tr>
<td>Lam et al. (2000)</td>
<td>64.40</td>
<td>2.34</td>
<td>Outdoor Shopping Area, Hong Kong</td>
</tr>
<tr>
<td>Lam et al. (2000)</td>
<td>67.40</td>
<td>1.74</td>
<td>Indoor Commercial Area, Hong Kong</td>
</tr>
<tr>
<td>Lam et al. (2000)</td>
<td>61.50</td>
<td>2.65</td>
<td>Indoor Shopping Area, Hong Kong</td>
</tr>
<tr>
<td>Yuan et al. (2008)</td>
<td>48.6</td>
<td>1.48</td>
<td>Railway Station, China</td>
</tr>
<tr>
<td>Jia et al. (2009)</td>
<td>70</td>
<td>1.65</td>
<td>Transport Terminal, China</td>
</tr>
<tr>
<td>Chen et al. (2009)</td>
<td>58.8</td>
<td>2.02</td>
<td>Subway Station, China</td>
</tr>
<tr>
<td>Wong et al. (2010)</td>
<td>96</td>
<td>2.5</td>
<td>Controlled environment, Hong Kong</td>
</tr>
</tbody>
</table>
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