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Pedestrian Crossing Behavior Model Based on Human Factor. Case Study: Shah Alam City, Malaysia.

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Abstract
The study aimed to develop models for pedestrian crossings behaviour based on road traffic and human factors. A questionnaire distributed to 663 Shah Alam pedestrians. Respondents were asked to fill out a questionnaire on their perceptions of risks and attitudes concerning walking and road crossings. The modelling analysis showed that there is a significant relationship between the Human Factor and the Crossing Behavior, this study identified two components of the Human Factor that influenced the behaviour of the pedestrian crossing, namely the "risk-taker" and the "rule-follower." Analysis of pedestrian crossings behaviour useful to evaluate the implementation of new pedestrian crossing environments.

Keywords: pedestrian crossing; pedestrian crossing behaviour; human factor; pedestrian behaviour

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1.0 Introduction

Human factors related to pedestrians have obtained little attention in the literature than most other road users. However, it is also highlighted that road, and traffic factors alone can explain only a minor part of walking and crossing behaviour in urban areas. Study on pedestrian crossing behaviour in urban areas is comprehensive. It has provided some useful insight into the role of road, traffic and pedestrian characteristics on pedestrian crossing decisions, their compliance with traffic rules and related safety. Despite a strong emphasis on pedestrian behavioural studies, the connection between pedestrian behaviour and human factors minimally been explored. This study aims to develop models for pedestrian crossings behaviour based on road traffic and human factors. More precisely, the purpose of this research is to capture and examine critical components influencing pedestrian walking and crossing behaviour, namely the attitudes, expectations, motives, behaviour and habits of pedestrians based on these human factors.

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2.0 Literature Review

The literature on road user behaviours and human factors in road and transport design is comprehensive (Fuller & Santos, 2002). There are several studies related to human factors of pedestrians' crossing behaviour, using questionnaires or in-depth interviews. Evans and Norman (1998) developed hierarchical regression models for road crossing behaviour, using questionnaire as an instrument which included scenarios of three specific potentially dangerous road crossing behaviours. Earlier than that, in 1996, Hine used in-depth interviews to discovered pedestrians' perception and assessment of traffic conditions and crossing facilities in the city of Edinburgh. Yagil (2000) was then modelled pedestrians crossing behaviour concerning measures of attitude, subjective norm, perceived behavioural control, intention and self-identity. Yagil proposed multivariate regression models of unsafe crossings relating to values the consequences of the behaviour, instrumental and normative motives for compliance with safety rules, and situational factors by using respondents' self-reported frequency. On the other hand, Diaz (2002) developed a structural equation model for explaining pedestrian risk-taking behaviour based on attitude, subjective norm, behavioural intention and reported violations, errors and lapses.

Pedestrian behaviour is very complex and influenced by environmental and urban designs. Appropriate design of facilities will encourage walking without compromising safety and convenience (Shriver K,1997). Waiting time and distance crossing (distance between the destination of the trip and the actual location of the crossing) are mainly external factors that would cause a dangerous crossing. The need to rush or the desire to keep moving along the shortcut is the main subjective reason behind the lack of compliance with pedestrian signals or crossing facilities. Pedestrian violations can be considered as the predictable outcome of the contradiction between external factors and human factors. Chu et al. (2003) used data obtained from pedestrians' stated crossing preference and explained the stated preference with the street environment within the framework of disaggregate models. Yannis et al. (2007) improved Chu's model to evaluate accident risk along a trip with the estimated crossing behaviour of pedestrians. Nassiri and Sajed (2009) assessed and identified the valid parameters in pedestrian's decision-making process based upon vehicle speed and headway on multi-lane streets by using the logit model. Papadimitriou et al. (2013) revealed the statistical analysis of their study and discovered seven components of pedestrian attitudes and behaviour (formed based on 54 questionnaire elements. Based on the literature review, the human factors to be examined in the present research were defined, and the specific question was designed to be tested according to pedestrian perceptions, attitudes, beliefs, motivation etc.

3.0 Method

The aim of this study is the development of pedestrian crossing choice models based on road and traffic. More specifically, to develop choice models for estimating the probability to cross at each location along a pedestrian trip concerning roadway design, traffic flow and traffic control. This paper also analyzed the pedestrian crossing behaviour based on pedestrian's gender and age group. The data used in the study collected through a questionnaire survey of 663 pedestrians aged from 13 to 75 years old at eight different areas in Shah Alam City. The selected sample was calculated based on the total population, which is about 336590 peoples, with a 99% degree of confidence, and 5% of the margin of error. For the development of the questionnaire, several questionnaires from the existing studied literature. The question was designed to be rated based on Likert Scales such as always/never or agree/disagree scale. The Questionnaire was developed based on related crossing behaviour elements, for example, perceptions, attitudes, beliefs, motivation etc. The questionnaire includes four sections:

- Section A: Demographics
- Section B: Risk Perception, Attitudes and Preferences (Human Factors)
- Section C: Pedestrian Crossing Behavior
- Section D: Pedestrian Perceptions of Drivers

3.1 Field Survey Design

The field survey design consists of three walking conditions, and several places identified as survey areas according to these three crossing conditions.

• Crossing a main urban road with signal-controlled and uncontrolled crosswalks.

For this particular crossing condition, Section 7, Shah Alam has been identified as a survey area that involved UiTM's students crossing the road as access to commercial facilities near the campus. Besides that, crossing facilities near the Shah Alam's Hospital also have been surveyed to measure the effectiveness of crossing pedestrian provided and its relation to crossing behaviour.

• Crossing a minor (residential) road with or without marked crosswalks.

Several schools located near the residential areas have been chosen as a survey area. For example, section 6, section 7, section 9, section 15 and section 19. Besides that, the area that facilitates public transport also have been chosen as a survey area such as section 15 (Padang Jawa) and Section 19.

• Crossing a major urban arterial with signal-controlled crosswalks.

For this particular crossing condition, the high capacity urban road has been chosen as a study area such as crossing pedestrian to access the bus station in section 13, near to the Federal Highway. This crossing pedestrian has also been used to access AEON Mall.

4.0 Findings

4.1. Descriptive statistics

Table 1. Farthest distance respondents willing to walk

Farthest Distance	Frequency	Percent
Less than 500 meters	273	41.2
500 meters to 1 kilometre	250	37.7
1 kilometre to 2 kilometres	75	11.3
More than 2 kilometres	65	9.8
Total	**663**	**100.0**

Table 1 shows the farthest distance respondents can walk. 41.2 % response that they prefer to choose to walk in the distance less than 500 meters, followed by 37.7% said that the farthest distance they can walk is within 500 meters to 1 kilometre.

Table 2. Attitudes and preferences of walk

Reason to Walk	Frequency	Percent
In short trips, I prefer to walk	399	60.2
I have to walk because I am taking public transport	206	31.1
I walk because it is healthy	186	28.1
I walk because I have no other choice	150	22.6
I walk because it saves my time to arrive at the destination	133	20.1
I walk to avoid traffic congestion	111	16.7
I walk for the pleasure of it	71	10.7

In terms of the reason for walking, most participants said that they prefer to walk on a short trip (60.2%). Most respondents did not give a positive travel motivation (e.g. health and pleasure purposes have low scores). More than one third (31.1%) of the respondents' reported that they walk because they were taking public transport. Azmi, D.I., & Abdul Karim, H (2018) in their study also found that people in the urban area, especially in Putrajaya and Shah Alam, are more likely to drive rather than to walk.

Table 3. Distribution of pedestrian perceptions, attitudes and preferences on the pedestrian crossing

		1	2	3	4	5	Mean
B_2	Crossing roads at designated locations reduce the risk of accident	1 0.2%	3 0.5%	56 8.4%	390 58.8%	213 32.1%	4.22
B_3	Crossing roads outside designated locations are wrong	8 1.2%	21 3.2%	112 16.9%	372 56.1%	150 22.6%	3.96
B_4	I prefer routes with signalized crosswalks	1 0.2%	5 0.8%	113 17.0%	349 52.6%	195 29.4%	4.10
B_5	I try to make a few road crossings as possible	2 0.3%	20 3.0%	111 16.7%	370 55.8%	160 24.1%	4.00
B_8	I am willing to take any opportunity to cross	4 0.6%	19 2.9%	136 20.5%	308 46.5%	196 29.6%	4.02
B_9	Crossing roads outside designated locations save time	4 0.6%	29 4.4%	167 25.2%	301 45.4%	162 24.4%	3.89
B_10	Crossing roads outside designated locations are acceptable because other people do it	9 1.4%	34 5.1%	161 24.3%	274 41.3%	185 27.9%	3.89

*1: strongly disagree; 2: disagree; 3: undecided; 4: agree and 5: strongly agree

Table 3 summarizes the responses on risk perceptions related to the road crossing, value of time and opportunistic behaviour etc. Most pedestrians have positive attitudes and preferences (e.g. risk-conscious and compliant), as they tend to agree that crossing roads outside designated locations is risky and wrong. However, the majority of pedestrians also agree with crossing roads outside designated locations saves time, and crossing roads outside designated locations is acceptable because other people do it.

Table 4 summarises the participants' self-reported behaviour, compliance and risk-taking. The result shows majority pedestrians have less positive behaviour when they choose 'sometimes,' in terms of crossing at a designated crosswalk. Most pedestrians will cross at the designated crosswalk when they were in a hurry when there is no oncoming traffic or between stopped vehicles in traffic jams. Less than 5% reported that they never cross at a designated crosswalk in the major urban road.

Nevertheless, the majority of pedestrian responded they 'never' crossing without paying any attention to traffic. The majority of respondents reported they 'sometimes' cross the road even though the pedestrian light is red. They also 'sometimes' cross at designated with absent-minded while crossing, talking on a cell phone and listening to music on headphones. It may be interesting to note that pedestrians report that they 'often' cross at a designated crosswalk when they see other people do it.

Table 4. Distribution of pedestrian behaviour, compliance and risk-taking

Pedestrian Crossing Behavior		Never		Rarely		Sometimes		Often		Almost	
		N	%	N	%	N	%	N	%	N	%
C_1	I cross at a designated crosswalk when there is no oncoming traffic	2	0.3	8	1.2	401	60.5	129	19.5	123	18.6
C_2	I cross at a designated crosswalk when I am in a hurry	17	2.6	19	2.9	434	65.5	107	16.1	86	13.0
C_3	I cross at a designated crosswalk when there is a shop I like on the other side	13	2.0	18	2.7	414	62.4	126	19.0	92	13.9
C_4	I cross even though the pedestrian light is red	226	34.1	136	20.5	235	35.4	53	8.0	13	2.0
C_5	I cross between vehicles stopped on the roadway in traffic jams	17	2.6	25	3.8	419	63.2	121	18.3	81	12.2
C_6	I cross without paying attention to traffic	269	40.5	209	31.5	116	17.4	39	5.9	30	4.5
C_7	I am absent-minded while crossing	65	9.8	52	7.8	374	56.4	99	14.9	73	11.0
C_8	I cross while talking on my cell phone	58	8.7	40	6.0	390	58.8	99	14.9	76	11.5
C_9	I cross while listening to music on my headphones	150	22.6	45	6.8	348	52.5	50	7.5	70	10.6
C_10	I cross even though obstacles (parked vehicles, buildings, trees, etc.) obstruct visibility	33	5.0	24	3.6	384	57.9	158	23.8	64	9.7
C_11	I cross even though there are oncoming vehicles	147	22.2	364	54.9	40	6.0	46	6.9	66	10.0
C_12	I cross at a designated crosswalk when I see other people do it	13	2.0	20	3.0	178	26.8	381	57.5	71	10.7
C_13	I cross at a designated crosswalk when my company prompts me to do it	35	5.3	75	11.3	245	37.0	219	33.0	89	13.4
C_14	I inspire my company to cross at a designated crosswalk	25	3.8	65	9.8	240	36.2	205	30.9	128	19.3

4.2 Confirmatory Factor Analysis (CFA) in Measurement Model

Table 5 shows the summary of confirmatory factor analysis (CFA) for every construct in the measurement model. Based on Table 5, the value of factor loading for each item is higher than 0.60. Item B6, B7, C4, C13 and C14 were deleted due to low factor loading less than 0.60. The requirement for unidimensionality was achieved through the item deletion procedure for low factor loading items. The value of AVE obtain from every construct is higher than 0.50. Thus, the Convergent Validity for the measurement model is achieved since all the values for AVE are higher than 0.50, as suggested by Fornell and Larcker (1981).

Table 5. Summary for Confirmatory Factor Analysis (CFA) in Measurement Model

Construct	Component	Item	Factor Loading	CR	AVE
Human Factor	Component 1	B2	0.74	0.89	0.68
		B3	0.87		
		B4	0.81		
		B5	0.86		
	Component 2	B8	0.87	0.93	0.81
		B9	0.86		
		B10	0.96		
Crossing Behavior	Component 1	C1	0.61	0.84	0.65
		C2	0.94		
		C3	0.83		
	Component 2	C6	0.93	0.95	0.87
		C7	0.91		
		C8	0.96		
	Component 3	C9	0.90	0.93	0.80
		C10	0.88		
		C11	0.91		

Based on Table 6, when the three Fitness Indexes categories, namely Absolute Fit, Incremental Fit and Parsimonious Fit, achieved the requirements, the Construct Validity is achieved. CFI is equal to 0.90 or higher, RMSEA is equal to 0.08 or lower, and the ratio of Chisq/df is less than 5.0.

Table 6. Summary for the Assessment of Fitness Indexes

Category	Fit statistics	Recommended	Obtain	Comment
Absolute Fit	RMSEA	<0.08	0.085	Satisfied

Incremental Fit	CFI	>0.90	0.954	Achieved
Parsimonious Fit	Chisq/df	<3.0	5.722	Satisfied

4.3 Reliability and Validity of the Measurement Model

For the component Validity, the value of AVE obtains from every construct are higher than 0.50. Thus, the Convergent Validity of the measurement model is achieved since all the values for AVE are greater than 0.50, as suggested by Fornell and Larcker (1981). In terms of Reliability, the Cronbach's Alpha of 0.6 or higher for a component reflects the measuring items under that particular component provides a reliable measure of internal consistency. Nunnaly (1978) suggested that the value of Cronbach Alpha must be greater than 0.60. The value of Cronbach Alpha for each construct in this study exceeded the minimum value of 0.6, as recommended by Nunally (1978). Therefore, Internal Reliability was achieved.

4.4 Relationship between Human Factor and Crossing Behavior

Table 7 shows that the standardized regression weight for the structural model. Based on the table, the path coefficient of the Human Factor to Crossing Behavior is 0.49. This value indicates that for every one-unit increase in Human Factor, its effects would contribute a 0.49 unit increase in Crossing Behavior since the p-value is less than 0.05 (p=0.0001 < 0.05), therefore we can conclude that there is a significant relationship between human factor and crossing behaviour.

Table 7. Relationship between Human Factor and Crossing Behavior.

Path Coefficient			**Estimate**	**P-value**	**Comment**
Human Factor	to	Crossing Behavior	0.49	0.0001	Significant

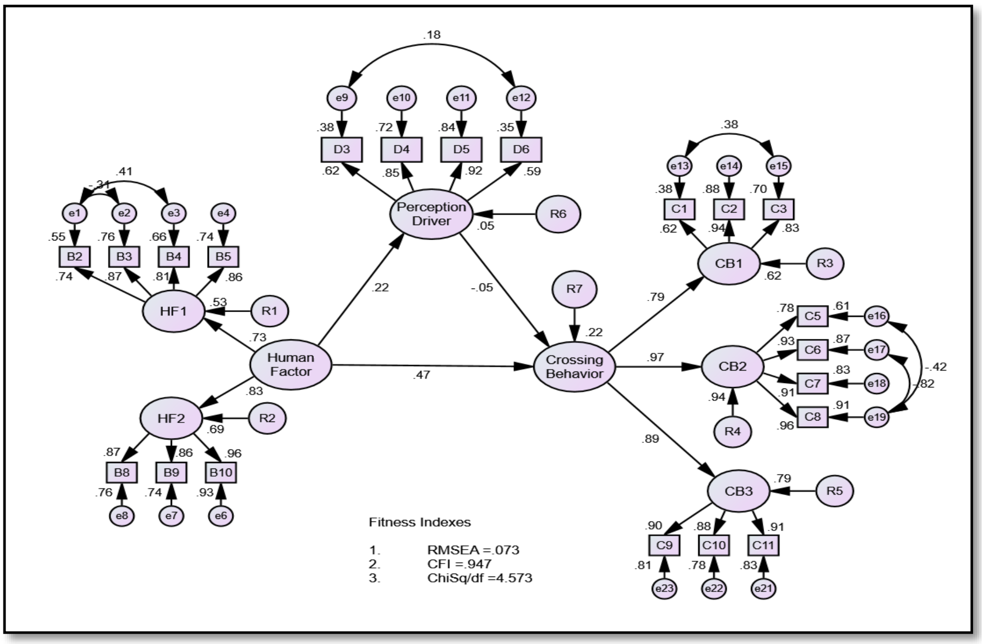

Figure 1. Structural Model

5.0 Discussion

5.1 Contribution of Dimension Human Factor To Crossing Behavior Model.

From the modelling analysis, the results showed that there were two components of Human Factor that influenced pedestrian crossing behaviour to emerge, namely a "risk-taker" and "rule-follower." Based on the 'path coefficient' of Human Factor analysis, this study concludes that a 'risk-taker' component contributed more to Crossing Behavior.

Table 8. Contribution Dimension Human Factor To Crossing Behavior

Path	Estimate	P-value	Comment
HFC 1(Rule-Follower) to Crossing Behavior	0.11	0.029	Significant
HFC2(Risk-Taker) to Crossing Behavior	0.25	0.0001	Significant

Based on Table 8 above, the path coefficient of Human Factor -Component 1 (HFC1) to Crossing Behavior is 0.11, and the path coefficient of Human Factor -Component 2 (HFC2) to Crossing Behavior is 0.25. The value of beta estimate for HFC2 to Crossing Behavior is higher than the value of beta estimate for HFC2 to Crossing Behavior, which is 0.25 > 0.11. Therefore, we can conclude that HFC2 contributes more to Crossing Behavior.

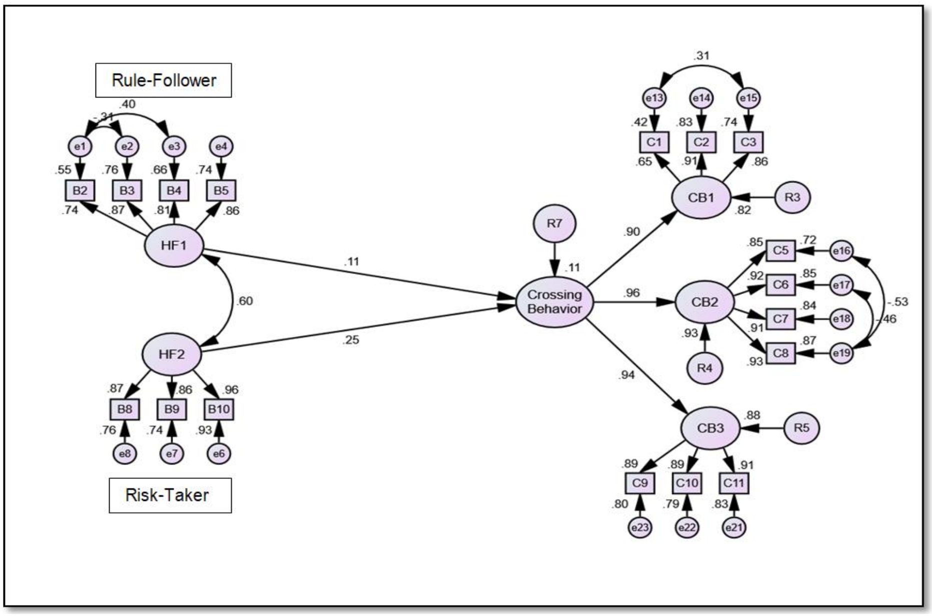

Figure 2. Contribution Dimension Human Factor To Crossing Behavior

The two group components of the Human Factor that influenced pedestrian crossing behaviour can be described as follows:

- "Rule-Follower" pedestrians in this group have slightly positive attitudes, perceptions and behaviour, as they have low scores on risk-taking (i.e. 'crossing roads at designated locations reduce the risk of an accident,' crossing roads outside designated locations is wrong,' 'prefer routes with signalized crosswalks,' and 'trying to make a few road crossings as possible')
- "Risk-Taker" pedestrians in this group have negative attitudes, perceptions and behaviour, as they have high scores on risk-taking behaviour ('I cross even though there are oncoming vehicles, ''I cross even though the pedestrian light is red, I cross even though obstacles obstruct visibility' and 'I am absent-minded while crossing').

The introduction of two components of pedestrian crossing behaviour as explanatory variables, namely a 'rule-follower' and 'risk taker' component, indicating that human factors have additional explanatory power over traffic and road factors of pedestrian behaviour. This study is therefore expected to meet the government's strategy to reduce road accidents and create more sustainable mobility environments in our cities. Sustainable mobility not only will add values to environmental but to enhance economic vitality as well (Rahman A.R et al. (2015).

6.0 Conclusion & Recommendations

From the modelling analysis in the study area, the results showed that a 'risk-taker' component contributed more to Crossing Behavior. This group can be considered as a vulnerable pedestrian since they have a high score on risk-taking behaviour.
Several actions can be suggested as an effective way of reducing risk to this type of pedestrians:

- **Creation of dedicated spaces for vulnerable road users,** such as upgraded sidewalks, wide pedestrian paths, and even partially or completely pedestrianized streets and squares. Safe crosswalks are essential and should be signposted and positioned appropriately. Other notable design features include excellent visibility, lighting, and the absence of visual obstacles.
- **Speed reduction**, which involves establishing speed limits appropriate to each environment and ensuring they are respected. The speed in urban areas, for example, should be limited to 50 km/h, or even 10, 20, 30 km/h in some neighbourhoods to encourage walking and non-motorized mobility. Adapting the road infrastructure—by narrowing the road, building refuge islands, curb extensions, raised pedestrian crossings and speed bumps— is vital to achieving speed reduction.
- **Promotion of greater awareness** through road safety education and training, and by ensuring that the traffic laws that prioritize pedestrians are widely known and adequately enforced.

Pedestrian safety requires a multi-pronged approach that combines smart and inclusive road design, effective enforcement of traffic regulations, prompt post-crash response, and improved road safety education. The results suggest that there is a need for a substantial contribution of the governments, planners and engineers to obtain an even more positive change in the safety of vulnerable road users. By bringing all stakeholders around the same table to implement these solutions in an effective and coordinated way, we can make a real difference and save countless pedestrian lives.

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