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MODEL OF PEDESTRIAN CROSSING BEHAVIOUR BASED ON ROAD TRAFFIC AND HUMAN FACTORS: A CASE STUDY OF MALAYSIA'S SHAH ALAM CITY

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Abstract

The present study intends to develop pedestrian crossing behaviour models based on road traffic and human factors. A questionnaire was distributed to 663 pedestrians in Shah Alam. Respondents were asked to complete a questionnaire regarding their risk perceptions and attitudes pertaining to walking and road crossings. This study identified two human factors that influenced pedestrian crossing behaviour: the "risk-taker" and the "rule-follower." The modelling analysis revealed a substantial correlation between human factors and crossing behaviour. Analysis of pedestrian crossing behaviour is useful to evaluate the implementation of novel pedestrian crossing environments. The study offers insights applicable to urban planning and policy approaches for reducing pedestrian accidents by utilising strategies such as extended signal timing, audible signals, countdown timers, and optimising intersection design to improve pedestrian safety.

Keywords: Pedestrian crossing; Pedestrian crossing behaviour; Human factors; Pedestrian behaviour

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INTRODUCTION

Human factors associated with pedestrians have received less attention in the literature than those associated with the majority of other road users. However, it is also highlighted that road and traffic factors alone can only explain a minor portion of urban pedestrian and crossing behaviour. Comprehensive research has been conducted on pedestrian crossing behaviour in urban areas, which has provided beneficial insight into the roles of road, traffic, and pedestrian characteristics on pedestrian crossing decisions, their compliance with traffic rules, and related safety. Despite a significant emphasis on pedestrian behavioural studies, the correlation between pedestrian behaviour and human factors has been minimally explored. The present study aims to develop pedestrian crossing behaviour models based on road traffic and human factors. Specifically, the objective of this study is to identify and analyse critical components influencing pedestrian walking and crossing behaviour, including pedestrians' attitudes, expectations, motives, behaviours, and habits based on these human factors.

LITERATURE REVIEW

The number of published articles on research on human factors in road and transportation design and the behaviours of road users is extensive (Fuller & Santos, 2002). Several studies have been conducted related to human factors in pedestrians' crossing behaviour using questionnaires or in-depth interviews. Evans and Norman (1998) developed hierarchical regression models for road crossing behaviour using a questionnaire as an instrument that included scenarios of three specific potentially dangerous road crossing behaviours. Earlier in 1996, Hine used in-depth interviews to discover pedestrians' perceptions and assessments of traffic conditions and crossing facilities in the city of Edinburgh. Yagil (2000) modelled pedestrian crossing behaviour concerning measures of attitude, subjective norm, perceived behavioural control, intention, and self-identity, subsequently proposing 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. Alternatively, 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 incredibly complex and influenced by environmental and urban design. 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 may cause a dangerous crossing. The need to rush or the desire to keep moving along a shortcut is the main subjective reason behind the lack of compliance with pedestrian signals or crossing facilities. Pedestrian violations can be considered the predictable outcome of the contradiction between external factors and human factors. Chu et al. (2003) used data obtained from pedestrians' stated crossing preferences and explained them within the framework of disaggregate models. Yannis et al. (2007) improved Chu's model by evaluating accident risk along a trip based on the estimated crossing behaviour of pedestrians. Nassiri and Sajed (2009) assessed and identified the valid parameters in a 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 have been defined, and the specific question has been designed to be tested according to pedestrian perceptions, attitudes, beliefs, motivation, etc.

METHOD

The present study aims for the development of pedestrian crossing choice models based on road and traffic conditions. More specifically, it intends to develop choice models for estimating the probability of crossing at each location along a pedestrian's trip concerning roadway design, traffic flow, and traffic control. This paper also analyses pedestrian crossing behaviour based on pedestrians' gender and age group. The data used in this study was collected through a questionnaire survey of 663 pedestrians aged from 13 to 75 years old in eight different areas of Shah Alam City. The selected sample was calculated based on the total population, which is about 336590 people, with a 99% degree of confidence and a 5% margin of error. For the development of the questionnaire, several questionnaires were adapted from the existing literature. The questions were designed to be rated based on Likert-type scales, including responses like "always/never" or "agree/disagree". The questionnaire for this study was developed based on related crossing behaviour elements, such as 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 Behaviour
- Section D: Pedestrian Perceptions of Drivers

Field Survey Design

The field survey design consists of three walking conditions, and several places have been 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 the survey area that involves UiTM students crossing the road to access commercial facilities near the campus. Besides that, crossing facilities near Shah Alam's Hospital have also been surveyed to measure the effectiveness of pedestrian crossing facilities and their relation to crossing behaviour.

- Crossing a minor (residential) road with or without marked crosswalks:
  Several schools located near residential areas have been chosen as the survey area, which includes Sections 6, 7, 9, 15, and 19. Besides that, locations that facilitate public transport have also been chosen as the survey area, such as Section 15 (Padang Jawa) and Section 19.

- Crossing a major urban arterial road with signal-controlled crosswalks:

For this particular crossing condition, a high-capacity urban road has been chosen as the study area, which involves a pedestrian crossing that accesses a bus station in Section 13, close to the Federal Highway. This pedestrian crossing is also being used to access AEON Mall.

Table 1: Study Areas with the Number of Populations and Sample Size

Locations	**Population**	**Sample Size**
Section 7 (Pusat Komersil Sek.7, KFC, McD)	37,415	100
Section 7 (SMK Section 7)		50
Section 7 (SK Section 7)		50
Section 13 (MSU)	2,075	100
Section 14 (PAS, PKNS, SACC)	City Centre	100
Section 16 (Padang Jawa, SK Padang Jawa)	5,355	60
Section 18 (Ole-Ole, Pusat Komersil)	10,320	100
Section 19 (KTM, SK Section 19, Integrated Islamic School)	10,900	103
Total	**66,065**	**663**

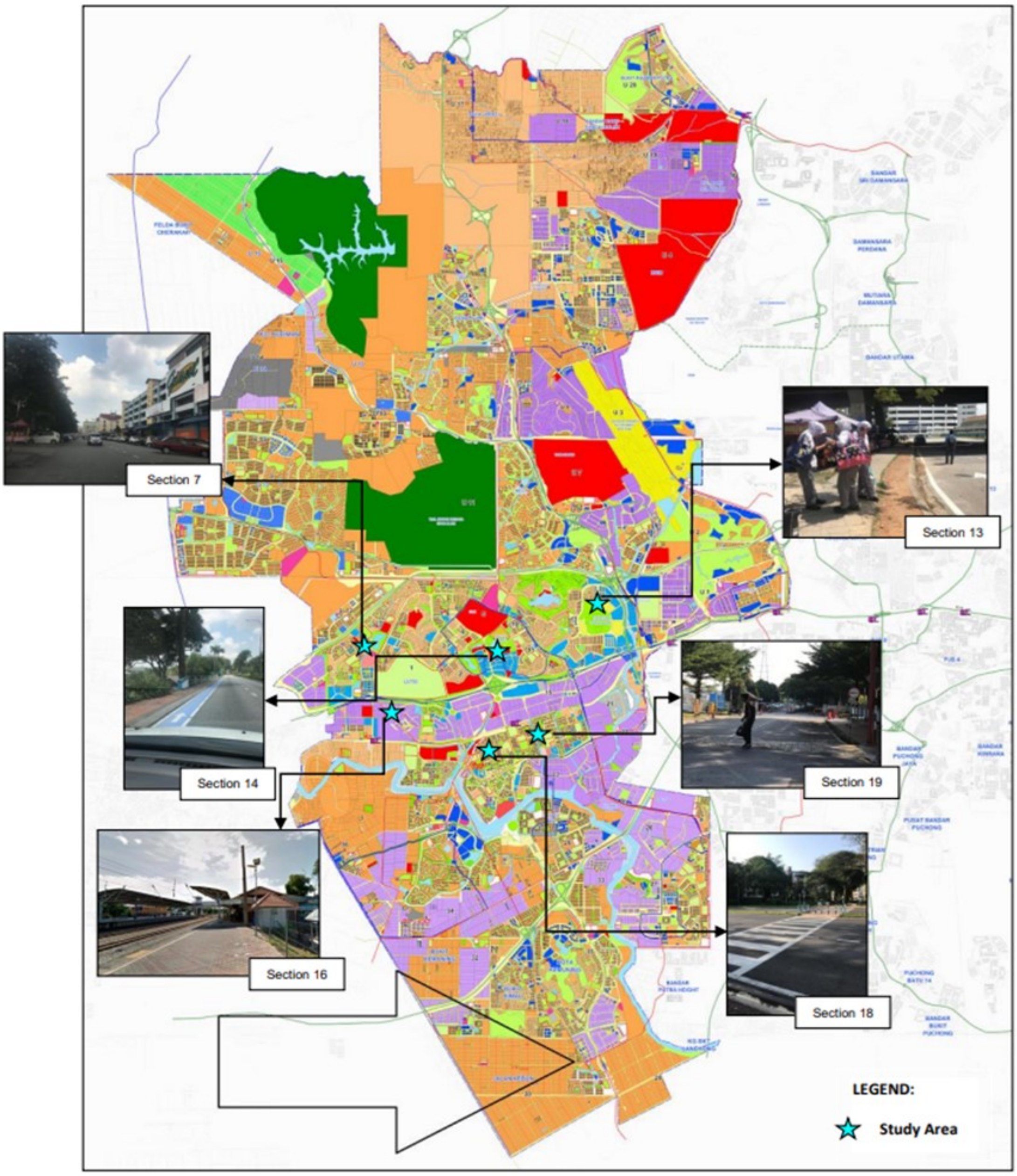

Figure 1: Location of Study Area

FINDINGS

Descriptive statistics

A survey was created and implemented to evaluate the assumptions specified in the study. Ultimately, a survey was created to ascertain respondents' perceptions, attitudes, and preferences pertaining to pedestrian crossing, including individuals' preferences and desire to walk. A number of behavioural and compliance-related inquiries were conducted, which were further supplemented with information from additional published surveys pertaining to perceptions, attitudes, beliefs, motivations, and associated factors (Evans & Norman, 1998; Bernhoft & Carstensen, 2008; Yagil, 2000; Sisiopiku & Akin, 2003).

Table 2: Attitudes and Preferences for Walking

Reasons for Walking	Frequency	Percentage
For short trips, I prefer to walk.	399	60.2
I have to walk because I am taking public transportation.	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 me time to arrive at my destination.	133	20.1
I walk to avoid traffic congestion.	111	16.7
I walk for the pleasure of it.	71	10.7

Table 2 shows that the majority of respondents 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 walked because they were taking public transportation. Azmi and Abdul Karim (2018), in their study, also found that people in urban areas, especially in Putrajaya and Shah Alam, are more likely to drive rather than walk. In terms of their willingness to walk, 41.2% of respondents said that the farthest distance they are willing to walk is less than 500 metres, followed by 37.7% who said that the farthest distance they are willing to walk is between 500 metres and 1 kilometre.

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

Table 3: Distribution of Pedestrian Perceptions, Attitudes, and Preferences at the Pedestrian Crossing

		1	**2**	**3**	**4**	**5**	**Mean**
B_2	Crossing roads at designated locations reduces the risk of accidents.	1 0.2%	3 0.5%	56 8.4%	390 58.8%	213 32.1%	4.22
B_3	Crossing roads outside the designated locations is illegal.	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 as 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 the designated locations saves time.	4 0.6%	29 4.4%	167 25.2%	301 45.4%	162 24.4%	3.89
B_10	Crossing roads outside the designated locations is 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 4 summarises the respondents' self-reported behaviour, compliance, and risk-taking. The result shows the majority of pedestrians have less positive behaviour when they choose "sometimes "in terms of crossing at a designated crosswalk. Even in situations where pedestrians are pressed for time and there is no approaching traffic or when vehicles are stationary due to traffic congestion, it is observed that a majority of pedestrians opt to cross the road at the designated crosswalk. Less than 5% reported that they never cross at a designated crosswalk on a major urban road.

Nevertheless, the majority of pedestrians responded that they "never" cross roads without paying any attention to traffic. The majority of respondents reported they "sometimes" cross roads even when the pedestrian signal light is red. They also "sometimes" cross designated crosswalks absent-mindedly, like talking on a cell phone or listening to music on headphones. It may be interesting to note that pedestrians report that they "often" cross at designated crosswalks when they see other people do so.

Table 4: Distribution of Pedestrian Behaviour, Compliance, and Risk-Taking

Pedestrian Crossing Behaviour		**Never**		**Rarely**		**Sometimes**		**Often**		**Always**	
		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 so.	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 so.	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

Confirmatory Factor Analysis (CFA) in the Measurement Model

Table 5 shows the summary of confirmatory factor analysis (CFA) for every construct in the measurement model. Based on Table 4, the value of factor loading for each item is higher than 0.60. Item B6, B7, C4, C13, and C14 were deleted due to a low factor loading of less than 0.60. The requirement for unidimensionality was achieved through the item deletion procedure for low-factor loading items. The value of AVE obtained from every construct is higher than 0.50. Thus, 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 the Measurement Model

Construct	Component	Item	Factor Loading	CR	AVE
Human Factors	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 Behaviour	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 index categories, namely Absolute Fit, Incremental Fit, and Parsimonious Fit, meet the requirements, 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	Recommended	Obtained	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

Reliability and Validity of the Measurement Model

For component validity, the value of AVE obtained from every construct is 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, a Cronbach's Alpha of 0.6 or higher for a component reflects the measuring items under that particular component and provides a reliable measure of internal consistency. Nunnaly (1978) suggested that the value of Cronbach's Alpha must be greater than 0.60. The value of Cronbach's Alpha for each construct in this study exceeded the minimum value of 0.6, as recommended by Nunally (1978). Therefore, internal reliability is achieved.

Relationship between Human Factors and Crossing Behaviour

Table 7 shows the standardised regression weight for the structural model. Based on the table, the path coefficient of human factors to the crossing behaviour is 0.49. This value indicates that for every one-unit increase in human factors, its effects will contribute an increase of 0.49 units in crossing behaviour since the p-value is less than 0.05 ($p = 0.0001 < 0.05$); therefore, it can be concluded that there is a significant relationship between human factors and crossing behaviour.

Table 7: Relationship between Human Factors and Crossing Behaviour

Path Coefficient	Estimate	P-value	Comment
Human Factors to Crossing Behaviour	0.49	0.0001	Significant

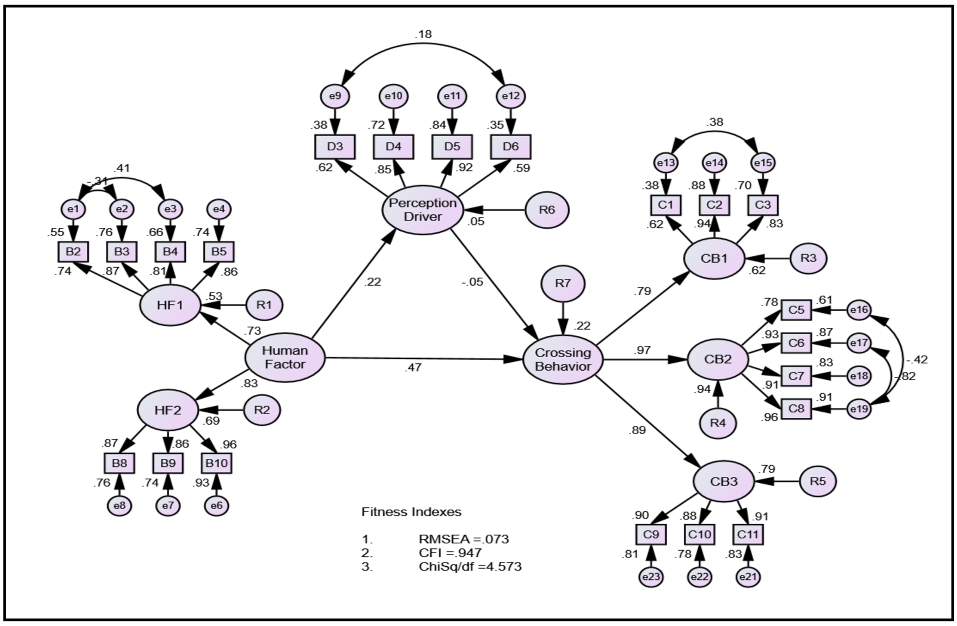

Figure 2: Structural Model

DISCUSSION

Contribution of the Human Factors Dimension to the Crossing Behaviour Model

The results of the modelling research indicated the presence of two distinct factors within human factors that exert an influence on pedestrian crossing behaviour. These factors were identified as a "risk-taker" component and a "rule-follower" component. This study suggests that the "risk-taker" component has a higher contribution to crossing behaviour, as indicated by the path coefficient in the human factors analysis.

Table 8: Contribution of the Human Factors Dimension to the Crossing Behaviour

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

Based on Table 8 above, the path coefficient of human factor-component 1 (HFC1) to the crossing behaviour is 0.11, and the path coefficient of human factor-component 2 (HFC2) to the crossing behaviour is 0.25. The value of the beta estimate for HFC2 to the crossing behaviour is higher than the value of the beta estimate for HFC2 to the crossing behaviour, which is 0.25 > 0.11. Therefore, it can be concluded that HFC2 contributes more to crossing behaviour.

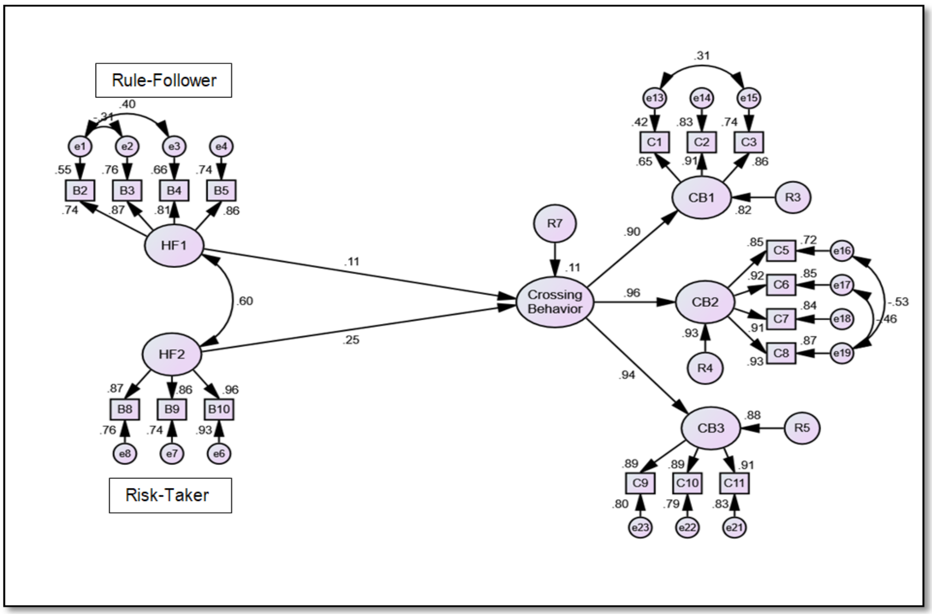

Figure 3: Contribution of the Human Factors Dimension to the Crossing Behaviour

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

- "Rule-Follower" pedestrians have slightly positive attitudes, perceptions, and behaviours, as they have low scores on risk-taking (e.g., "crossing roads at designated locations reduces the risk of an accident," "crossing roads outside designated locations is illegal," "prefer routes with signalized crosswalks, "and "trying to make as few road crossings as possible").
- "Risk-Taker" pedestrians have negative attitudes, perceptions, and behaviours, as they have high scores on risk-taking behaviour (e.g., "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 the" rule-follower" and "risk-taker" components, indicates 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 will not only add value to the environment but also enhance economic vitality (Rahman A. R. et al., 2015).

RECOMMENDATION

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

- **The Creation of dedicated spaces for vulnerable road users**, such as upgraded sidewalks, wide pedestrian paths, and even partially or completely pedestrianised streets and squares, is recommended. Safe crosswalks are essential and should be marked and positioned appropriately. Other notable design features include excellent visibility, lighting, and the absence of visual obstacles.
- **Speed reduction** is to be made mandatory, which involves establishing speed limits appropriate to each environment and ensuring they are respected. In urban areas, for example, the speed should be limited to 50 km/h, or even 10, 20, or 30 km/h in some neighbourhoods, to encourage walking and non-motorised 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** should be carried out through road safety education and training and by ensuring that the traffic laws that prioritise pedestrians are widely known and adequately enforced.

The spatial needs, mobility challenges, and cognitive capacities of pedestrians can be distinguished from each other in addition to walking pace. To help create the safest system feasible, it is essential to understand the characteristics of the variety of pedestrians who may use transit.

Table 9 below summarises some important pedestrian characteristics to consider when making pedestrian safety improvements near transit.

Table 9: Pedestrians' Spatial Needs, Mobility Issues, and Cognitive Abilities

Pedestrian Group	Characteristics & Behaviours
Children Pedestrians	• May have difficulty choosing where and when it is safe to cross the street. • May have difficulty seeing (and being seen by) drivers of all types of vehicles, including buses, because of less peripheral vision and shorter stature than adults. • May have difficulty judging the speed of approaching vehicles. • May need more time to cross a street than adults.
Elderly Pedestrians	• May have reduced motor skills that limit their ability to walk at certain speeds or turn their heads. • May need more time to cross a street than younger adults. • May have difficulty with orientation and understanding traffic signs, so they may need more information about how to access transit and get around safely. • May have difficulty judging the speed of approaching vehicles.
People with Disabilities (e.g., people using wheelchairs, crutches, canes, or people with visual or cognitive impairments)	• May be more affected by surface irregularities in the pavement and changes in slope or grade. • May need more time to cross a street than people without disabilities. • May benefit from pedestrian signal information provided in multiple formats (audible, tactile, and visual). • May have trouble seeing (and being seen) by drivers of all types of vehicles due to their seated position (for individuals using wheelchairs). • Pedestrians who are blind or who have low vision may have trouble detecting yielding vehicles or communicating visually with drivers when crossing at unsignalized crosswalks.

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 a need for a substantial contribution from governments, planners, and engineers to obtain an even more positive change in the safety of vulnerable road users. By convening all stakeholders in a collaborative manner to effectively and cohesively implement these proposed solutions, there is the potential to significantly impact and preserve numerous pedestrian lives.

CONCLUSION

The study of pedestrian crossing behaviour has underscored the significance of multiple elements that influence pedestrian safety at crosswalks. The use of these findings in the field of urban planning and policymaking has the potential to facilitate the implementation of customised infrastructural improvements aimed at enhancing pedestrian safety in high-density areas. Furthermore, the present study advocates for further research into other potentially influential factors, such as lighting and social group dynamics, to fully understand pedestrian behaviour at crosswalks. Overall, the study on pedestrian crossing behaviour serves as a critical reminder of the imperative to prioritise pedestrian safety and incorporate pedestrian-centric design into infrastructural development. It is essential that The study's findings on pedestrian crossing behaviour be duly considered by policymakers and urban planners in order to formulate specific infrastructural interventions that prioritise pedestrian safety in high-density areas. In conclusion, the study of pedestrian crossing behaviour sheds light on a crucial issue affecting urban areas and underscores approaches for improving pedestrian safety through infrastructural interventions that employ strategic measures.

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