MODELLING PEDESTRIANS' UTILISATION OF CROSSING FACILITIES, GAP ACCEPTANCE AND CROSSING DECISION IN URBAN AREA

WALID ABDULLAH ALI AL BARGI

A thesis submitted in
fulfillment of the requirement for the award of the
Doctor of Philosophy

Faculty of Civil and Environmental Engineering
Universiti Tun Hussein Onn Malaysia

MAY 2018

DEDICATION

For my beloved Father and Mother,
My brothers, sisters and friends
Thanks for always being there with me,
And always pray for me to success
"Alhamdulillah"

ACKNOWLEDGEMENT

In the name of Allah, the most merciful, the most compassionate all praise be to Allah, the Lord of the worlds; and prayers and peace be upon Mohamed his servant and messenger.

First and foremost, I must acknowledge my limitless thanks to Allah, the ever-magnificent; the Ever-Thankful, for his help and bless. I am totally sure that this work would have never become truth, without His guidance.

I owe a deep debt of gratitude to Universiti Tun Hussein Onn Malaysia (UTHM) for giving me an opportunity to complete this work.

I am grateful to some people, who worked hard with me from the beginning till the completion of the present research particularly my supervisor Dr. Basil David Daniel, who has been always generous during all phases of the research, and I highly appreciate the efforts expended by him

I would like to take this opportunity to say warm thanks to all my beloved friends, who have been so supportive along the way of doing my thesis.

I also would like to express my wholehearted thanks to my family for their generous support they provided me throughout my entire life and particularly through the process of pursuing the Ph.D degree. Because of their unconditional love and prayers, I have the chance to complete this thesis.

I owe profound gratitude to my friend, Chew, whose constant encouragement, limitless giving and great sacrifice, helped me accomplish my degree.

Last but not least, deepest thanks go to all people who took part in making this thesis real.

ABSTRACT

A pedestrian intending to cross a roadway has to decide whether to use a crossing facility or to cross a street illegally. An incorrect decision made will expose the pedestrian to the risk of accident. Pedestrian crossing behaviour has been sighted in the focus in the last decades. In the past, several studies investigating the risk of crossing a road focusing on walk trip frequency or mode choice behaviours have been conducted. Numerous factors which affect the behaviour of pedestrians have been identified. Up to now, far too little attention has been paid to pedestrian road crossing behaviour in Malaysia. The specific aim of this study was to provide new insights and develop models for pedestrian gap acceptance, crossing decision and utilisation of zebra crossings among pedestrians using regression model techniques. The critical gaps for pedestrians were estimated using Raff's method from studies conducted at 12 locations in different regions across Malaysia. The results show that the average critical gap was 9.9 seconds. Studies on gap acceptance found that nine factors such as baggage effect, pedestrian gender, vehicle size, crossing distance and etc influenced the pedestrians' crossing behaviour in terms of accepted gap size. Meanwhile, studies on crossing decision showed that four parameters, i.e. traffic speed, driver yield, pedestrian number and pedestrian age significantly influenced pedestrians' crossing choice. In addition, the findings indicated that while there were three significant factors i.e. length of zebra crossing, guardrail and number of lanes that positively influenced the pedestrian utilisation rate of crossing facilities, four variables were found to have significant direct effect on the decision to use zebra crossings. The models developed for pedestrians' use of zebra crossings, gap acceptance and crossing decision were found to be significant and thus can be used to gauge the pedestrians' crossing behaviour in urban areas. Hence, this study would help improve pedestrian crossing behaviours and influence the local authorities to draw up street design policies and pedestrian facility specifications that will improve the safety of pedestrians and other road users in Malaysia.

ABSTRAK

Seorang pejalan kaki yang berhasrat untuk melintas jalanraya perlu memutuskan sama ada beliau ingin menggunakan kemudahan melintas jalan atau melintas jalan secara haram. Satu keputusan yang tidak tepat akan mendedahkan pejalan kaki kepada risiko kemalangan. Tingkahlaku melintas jalan pejalan kaki telah menjadi perhatian sejak dekad-dekad kebelakangan ini. Kajian-kajian terdahulu mengkaji risiko melintas jalan di mana fokusnya adalah kepada frekuensi perjalanan atau tingkahlaku pilihan mod. Pelbagai faktor yang memberi kesan kepada tingkahlaku pejalan kaki telah dikenalpasti. Sehingga ke hari ini, hanya sedikit sahaja perhatian diberikan kepada tingkahlaku melintas jalan para pejalan kaki di Malaysia. Tujuan khusus kajian ini adalah untuk memberikan satu kefahaman baru dan membangunkan model-model untuk penerimaan jurang pejalan kaki, keputusan melintas dan penggunaan lintasan jalan dalam kalangan pejalan kaki menggunakan teknik-teknik model regresi. Jurang-jurang kritikal untuk pejalan kaki dianggarkan menerusi kaedah Raff dari kajian-kajian yang dijalankan di 12 lokasi di pelbagai kawasan di Malaysia. Keputusan menunjukkan bahawa purata jurang kritikal ialah 9.9 saat. Kajian-kajian ke atas penerimaan jurang mendapati bahawa sembilan faktor seperti kesan bagasi, jantina pejalan kaki, saiz kenderaan dan jarak lintasan jalan dan sebagainya mempengaruhi tingkahlaku melintas pejalan-pejalan kaki dari aspek saiz jurang yang diterima, sementara kajian-kajian ke atas keputusan melintas menunjukkan bahawa empat parameter, iaitu kelajuan trafik, hasil pemandu, bilangan pejalan kaki dan usia pejalan kaki mempengaruhi secara ketara pilihan lintasan para pejalan kaki. Tambahan pula, dapatan menunjukkan bahawa terdapat tiga faktor yang signifikan seperti jarak lintasan pejalan kaki, selusur adang dan bilangan laluan yang mempengaruhi secara positif kadar penggunaan kemudahan melintas jalan, sementara empat pembolehubah didapati mempunyai kesan langsung yang signifikan ke atas keputusan untuk menggunakan lintasan pejalan kaki. Model-model ini dibangunkan untuk penggunaan lintasan jalan oleh pejalan kaki, penerimaan jurang dan keputusan untuk melintas jalan didapati signifikan, oleh itu ia

boleh digunakan untuk mengkaji tingkahlaku para pejalan kaki dalam melintas jalan di kawasan-kawasan bandar. Maka, kajian ini akan meningkatkan lagi kefahaman ke atas tingkahlaku melintas jalan para pejalan kaki, dan ia juga boleh mempengaruhi pihak berkuasa tempatan untuk mengeluarkan dasar rekabentuk jalan dan spesifikasi kemudahan untuk pejalan kaki yang mana ini akan memperbaiki tahap keselamatan pejalan kaki dan para pengguna jalan yang lain di Malaysia.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

AASHTO	American association of state highway and transport officials American
FHWA	Federal highway administration
HCM	Highway Capacity Manual
NHTS	National Highway Transportation Safety Administration
ITE	Institute of Transportation Engineers
MUTCD	Manual on Uniform Traffic Control Devices
MIROS	Malaysian Institute of Road Safety Research
SWOV	Institute of road safety
PDRM	Polis Diraja Malaysia
ADA	Americans with disabilities act
JKR	Jabatan Kerja Raya
MLR	Multiple Linear Regression
BL	Binary logistic regression
SPSS	Social Science software
GAM	Gap acceptance Model
PUR	Pedestrian utilisation rate
Log (gap size)	logarithm of accepted gaps
PVI	Pedestrian Vehicle Interaction
TG	Traffic gap
TS	Traffic Speed
PWT	Pedestrian waiting time
FA	Frequency of attempt
PS	Pedestrian speed
AG	Age group
m	Meter
s	Second
m/s	Meter per second

m/s^2	Meter per second square
TV	Type of vehicle
CD	Crossing Distance
DY	Driver yielding
ADT	Average daily traffic
PGA	Pedestrian Gap Acceptance
VRU	Vulnerable road user

LIST OF APPENDICES

LIST OF PUBLICATIONS

Peer –reviewed journals					
NO	**Title**	**Journal**	**Submission date**	**Quality metrics**	**Status**
1	**Modeling pedestrian gap crossing index under mixed traffic condition**	Journal of Safety Research / Elsevier	16/06/2016	SJR (Q1)	Published
2	**Modelling Pedestrians' Gap Acceptance Behavior When They Jaywalk Outside Crossing Facilities In Malaysia**	Jurnal Teknologi	01/11/2016	ISI (Q3)	Accepted
3	**Modelling Pedestrians' Utilisation of Crossing Facilities along Urban Streets**	Case Studies on Transport Policy / Elsevier	05/09/2017	SJR (Q2)	Under review

Conference proceeding					
NO	**Title**	**Conference name**	**Submission date**	**Quality metrics**	**Status**
1	**Crossing Behaviour of Pedestrians Along Urban Streets in Malaysia**	International Conference on Sustainable Infrastructure Engineering (ICSIE 2016)	31/08/2016	Scopus index	Published In MATEC Web of Conferences
2	**Mid-block crossing behavior: a study of pedestrians and vehicles interaction along urban streets in malaysia**	International Conference on Urban Design & Cities Planning (UDCP 2017)	28/04/2017	Scopus index	Published in NZAAR New Zealand Academy of Applied Research Limited

CHAPTER 1

INTRODUCTION

1.1 Introduction

The introduction of this research consists of several components. The research background, problem statement, research objectives, significance of the study and scope of the study are discussed in detail in the following sections.

1.2 Research background

The term “pedestrian” has various definitions. The transport research board defines a ‘pedestrian’ as an individual traveling on foot (Transportation Research Board, 2010). A pedestrian is also known as “a person walking on foot in the street and not travelling in a vehicle” (National Highway Traffic Safety Administration, 2014).

Pedestrians are always at risk while attempting to cross roads or when they’re using crossing facilities. However, transportation planners must consider factors of safety during the design of crossing facilities, traffic control devices and roadways to protect pedestrians (Goh et al, 2012). In underdeveloped countries, crossing facility users face challenges in crossing roads safely due to the driver's behaviour towards pedestrians. In some situations such as congestion, pedestrians need to wait on the street shoulder to find a proper gap to cross safely. Otherwise, pedestrians must wait until there is no more oncoming traffic. This might be due to the lack of awareness on traffic rules or the right of way of pedestrians (Ibrahim et al,

2005). Pedestrians' behaviour at road crossings depends on their characteristics, vehicle behavioural characteristics and road design geometry (Kadali & Vedagiri, 2013b). Pedestrians crossing a road stream is a task that needs to be achieved successfully on a daily basis through the identification of safe gaps between passing cars (Petzoldt, 2014). Pedestrian crossing behaviour has been focused on by previous research in the past decades. Research shedding new light on accepted gap size by pedestrians who attempt to cross roads at mid-blocks has been conducted by several researchers at different times across the globe (Sun et al., 2002; Oxley et al., 2005; Wang & Tian., 2010; Rastogi et al., 2011). The space between the incoming vehicles and pedestrians seems to affect the most minimum gap accepted by pedestrians. Furthermore, an increase in traffic volume stream leads to smaller gaps. These gaps are normally defined by valuing the means of probability distributions or by regression modelling. Recent evidence suggests that the mean accepted gap has been estimated to be 8 seconds while the minimum accepted gap has been estimated to be 2 seconds (Yannis et al, 2013).

In the past, several studies have been documented on the behaviour of pedestrians, crossing the road, have been completed. Numerous factors which affect the behaviour of pedestrian have been identified. The factors are considered as pedestrians, traffic factors and road setting. Long-time waiting affect pedestrian behaviour significantly. Pedestrians have a higher trend to cross street carelessly after a long waiting time. Pedestrian lose patience while waiting to accept harmless gaps. Instead of waiting for harmless gaps, a pedestrian may decide to use rolling gaps across several paths (Brewer et al., 2006; Kadali & Vedagiri, 2013a). Pedestrian waiting time for suitable gaps depends on whether the pedestrian intending to cross alone or accompanied. However, if a person amongst the group initiates the road-crossing violations, pedestrians tend to cross illegally (cross on red). From Previous research comparing male pedestrians and females pedestrians has found that male were more likely to road-crossing violations compared to females (Lobjois & Cavallo, 2007). More also, pedestrians number waiting in a group has direct effects on pedestrian behaviour in that group. large groups found to be more likely to make legal crosses compared to smaller ones (Rosenbloom, 2009). In terms of accepting suitable gaps size to cross, each pedestrian has his own perception on decide on the safest gap. Physical characteristics of pedestrian affect their movement, i.e. walking speed. Taller pedestrians more likely to accept smaller gaps compared to shorter

pedestrians due to them commonly being able to walk quickly (Goh *et al.,* 2012).The space between pedestrians and vehicles has a direct influence on the safe gap size accepted to cross Oxley et al (2005). Interestingly, female pedestrians made the most accurate choices where they accept a larger gap size compared to their male counterparts (Ishaque & Noland., 2008). When to cross or wait, and where to cross the street are very complex tasks during the pedestrians' decision making process. In fact, many factors which can affect pedestrian decision including the convenience to cross, safety and comfort level. traffic volume, roadway surface condition, street width, crosswalk width, walkway obstructions and pedestrian flow were found to significantly affect pedestrian safety and comfort (Daniel et al., 2016). The behaviour of pedestrians is not always constant. It changes based on road environments or the surroundings. However, pedestrians innately accommodate to their surroundings (Ishaque & Noland., 2008).

A number of researchers have investigated the usage of crossing road facilities. Knoblauch *et al.,* (2001) show how, in the past, research into eleven un-signalized intersections was mainly concerned with appraising the influence of crosswalk towards the behaviour of pedestrian. Moyano (2002) discovered that a waiting time in range of 45~60 s was the longer waiting time pedestrian may take when crossing street. Lobjois *et al.,* (2013) concluded that a longer pedestrian waiting time while attempting to cross road stream is one of the reasons why pedestrians tends to violate traffic rules. Other reasons are age, gender, and crosswalk type, crossing distance, ease of access, vehicular, traffic (volume and speed), waiting time, and group dynamic. Surveys such as that conducted by (Rizati *et al.,* 2013) showed that the pedestrian utilisation rates of bridges crossing facility in Malaysia, are dependents on several factors such as the location of the crossing facility from the place of destination was found to be the most influential factor for pedestrian to decide on utilizing the crossing facility.

Several authors (Hamed., 2001; Sisiopiku & Akin., 2003; Rosenbloom., 2009; Zhang & Chang., 2014; Demiroz *et al.,* 2015; Pawar *et al.,* 2016; Pawar & Patil., 2016; Pešić *et al.,* 2016) has reached to advanced level of researches for traffic and pedestrian crossings behavior, but in Asian countries such as Malaysia many studies regarding this matter are still in preliminary stages . Therefore, this research will investigate and model the accepting safe gaps and making decisions cross and modelling utilisation of Zebra crossing in urban streets in Malaysia.

1.3 Problem statement

The behaviour of pedestrians while crossing and their decision to make the crossing are direct representations of how they value their lives, how they react to their surroundings, and how they interact with other pedestrians. Jaywalking, i.e. crossing the street illegally or recklessly is one of the major causes of road accidents involving pedestrians (Loh, 2016). Apart from that, incompetent crossing, mostly among children and the elderly, has also been singled out as one of the contributory factors. Children accounted for 16% of total pedestrian casualties in the US, while 16% of pedestrian deaths in 2009 were the elderly aged 65 and above (Harless & Hoffer, 2007; NHTSA, 2014, 2016). A study in the Netherlands revealed that 33% of pedestrian-related fatal crashes and 42% of pedestrian-related injury crashes actually took place on crossing facilities (SWOV, 2012).

It was reported by the Malaysian Institute of Road Safety Research (2017) that pedestrians form the second largest group of vulnerable road users killed on Malaysian roads. An average of 13% of all pedestrian casualties is caused by motor vehicles each year. Figure 1.1 shows the number of pedestrian casualties along urban streets.

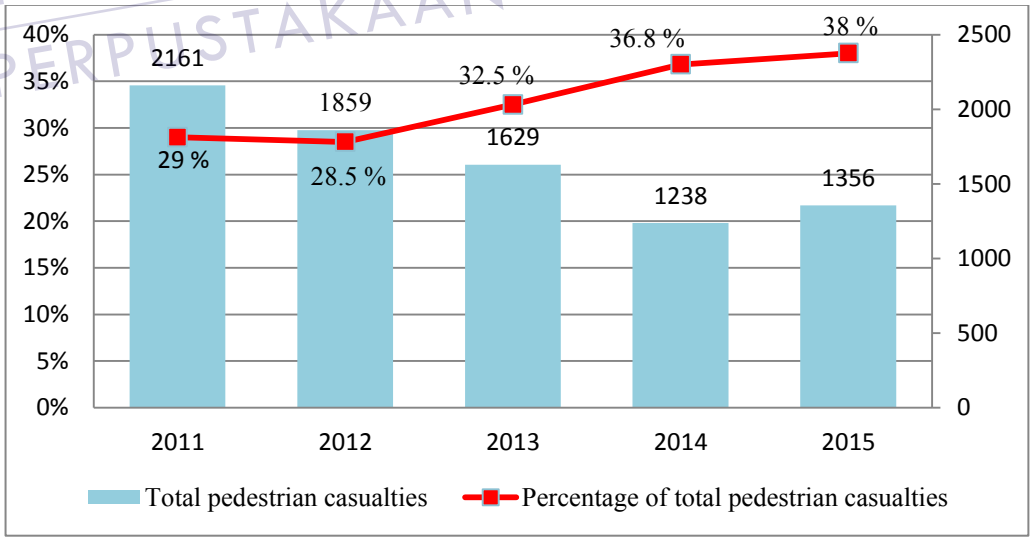

Figure 1.1: Number of pedestrian related crashes and percentage of pedestrian fatality (MIROS, 2017)

Pedestrian related collision can be attributed to various reasons as described by (Ariffin et al., 2017) . Causes of collision are influenced by factors such as area

REFERENCES

AASHTO. (2006). Federal Highway Administration University Course on Bicycle and Pedestrian Transportation /Lesson 9: Walkways, Sidewalks, and Public Spaces. https://doi.org/FHWA-HRT-05-133

Ahuja, S., Hao, X., BELL, M., & PHULL, S. (2008). Pedestrian crossing behaviour at signalised crossings. In european transport conference 2008; proceedings.

Al Bargi, W. A., Daniel, B. D., Prasetijo, J., Rohani, M. M., & Nor, S. N. M. (2017). Crossing Behaviour of Pedestrians Along Urban Streets in Malaysia. In MATEC Web of Conferences (Vol. 103, p. 8003). EDP Sciences.

Amin, H. J., Desai, R. N., & Patel, P. S. (2015). Modelling the Crossing Behavior of Pedestrian at Uncontrolled Intersection in Case of Mixed Traffic Using Adaptive Neuro Fuzzy Inference System. Journal of Traffic and Logistics Engineering, 2(4), 263–270.

Ariffin, A. H., Hamzah, A., Paiman, N. F., Solah, M. S., Zakaria, S. F. M. H. Z., Osman, M. R., & Voon, W. S. (2017). Risk Factors Identification and Issues Pertaining to Road Collisions Involving Pedestrian and Motorcycle.

Ariffin, A. H., Jawi, Z. M., Isa, M. H., Anwar, K., & Kassim, A. (2012). Pedestrian Casualties in road accidents-Malaysia prespective. Pedestrian Casualties In Road Accidents, 280–289.

Baba, A. (1997). Statistical Research in Education and Social Sciences. Malaysia: National University of Malaysia.

Bahari., N. ., Arshad, A. ., & ahya, Z. (2011). Pedestrians' Perception of the Sidewalk Facilities in Kuala Lumpur's Commercial Areas. International Sustainability and Civil Engineering Journal, 1(September), 28–36.

Bracken, G. (2016). Asian cities: colonial to global. Amsterdam University Press. Retrieved from http://postcolonial.org/index.php/pct/article/viewFile/2051/1991

Brewer, M., Fitzpatrick. (2006). Exploration of Pedestrian Gap-Acceptance Behavior at Selected Locations. Transportation Research Record, 1982(1), 132–140.

Brilon, W., & Koenig, R. (2011). Useful Estimation Procedures for Critical Gaps. In Third International Symposium on Intersection Without Traffic Signals (pp. 71–87).

British Columbia Ministry of Transportation and Highways. (1996). Pedestrian Crossing Control Manual for British Columbia (Vol. 5838).

Chandra, S., Rastogi, R., & Das, V. R. (2014). Descriptive and parametric analysis of pedestrian gap acceptance in mixed traffic conditions. KSCE Journal of Civil Engineering, 18(1), 284–293.

Choudhury, C. F. (2008). A lane changing model for urban arterials. In 3rd International Symposium of Transport Simulation (pp. 1–25).

Chu, X., & Baltes, M. R. (2001). Pedestrian Mid-block Crossing Difficulty. National Center for Transit Research (NCTR) University of South Florida.

Chu, X., Guttenplan, M., & Baltes, M. (2004). Why People Cross Where They Do: The Role of Street Environment. Transportation Research Record, 1878(1), 3–

Clarke, D. D., Ward, P., Bartle, C., & Truman, W. (2007). The role of motorcyclist and other driver behaviour in two types of serious accident in the UK. Accident Analysis and Prevention, 39(5), 974–981.

Daamen, W., Hoogendoorn, S., & Bovy, P. (2001). Modelling Pedestrians in Transfer Stations. M Schreckenberg & SD Sharma (Eds): Springer Verlag, 59–74.

Daniel, B. D., Lay, C. S., Ambak, K., & Abdullah, A. E. (2007). Pedestrian level of service model for crosswalks at signalized intersections. In Seminar on Pedestrian Level of Service Model for Crosswalks at Signalized Intersections.

Daniel, B. D., Nor, S. N. M., Rohani, M. M., Prasetijo, J., Aman, M. Y., & Ambak, K. (2016). Pedestrian Footpath Level of Service (FOOT-LOS) Model for Johor Bahru. In MATEC Web of Conferences (Vol. 47, pp. 3–7). EDP Sciences.

Das, S., Manski, C. F., & Manuszak, M. D. (2005). Walk or Wait ? An Empirical Analysis of street Crossing Decisions. Journal of Applied Econometrics, 20(4), 529–548.

Daud, N., Malek, H. A. B., & Mara, U. T. (1992). Modelling on Pedestrian Accidents in Malaysia Faculty of Computer and Mathematical Sciences. Recent Researches in Mechanics Modelling, 235–238.

Demiroz, Y. I., Onelcin, P., & Alver, Y. (2015). Illegal road crossing behavior of

pedestrians at overpass locations: Factors affecting gap acceptance, crossing times and overpass use. Accident Analysis and Prevention, 80, 220–228.

Department for Transport. (2009). Local Transport Note 1/09, (April).

Department of Statistics Malaysia. (2010). Population and Housing Census of Malaysia 2010,Department of Statistics Malaysia, Kuala Lumpur, Malaysia.

Department of Transportation. (2002). Wisconsin Pedestrian Laws. State of Wisconsin. Retrieved from

Department of Transportation. (2012). Pedestrians.

Dissanayake, S., Lu, J. J., & Yi, P. (2001). Driver age differences in day and night gap acceptance capabilities. International Association of Traffic and Safety Sciences, 26(1), 71–79.

Dixon, M. a., Alvarez, J. a., Rodriguez, J., & Jacko, J. a. (1997). The effect of speed reducing peripherals on motorists' behavior at pedestrian crossings. Computers & Industrial Engineering, 33(1–2), 205–208.

Domínguez-Almendros, S., Benítez-Parejo, N., & Gonzalez-Ramirez, A. R. (2011). Logistic regression models. Allergologia et Immunopathologia, 39(5), 295–305.

Eustace, D. (2001). Pedestrian reaction to crossing signal delay. Journal of the Transportation Research Forum, 40(1), 118–128.

Evans, D., & Norman, P. (1998). Understanding pedestrians' road crossing decisions: an application of the theory of planned behaviour. European Transport - Trasporti Europei, 13(4), 481–489.

Feng, S. M., Ding, N., & Zhang, Y. (2010). Research on the utilizing features of pedestrian crossing facilities. Proceedings - 2010 WASE International Conference on Information Engineering, ICIE 2010, 3, 396–400.

Gallin, N. (2001). Quantifying Pedestrian Friendliness: Guidelines for Assessing Pedestrian Level of Service.

Gattis, J. L., Low, S. T., Department, A. S. H. & T., & (U.S.), M.-B. N. R. T. S. C. (1998). Gap Acceptance at Non-standard Stop-controlled Intersections. University of Arkansas, Mack-Blackwell National Rural Transportation Study Center.

Goh, B. H., Subramaniam, K., Wai, Y. T., & Mohamed, A. A. (2012). Pedestrian crossing speed: the case of Malaysia. International Journal for Traffic and Transport Engineering, 2(4), 323–332.

Griffiths, J. D., Hunt, J. G., & Marlow, M. (1984). Delays at pedestrian crossings. 1. Site observations and the interpretation of data. Traffic Engineering & Control, 25(7–8), 365–371.

Haleem, K., Alluri, P., & Gan, A. (2015). Analyzing pedestrian crash injury severity at signalized and non-signalized locations. Accident Analysis & Prevention, 81, 14–23.

Hamed, M. M. (2001). Analysis of pedestrians' behavior at pedestrian crossings. Safety Science, 38(1), 63–82. https://doi.org/10.1016/S0925-7535(00)00058-8

Hamidun, R., Ishak, S. Z., & Endut, I. R. (2013). Assessing pedestrian crossing risk at signalised intersection. International Journal of Emerging Technology and Advanced Engineering, 3(1), 31–35.

Hamidun, R., Roslan, A., Shabadin, A., Ishak, S. Z., & Voon, W. S. (2017). Vulnerability of Pedestrians at Traffic Junction. Retrieved from https://www.miros.gov.my/1/publications.php?id_page=19&id_event=501

Hamiduna, R., Kordib, N. E., Endutb, I. R., & Ishaka, S. Z. (2016). Behavioral Observations of Crossing Pedestrians at Urban Signalized Intersection. Jurnal Teknologi (Sciences and Engineering), 2, 9–14.

Hanan, S. A., Said, N. F., Amelia, A., Kamel, M., Azwin, S., & Che, F. (2015). Factors that Influences Pedestrian Intention to Cross a Road While using Mobile Phone. International Journal of Economics and Financial, 5(2146–4138), 116–121.

Harless, D. W., & Hoffer, G. E. (2007). Do laboratory frontal crash test programs predict driver fatality risk? Evidence from within vehicle line variation in test ratings. Accident Analysis and Prevention, 39(5), 902–913.

Harwood, D. W., Torbic, D. J., Gilmore, D. K., Bokenkroger, C. D., Dunn, J. M., & Zeeger, C. V. (2008). NCHRP Web-Only Document 129, Phase 3: Pedestrian Safety Prediction Methodology. Washington, DC.: Transportation Research Board.

Hashim, Y. A. (2010). Determining Sufficiency of Sample Size in Management Survey Research Activities. International Journal of Organisational Management & Entrepreneurship Development, 6(1), 119–130.

Hazrati, A. (2012). Influence of urban form on pedestrian perception of walkable environment. University Technology Malaysia.

Hill, R. (1998). What Sample Size is " Enough " in internet Survey Research ? Nterpersonal Computing and Technology: An Electronic Journal for the 21st Century, 6(3), 1–10.

Hine, J. (1996). Assessing the impact of traffic on behaviour and perceptions of safety using an in-depth interview technique. Journal of Transport Geography, 4(3), 179–197. https://doi.org/10.1016/0966-6923(96)00003-8

Holland, C., & Hill, R. (2010). Gender differences in factors predicting unsafe crossing decisions in adult pedestrians across the lifespan: A simulation study. Accident Analysis and Prevention, 42(4), 1097–1106.

Hoogendoorn, S. P. (2001). Normative Pedestrian Flow Behavior Theory and Applications Normative Pedestrian Flow Behavior Theory and Applications. Civil Engineering, (May).

Hoogendoorn, S. P., & Bovy, P. H. L. (2004). Pedestrian route-choice and activity scheduling theory and models. Transportation Research Part B: Methodological, 38(2), 169–190.

Hosmer, D. W., & Lemeshow, S. (2000). Introduction to the logistic regression model. Applied Logistic Regression, Second Edition, 1–30.

Huang, L., Wong, S. C., Zhang, M., Shu, C.-W., & Lam, W. H. K. (2009). Revisiting Hughes' dynamic continuum model for pedestrian flow and the development of an efficient solution algorithm. Transportation Research Part B: Methodological, 43(1), 127–141.

Hubbard, S. M., Bullock, D. M., & Mannering, F. L. (2009). Right Turns on Green and Pedestrian Level of Service: Statistical Assessment. Journal of Transportation Engineering, 135(4), 153–159.

Hwang, S. Y., & Park, C. H. (2005). Modeling of the Gap Acceptance Behavior at a Merging Section of Urban Freeway. In Proceedings of the Eastern Asia Society for Tansportation Studies (Vol. 5, pp. 1641–1656).

Ibrahim, N. I., Kidwai, F. A., & Karim, M. R. (2005). Motorists and Pedestrian Interaction At Unsignalised Pedestrian Crossing. In Transportation (Vol. 5, pp. 120–125).

Ishaque, M. M. (2006). Policies for Pedestrian Access : Multi-Modal Trade-Off Analysis Using Micro-Simulation Techniques. Thesis, (PhD)., 272.

Ishaque, M. M., & Noland, R. B. (2008). Behavioural issues in pedestrian speed choice and street crossing behaviour: a review. Transport Reviews, 28(1), 61–85.

ITF. (2014). Road Safety Annual Report 2014, OECD Publishing, Paris ,DOI: http://dx.doi.org/10.1787/irtad-2014-en.

Jabatan Kerja Raya. (1986). A Guide on Geometric Design of Roads, Arahan Teknik (Jalan) 8/86. Kuala Lumpur.

Jabatan Kerja Raya Malaysia. (1997). Basic Guidelines on Pedestrian Facilities (JKR). Retrieved from http://www.jkrbentong.gov.my/images/e-Perpustakaan/01_Rujukan_Teknikal/03_Teknikal_Jalan/ATJ/07_Miscellaneous/18-97_Basic_Guidelines_On_Pedestrian_Facilities.pdf

Jabatan Keselamatan Jalan Raya. (2014). Road Safety Plan Of Malaysia 2006-2010. Retrieved from www.jkjr.gov.my

Jain, A., Gupta, A., & Rastogi, R. (2014). Pedestrian Crossing Behaviour Analysis At Intersections. International Journal for Traffic and Transport Engineering, 4(1), 103–116. https://doi.org/http://dx.doi.org/10.7708/ijtte.2014.4(1).08

Jain, U., & Rastogi, R. (2016). Pedestrian crossing warrants - a review of global practices. Current Science, 111(6), 1016–1027.

Jain, U., & Rastogi, R. (2017). Evaluating Methods of Critical Gap Estimation at Midblock Pedestrian Crossings Under Mixed Traffic Conditions.

Kadali, B. R., Rathi, N., & Perumal, V. (2014). Evaluation of pedestrian mid-block road crossing behaviour using artificial neural network. Journal of Traffic and Transportation Engineering (English Edition), 1(2), 111–119.

Kadali, B. R., & Vedagiri, P. (2013a). Effect of Vehicular Lanes on Pedestrian Gap Acceptance Behaviour. Procedia - Social and Behavioral Sciences, 104, 678–687.

Kadali, B. R., & Vedagiri, P. (2013b). Modelling pedestrian road crossing behaviour under mixed traffic condition. European Transport - Trasporti Europei, (55), 1–17.

Kadali, B. R., & Vedagiri, P. (2013c). Pedestrinns ' safety margin (PSM) for unprotected road crossing. In 13th WCTR (pp. 1–12).

Keegan, O., & O'Mahony, M. (2003). Modifying pedestrian behaviour. Transportation Research Part A: Policy and Practice, 37(10), 889–901.

Khan, F. M., Jawaid, M., Chotani, H., & Luby, S. (1999). Pedestrian environment and behavior in Karachi, Pakistan. Accident Analysis and Prevention, 31(4), 335–339.

King, M. J., Soole, D., & Ghafourian, A. (2009). Illegal pedestrian crossing at signalised intersections: Incidence and relative risk. Accident Analysis and Prevention, 41(3), 485–490.

Knoblauch, R. L., Nitzburg, M., & Seifert, R. F. (2001). Pedestrian Crosswalk Case Studies: Sacramento, California; Richmond, Virginia; Buffalo, New York; Stillwater, Minnesota. Transportation Research Board. Washington, 8, 103–199.

Knoblauch, R. L., Nitzburg, M., & Seifert, R. F. (2001). Pedestrian Crosswalk Case Studies: Sacramento, California; Richmond, Virginia; Buffalo, New York; Stillwater, Minnesota. Security, 8(August), 103–199.

Knoblauch, R., Pietrucha, M., & Nitzburg, M. (1996). Field studies of pedestrian walking speed and start-up time. Transportation Research Record: Journal of the Transportation Research Board, (1538), 27–38.

Koenig, D. J., & Wu, Z. (1994). The impact of a media campaign in the reduction of risk-taking behavior on the part of drivers. Accident Analysis & Prevention, 26(5), 625–633.

Krejcie, R. V, & Morgan, D. W. (1970). Determining Sample Size for Research Activities Robert. Educational and Psychological Measurement, 38(1), 607–610.

Lance E. Dougald. (2004). development of guidelines for the installation Of marked crosswalks; Transportation Engineering Technician; Virginia Transportation Research Council ; final report; VTRC 05-R18. Katalog BPS, XXXIII(2), 81–87. https://doi.org/10.1007/s13398-014-0173-7.2

Landis, B. W., Ottenberg, R. M., Mcleod, D. S., & Guttenplan, M. (2007). Modeling the Roadside Walking Environment: A pedestrian Level Of Service. Transportation Research Record: Journal of the Transportation Research Board, (1).

Lobjois, R., Benguigui, N., & Cavallo, V. (2013). The effects of age and traffic density on street-crossing behavior. Accident Analysis and Prevention, 53, 166–175. https://doi.org/10.1016/j.aap.2012.12.028

Lobjois, R., & Cavallo, V. (2007). Age-related differences in street-crossing decisions: The effects of vehicle speed and time constraints on gap selection in an estimation task. Accident Analysis and Prevention, 39(5), 934–943.

Lonsdorf, D. (2007). Motorcycle helmets work,there's no question about it. Wisconsin Department of Transportation.

Lyons, G., Hunt, J., & McLeod, F. (2001). Neural network model for enhanced operation of midblock signalled pedestrian crossings. European Journal of Operational Research, 129(2), 346–354.

Manan, M. (2014). Factors Associated with Motorcylists' Safety at Access Points along Primary Roads in Malaysia.

Marisamynathan, S., & Vedagiri, P. (2013). Modeling Pedestrian Delay at Signalized Intersection Crosswalks Under Mixed Traffic Condition. Procedia - Social and Behavioral Sciences, 104, 708–717.

Marisamynathan, S., & Vedagiri, P. (2014). Modeling Pedestrian Delay at Signalized Intersections Under Mixed Traffic Conditions. Transportation Research Board 93rd Annual Meeting CD ROM, Washington DC. Retrieved from http://amonline.trb.org/

Martin, A., & Ben, J. (2006). Factors influencing pedestrian safety: a literature review. TRL Report PPR.

Mathew, T. V. (2014). Pedestrian Studies. Transportaion Systems Engineering.

Mcleod, F. N., & Hounsell, N. B. (2004). Improving traffic signal control for pedestrians, 268–277.

Miller, T. R., Spicer, R. S., Lestina, D. C., & Levy, D. T. (1999). Safest to travel by bicycle, car, or big truck? Traffic Injury Prevention, 1(1), 25–34.

Moyano-Diaz, E. (2002). Evaluation of traffic violation behaviors and the causal attribution of accidents in Chile. Transportation Research Part F, 29(2), 264–282.

Moyano Díaz, E. (2002). Theory of planned behavior and pedestrians' intentions to violate traffic regulations. Transportation Research Part F: Traffic Psychology and Behaviour, 5(3), 169–175.

National Highway Traffic Safety Administration. (2014). Traffic safety facts 2012 data-pedestrians. https://doi.org/DOT HS 811 888

National Highway Traffic Safety Adminstration. (2014). Traffic Safety Facts 2012 Data.

National Highway Traffic Safety Adminstration. (2016). Traffic Safety Facts. https://doi.org/http://dx.doi.org/10.1016/j.annemergmed.2013.12.004

Nor, S. N. M., Daniel, B. D., Hamidun, R., Al Bargi, W. A., Rohani, M. M., Prasetijo, J., … Ambak, K. (2017). Analysis of Pedestrian Gap Acceptance and Crossing Decision in Kuala Lumpur. In MATEC Web of Conferences (Vol. 103, p. 8014). EDP Sciences.

NZ Transport Agency. (2007). Guidelines for the Selection of Pedestrian Facilities. Report, New Zealand.

NZ Transport Agency. (2009). Pedestrian planning and design guide. https://doi.org/10.1007/978-1-60327-563-7

Ogden, D. (2000). Guidelines for providing for journey on foot. Retrieved from http://www.ciht.org.uk/en/knowledge/publications/index.cfm/providing-for-journeys-on-foot-2000

Olszewski, P. (2007). Walking as a mode of transport - A planning and policy perspective. Prace Naukowe Politechniki Warszawskiej. Budownictwo.

Oxley, J. A., Ihsen, E., Fildes, B. N., Charlton, J. L., & Day, R. H. (2005). Crossing roads safely: An experimental study of age differences in gap selection by pedestrians. Accident Analysis and Prevention, 37(5), 962–971.

Oxley, J., Fildes, B., Ihsen, E., Charlton, J., & Day, R. (1997). Differences in traffic judgements between young and old adult pedestrians 1. Accident Analysis and Prevention, 29(6), 839–847.

Papadimitriou, E., Lassarre, S., & Yannis, G. (2016). Pedestrian Risk Taking while Road Crossing: A Comparison of Observed and Declared Behaviour. Transportation Research Procedia, 14, 4354–4363.

Papadimitriou, E., Yannis, G., & Golias, J. (2009). A critical assessment of pedestrian behaviour models. Transportation Research Part F: Traffic Psychology and Behaviour, 12(3), 242–255.

Pasanen, E., & Division, H. C. P. D. T. P. (2007). Traffic Safety At Pedestrian Zebra crossings. Ministry of Transport and Communications.

Pawar, D. S., Kumar, V., Singh, N., & Patil, G. R. (2016). Analysis of dilemma zone for pedestrians at high-speed uncontrolled midblock crossing. Transportation

Research Part C: Emerging Technologies, 70, 42–52.

Pawar, D. S., & Patil, G. R. (2016). Critical gap estimation for pedestrians at uncontrolled mid-block crossings on high-speed arterials. Safety Science, 86, 295–303.

Perez, G. J., Tapang, G., Lim, M., & Saloma, C. (2002). Streaming, disruptive interference and power-law behavior in the exit dynamics of confined pedestrians. Physica A: Statistical Mechanics and Its Applications, 312(3–4), 609–618.

Pešić, D., Antić, B., Glavić, D., & Milenković, M. (2016). The effects of mobile phone use on pedestrian crossing behaviour at unsignalized intersections - Models for predicting unsafe pedestrians behaviour. Safety Science, 82, 1–8.

Petzoldt, T. (2014). On the relationship between pedestrian gap acceptance and time to arrival estimates. Accident Analysis and Prevention, 72, 127–133. https://doi.org/10.1016/j.aap.2014.06.019

Pillai, K. S. (1975). Pedestrian Crossings. Traffic Engineering and Control (Vol. 16).

Rahman, N. S., Suhara, Y., Kamal, A., Mustafa, F. H., & Tey, L.-S. (2016). Pedestrian Travel Pattern At Public Transit Stations. International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD), 6(5), 33–42. Retrieved from

Rankavat, S., & Tiwari, G. (2016). Pedestrians perceptions for utilisation of pedestrian facilities – Delhi, India. Transportation Research Part F: Traffic Psychology and Behaviour, 42, 495–499.

Rastogi, R., Chandra, S., Vamsheedhar, J., & Das, V. R. (2011). Parametric Study of Pedestrian Speeds at Midblock Crossings. Journal of Urban Planning and Development, 137(4), 381–389.

Rizati, H., Ishak, S. Z., & Endut, I. R. (2013). The utilisation rates of pedestrian bridges in. BEIAC 2013 - 2013 IEEE Business Engineering and Industrial Applications Colloquium, 646–650.

Rosenbloom, T. (2009). Crossing at a red light: Behaviour of individuals and groups. Transportation Research Part F: Traffic Psychology and Behaviour, 12(5), 389–394.

Rouphail, N., Hughes, R., & Chae, K. (2005). Exploratory Simulation of Pedestrian Crossings at Roundabouts. Journal of Transportation Engineering, 131(March), 211–218.

Rouphail, N. M., & Allen, D. P. (1998). Recommended Procedures Chapter 13, "Pedestrians," of the Highway Capacity Manual. Highway Capacity Manual, (February), 1–56.

Sanik, M. E., Prasetijo, J., Mustakim, F., Hamid, B., Hakimi, A., Nor, M., … Ani, C. (2014). Drivers Lane Changing Behaviour at Urban Intersection by Using Gap Acceptance Approach. In International Integrated Engineering Summit (IIES 2014). Universiti Tun Hussein Onn Malaysia. Retrieved from

Sayer, I. a, & Palmner, C. J. (1997). Pedestrian accidents and road safety education in selected developing countries. 3rd African Road Safety Congress, Pretoria, 14–17.

Schneider, R., Stefanich, J., & Corsi, L. (2015). Wisconsin Pedestrian and Bicycle Crash Analysis : 2011-2013, 2011–2013.

Schroeder, E. I., Bastian, J., & Rouphail, N. M. (2007). A framework for evaluating pedestrian-vehicle interactions at unsignalized crossing facilities in a microscopic modeling environment. In Transportation Research Board 86th Annual Meeting.

Serag.M.S. (2014). Modelling pedestrian road crossing at uncontrolled mid-block locations in developing countries. International Journal of Civil and Structural Engineering, 4(3), 274–285.

Simpson, G., Johnston, L., & Richardson, M. (2003). An investigation of road crossing in a virtual environment. Accident Analysis and Prevention, 35(5), 787–796.

Sisiopiku, V. P., & Akin, D. (2003). Pedestrian behaviors at and perceptions towards various pedestrian facilities: An examination based on observation and survey data. Transportation Research Part F: Traffic Psychology and Behaviour, 6(4), 249–274.

Sombekke, E., & Katteler, H. (2008). Pedestrians: needs, facilities and interventions. ITS – Radboud University Nijmegen.

Sun, D., Ukkusuri, S. V. S. K., Benekohal, R. F., & Waller, S. T. (2002). Modeling of Motorist-Pedestrian Interaction at Uncontrolled Mid-block Crosswalks.

Transportation Research Record, 61801.

SWOV Institut for Road Safety Research. (2012). SWOV Fact sheet: Speed choice: the influence of man, vehicle, and road.

Taborsky, M. (2010). Sample size in the study of behaviour. Ethology, 116(3), 185–202. https://doi.org/10.1111/j.1439-0310.2010.01751.x

Tarawneh, M. S. (2001). Evaluation of pedestrian speed in Jordan with investigation of some contributing factors. Journal of Safety Research, 32(2), 229–236.

Toledo, T., Koutsopoulos, H., & Ben-Akiva, M. (2003). Modeling integrated lane-changing behavior. Transportation Research Record: Journal of the Transportation Research Board, (1857), 30–38.

Transportation Research Board. (2010). Highway capacity manual. Transportation Research Board of the National Academies, Washington, US.

Turner, S. M., & Carlson, P. J. (2000). Pedestrian Crossing Guidelines for Texas. U.S. Department of Transportation Federal Highway Administration (Vol. 7).

UNC Highway Safety Research Center. (2011). Raleigh Pedestrian Safety Demonstration Project: Pedestrian Crash Analysis and Needs Assessment, (November), 1–54.

Várhelyi, A. (1998). Drivers' speed behaviour at a zebra crossing: A case study. Accident Analysis and Prevention, 30(6), 731–743.

Virkler, M. (1998a). Pedestrian compliance effects on signal delay. Transportation Research Record: Journal of the Transportation Research Board, (1636), 88–91.

Virkler, M. (1998b). Prediction and measurement of travel time along pedestrian routes. Transportation Research Record: Journal of the Transportation Research Board, (1636), 37–42.

Walker, R., Winnett, M., & Martin, A. (2005). Puffin Crossing Operation and Behaviour Study. Nina Webster, London Road Safety Unit, Transport for London.

Wang, T., Wu, J., Zheng, P., & McDonald, M. (2010). Study of pedestrians' gap acceptance behavior when they jaywalk outside crossing facilities. IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC, 1295–1300.

Wang, X., & Tian, Z. (2010). Pedestrian Delay at Signalized Intersections with a Two-Stage Crossing Design. Transportation Research Record: Journal of the Transportation Research Board, 2173(1), 133–138.

Whelan, M., Elia, A. D., & Muir, C. (2008). Child Pedestrians : Factors Associated With Ability To Cross Roads Safely and Development of a. Monash University Accident Research Centre Report Documentation Page, (283), 93.

Williams, D. J. (1995). The Design Of Pedestrian Crossings Local Transport Note 2/95. Department of Transport (Vol. 8).

Wong, S. C., Sze, N. N., & Li, Y. C. (2007). Contributory factors to traffic crashes at signalized intersections in Hong Kong. Accident Analysis and Prevention, 39(6), 1107–1113.

a gil, D. (2000). Beliefs, motives and situational factors related to pedestrians' self-reported behavior at signal-controlled crossings. Transportation Research Part F: Traffic Psychology and Behaviour, 3, 1–13.

a ng, J., Deng, W., Wang, J., Li, Q., & Wang, Z. (2006). Modeling pedestrians' road crossing behavior in traffic system micro-simulation in China. Transportation Research Part A: Policy and Practice, 40(3), 280–290.

Yannis, G., & Papadimitriou, E. (2010). Pedestrian gap acceptance for mid-block street crossing. In 12th World Conference for Transportation Research (pp. 1–11).

Yannis, G., Papadimitriou, E., & Theofilatos, A. (2013). Pedestrian gap acceptance for mid-block street crossing. Transportation Planning and Technology, 36(5), 450–462.

Yannis, G., Papadimitriou, E., & Theofilatos, a. (2013). Pedestrian gap acceptance for mid-block street crossing. Transportation Planning and Technology, 36(5), 450–462.

Zegeer, C. V. (1998). Design safety of Pedestrian Facilities. ITE committee. Retrieved from http://www.ite.org

Zegeer, C. V., Stewart, J. R., Huang, H. H., & Lagerwey, P. A. (2001). Safety effects of marked vs unmarked crosswalks at uncontrolled locations: Executive summary and recommended guidelines (No. FHWA-RD-01-075).

Zegeer, C. V., Stewart, J. R., Huang, H. H., Lagerwey, P. A., Feaganes, J., & Campbell, B. J. (2005). Safety Effects of Marked Versus Unmarked Crosswalks

at Uncontrolled Locations: Final Report and Recommended Guidelines. The Federal Highway Administration (N0 FHWA–HRT–04–100).

Zegeer, C. V, Seiderman, C., Lagerwey, P., & Cynecki, M. (2001). Pedestrian facilities users guide. Providing safety and mobility. Highway safety research center : universty of north carolina.

Zhang, X., & Chang, G. (2014). A dynamic evacuation model for pedestrian--vehicle mixed-flow networks. Transportation Research Part C: Emerging Technologies, 40, 75–92.

Zohdy, I. (2009). Modeling permissive left-turn gap acceptance behavior at signalized intersections. Master Thesis, 1–19.

STANDARDS

AASHTO A Policy on Geometric Design of Highways and Streets (Green Book)
(*https://bookstore.transportation.org/item_details.aspx?ID=110)*

ADA Accessibility Guidelines (ADAAG)
(*http://www.access-board.gov/adaag/html/adaag.htm)*

Manual on Uniform Traffic Control Devices (MUTCD)
(*http://mutcd.fhwa.dot.gov/ser-pubs.htm)*

USEFUL WEBSITES AND REFERENCES

Department of Statistics Malaysia (*http://www.statistics.gov.my*)

MIROS -Malaysian Institute of Road Safety Research (*www.miros.gov.my*)

ASEAN New Car Assessment Program (*www.aseancap.org*)

Road Safety Department (*www.jkjr.gov.my*)