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FRAMEWORK TO ASSESS DRIVER'S VISIBILITY AT ROAD JUNCTION

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ABSTRACT

Modern lifestyles do influence Malaysian occupants to work long hours in a day in order to cope with large workloads and to meet a deadline. Majority of the occupants are overstressed, faced with negative emotions that lead to an unhealthy lifestyle. Studies show that nature is able to enhance human well-being by reconnecting human with natural elements in a built environment, which is known as biophilic design. Therefore, this study aims to create a biophilic design guideline to enhance occupants' well-being in heritage adaptive reuse indoor co-working space. This study is conducted in the Heritage World Site (WHS) in George Town, Penang. Mixed method research design was used to collect data from the site. Both qualitative and quantitative data were analysed using the triangulation method to validate the overall data and research by cross verifying the information from multiple methods to gather the data. The results proved that the existing biophilic design patterns do enhance co-workers' emotional well-being significantlyand it can be used as design guideline. In addition, this study also investigated different ways of biophilic design patterns application which can affect the quality of biophilic experiences.

Keywords: *Biophilic design, Heritage indoor, Co-working space, Human well-being*

INTRODUCTION

Private vehicle allows people to move from one place to another place in order to sustain good living standard. Nowadays ability to drive and being mobile is considered a necessity; thus, owning a private vehicle is considered pivotal for every household. This circumstance has contributed to consistent increase of number of road accident annually. Similarly, each year the number of drivers and passengers died due to road accidents is increasing consistently by 9 to 10 % (Che-Him et al., 2018; Masuri, Isa, & Tahir, 2012). It was recorded 2.55 deaths occurred due to road accident for every 10,000 vehicles registered in the country. Although wide-ranging factors contributed to road accident, most literature pointed to human factors as the common cause of road accident (Che-Him et al., 2018; Masuri, Isa, & Tahir, 2012)

For example, in the state of Perak there are 36 736 cases of road accidents recorded until 2015. The number was identified among the highest across the states in Malaysia. Among the contributing factors is high car ownership in the state. In addition to this, from the macro perspective, road accident was identified as the element that increases in parallel with the growth in population, economic in development, industrialisation and motorisation (Mustafa, 2005; Masuri et al., 2012). Whilst, at the micro level, three basic factors which are road user errors, road environment faults and vehicle defects are main causes of road accident (Mustafa, 2005).

Road accident has a significant impact on a person's quality of life, community safety, increase road maintenance cost, road accident education and accident prevention and awareness program and enforcement. The cost for conducting these measures are mainly absorbed by the government and road provider (Masuri et al., 2012). Due to the significant impacts study on accident, mitigation approaches have received attention in literature. Past literature on accidents in Malaysia centred on the issues of traveling behaviours towards accident occurrences, accident trends, accident injuries (Ahmed, Sadullah, & Yahya, 2017; Che-Him et al., 2018; Kareem, 2003; Masuri et al., 2012; Mustafa, 2005; Shahid, Minhans, & Bahru, 2016). Although, these researchers have identified significant finding and contributed significantly to the body of knowledge, the integration of infrastructure i.e road and junction with surrounding environments are

less explored. Therefore, this factor is worth to be explored. In addressing the issue, the aim of the study is to propose a framework using variables forming a road junction physical environment to assess driver's visibility. It is hoped the findings of the study will be able to assist local authorities i.e traffic planner to prudently plan and monitor road junction environment in order to provide a safer traffic environment in a commercial centre.

LITERATURE REVIEW

The literature section provides detail on three main components which are sustainable transportation, driver's safety and factors that determine the driver's visibility.

Sustainable Urban Transportation

Sustainable development approach ascertains economic, environmental, social dimensions and community as key domains. Whilst sustainable transport is regarded as development that meets the needs of the present without compromising the ability of future generations. The approach promotes increment in traveling ability of an individual to travel, ability to move freely, access, communicate, trade, and establishing relationships without sacrificing other essential human or ecological values (Nykvist & Whitmarsh, 2008). Transportation sustainability is commonly associated with accessibility, affordability, cost efficiency, liveability, efficiency, equity, climate change and pollution (Donegan, Adamson, & Donegan, 2007; Litman & Burwell, 2006; Yigitcanlar & Dur, 2010). In promoting community's health as main objective of sustainability, sustainable transport promotes safety environment (Litman & Burwell, 2006), by reducing the number of road causality as priority. In addition, using the measures, strategies of sustainability that is commonly engaged with traffic demand management, crash prevention and crash protection based solutions (Litman & Burwell, 2006). Similarly, issues of sustainable transport are also addressed by imposing macro level strategies through land use and infrastructure investment rearrangement and settings (Yigitcanlar, Rashid, & Dur, 2010).

In addition, poor transportation system is identified to be an attribute of poor infrastructure provision and geometrical design (Che-Him et al.,

2018; Dadashova, Ramírez, McWilliams, & Izquierdo, 2016). However, solutions embedded to address the issues of safety of road user are commonly limited to only mechanical or infrastructure mechanisms. , Furthermre, road environment consists of road, landscape, signage, built forms, traffic management strategies and geometry are factors that collectively determined the visibility of road user, while using or driving on the road. A way forward in establishing a safe environment for road user and addressing the sustainability of transportation system is the equilibrium between infrastructure, traffic and urban forms that encapsulate junction or road and surrounding environment during the planning, designing and maintaining stages.

Safe Driving and Causes of Accident

Safe driving involves the ability of a driver to manoeuvre a vehicle, being conscious of traffic and able to avoid from any possible accidents while driving. Safe driving is an outcome of a sequence of events and interactions among events occurring of a person, vehicle, and environment (Classen et al., 2010; De Waard, Steyvers, & Brookhuis, 2004). Besides, safe driving behaviour is complex as it composed with multiple underlying components that brings together attitude, mental and physical fitness. As such combination of all these components resulting attention, cognition and apt decision making while driving (Classen et al., 2010).

Safe driving does not just depend on skills and attitudes, but also environment an individual resides and the physical environments while driving. Past literatures have well documented causes of accident, which are the results of socio-economic issue, socio-demographic issue, socioeconomic status, rural or urban environment, age/gender, education level, living status, personality and condition of road or intersection (Masuri et al., 2012; Zulhaidi, Hafzi, Rohayu, Wong, & Farhan, 2010).

To physically address the issue of accident and creating a safe driving environment physical planning approaches that monitor road design and development are pivotal. Planning permission and planning approval within the city development process have long scrutinised road and junction design prior to any layout plan approval. However, as Masuri et. al. (2012) recorded, improper design of junction still occur. Thus, these

have caused significant increase of accident in the year 2003. For instance, accidents occurred at junction were quite significant, constituted 22 % of total accident. The finding showed that junction involved was identified did not provide enough storage lane for vehicle, while waiting to turn right, staggered, T and Y design or lack of safe sight distance (Che-Him et al., 2018; Mustafa, 2005). Furthermore, without proper street lighting and low visibility especially at night, these have increased the number of accidents especially to the pedestrian and small vehicles i.e motorcycle and bicycle (Mustafa, 2005). Therefore, it is strongly recommended that the issues of safe driving environment is not only limited to road and junction design, but consideration on the driver visibility which includes road design and environment surrounding a junction should be considered as an important assessment criteria during any planning permission and plan approval process. Thus, continuous occurrences of accident intensified the necessity to further investigate key features that determine the driver's visibility at junction or road.

Driver Visibility

Safe driving is pivotally determined by clear visibility (Haliza, Syah, & Norliza, 2010). Literally, visibility is defined as distance between drivers that provide good vision to observe surrounding environment while driving. Driving in city centre requires good visibility since there are various physical forms that reduce visual distance and high volumes of traffic.

Visibility at junctions particularly, and on road broadly is determined by quantity of illumination and visual distance. As such, driver's visual capability is reduced as the quantity of illumination reduces or distance of visual is restricted. There are various factors contributed to aforementioned situations, mainly due to weather, reduce of sunlight due to change of time from day to night, natural circumstances i.e fog, mist, haze, glare of sunrise and sunset (Goh, Subramaniam, Wai, Mohamed, & Ali, 2012; Tarel, Hautiere, Cord, Gruyer, & Halmaoui, 2010; Zulhaidi et al., 2010). In addition, aforementioned factors are mainly temporary circumstances and subjected to weather and natural phenomenon.

Distance visibility on the other hand is mainly subjected by forms and structures that are composed by environment that forms a junction or

road. These forms and structures may exist in form of nature landscape and topography e.g. hills, slopes or three that have long existed or in build forms e.g. building, signage, landmarks, or planned landscape i.e tree and scrubs (Bartie & Kumler, 2010). The availability of these elements within certain distance from junctions or roads will limit the driver's visibility of incoming traffic and reduce time in making judgments due to visual search and visual distraction (De Waard et al., 2004).

Since visibility corresponds to time making judgment while driving (De Waard et al., 2004; Kwan & Mapstone, 2006; Tarel et al., 2010), traffic management approaches are commonly embedded to assist driver to regulate traffic movements, determine speed allowed and inform desired destination. As such, visible road mark on the road surface are perfect example that helps driver to manoeuvre constant and comfortably (De Waard et al., 2004). Unavailability of such measures will certainly consume more time in making decision and causing potential delays. Furthermore, road layout i.e. width, corners and distance between junctions have significant impact on driver's visibility (Dadashova et al., 2016). Smaller road layouts coincide with slower driving speed. As the road width reduces, driver intends to reduce vehicle speed while driving or taking turn due to limited space.

Next, imposing physical measures to increase visibility of drive are identified to have significant impact to reduce accident occurrences. Furthermore, imposing physical measures such as fluorescent light, retro reflective materials and flashing lights have the potential to improve detection and recognition of vehicles and incoming traffics (De Waard et al., 2004; Zulhaidi et al., 2010). However, measures such as reactive measures rather than preventive measures do increase road or junction maintenance. Therefore, this study highlights that visibility of road junctions could be improved by proper integration between physical characteristic of road junction and environmental elements that surrounded the road junction.

Previous studies have identified landscape, signage, street light, and road junction geometrical design are pivotal elements (JLN, 2008; AASHTO; n.d; JPBD, 2009; FHWA, 2002; TII, 2017; NOAO, n.d; Garda, 2012) to asses driver's visibility. As tree is a living thing, selection of tree is the primary concern for landscape architect and planner to ensure good visibility at junction. Thus, availability of tree within certain distance, type

of tree, height and maintenance are commonly measured by agencies to manage and maintain good visibility of driver (JLN, 2008). Conversely, signage or billboard is man-made object that is instilled at road junction for road information or marketing purposes. The items mentioned may affect driver's visibility due to improper sizing and small gaps between signage. Thus, unclear sign or fuzzy wording may cause the driver to take more time to comprehend information, subsequently contributed to lowering travel speed (FHWA, 2002). Geometrical elements that include design, distance between junction and road surface are among common physical elements contributed to the ability of driver to observe traffic condition while driving. Furthermore, staggered or Y type junction design reduces visibility, close distance between junction will result in shorter egress time from junction, while poor road surface may reduce attention of the driver to the surrounding traffic. Moreover, street light determines the visibility of driver primarily during bad weather or at night. As such measures in this category is designated to assess visibility based on availability of light based on presence of street light and quality of light produced. Therefore, measures mentioned in the earlier section are composed to form a framework that consists of 15 variables to assess visibility of driver at junction.

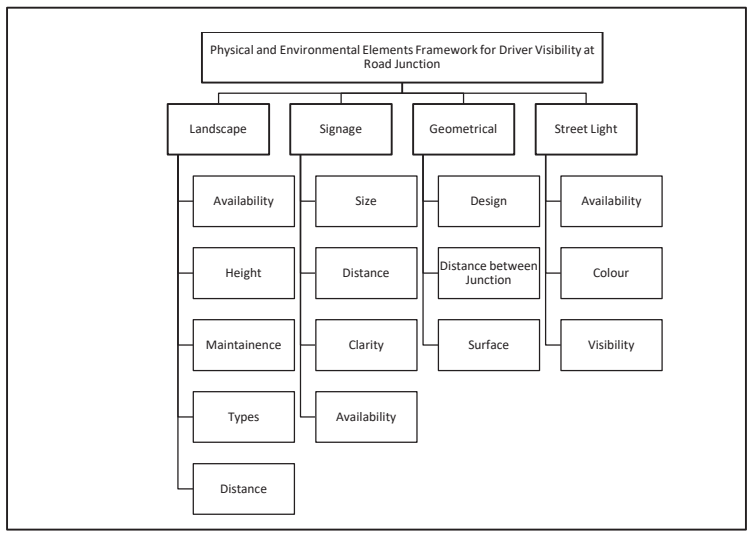

Figure 1: Framework of Road Junction Visibility for Driver
Source: Author

METHODOLOGY

Instrument Development

Instrument for the study was designed to adapt subject completed instrument or self-administrated data collection method to capture the visibility of driver at road junction both day and night time. The literature obtained is mainly from journals that are accessible in Google Scholar and University Technologi MARA (UiTM) databases, which were read thoughtfully to identify factors that determine the driver's visibility at road junction. This led to identification of 15 variables that are categorised into landscape, signage, geometry and street light (refer Figure 1). Each variable is arranged into 3 scales ranging from poor, moderate and good, with parameters for each scale and variable were based on measurement found in the literature. The instrument developed were then applied on case study environment to determine the suitability and validity purposes.

For the case study, elements formed each road junction was measured and observed, subsequently recorded in a survey form. Data gathered for each junction were then transformed into 3 parameter scores which are poor, moderate and good. In addition, descriptive analyses were also performed to each variable to observe the percentage of variables across all road junctions.

Following this, each variable observation was arranged in a matrix table whereas at this stage, each observation and parameters entailed were scrutinised for suitability or ground-truthing based on its site condition. This technique is commonly used in land use inventory analysis or in GIS based research (Rashid, 2013; Teriman, 2012) for variables and parameters validation. Therefore, the methods used for this research is not primarily for generalisation findings to a larger context, instead the analyses seek to determine the capability of variables used to capture the key features that form road or junction physical environments.

Table 1: Category, Variable and Parameter Scale

Category	Variable	Parameter Scale			Source
		Poor	Moderate	Good	
Landscape	Availability	Less than 1.5 meter	Within 1.5 meter	More than 1.5 meter	JLN (2008)
	Height	More than 1 meter	0.5 meter to 1 meter	less than 0.5 meter	JLN (2008)
	Maintenance	There are branches less than 3 meters from street level	There are branches within 3 meters from street level	No branches within 3 meters from street level	JLN (2008)
	Types/ Suitability	Availability of big sized tree	Availability of medium sized tree	Availability of scrub	
	Distance	Presence of tree/scrub less within 22-meter triangle from junction	Presence of tree/scrub within 22-meter triangle from junction	Presence of tree/scrub more than 22-meter triangle from junction	
Signage	Size of signage	More than 5-meter sq	Within 5-meter sq	Less than 5-meter sq	JPBD (2009)
	Distance of signage	Less 0.3 km between signage	Within 0.3 km between signage	More than 0.3 km between signage	JPBD (2009)
	Retro reflectivity- o show the same shape and similar color by both day and night	Information are not readable	Only some of the information is readable	Most of the information is readable	FHWA (2003)
	Availability	Less than 50 meters from junction	Within 50 meters from junction	More than 50 meters from junction	JPBD (2009)
Junction Design	Junction to Junction Distance	Less than 110 meter	Within 110 meter	More than 110 meter	TII (2017)
	Junctions Design	Staggered	Y-Junction	T-Junction	TII (2017)
Street Light	Availability	1 street light found more than 35 meters	1 street light found within 35 meters	1 street light found less than 35 meters	MPSP (2017)
	Street Light Colour	yellow-orange - LPS lamp	yellow-orange glow - HPS lamp	White - using Metal halide lamps	NOAO (n.d)
	Night Visibility	Poor visibility of surrounding	Moderate visibility of surrounding	Clear visibility of surrounding	Garda (2012)

Study Area

SIBC is a commercial business district located in Bandar Baru Seri Iskandar, Perak. The site was selected as case study mainly due to data availability and accessibility factors. The study area was also identified suitable to meet the purpose of the study as this area as composed to various road hierarchies and junction designs. Thus, the build environment of the area that combines both building and nature forms make the study area as suitable. Importantly, with a few number of accident cases reported, although conflicting road designs are existed. This will be interesting to determine the level of driver visibility at road junction in this area.

There are 13 junctions involved in the study, with movements at junctions between 1 to 13 movements (refer Table 2). Number of lanes for each road was between 1 of 2 lanes with the smallest road width was 7 feet and the widest was almost 16 feet.

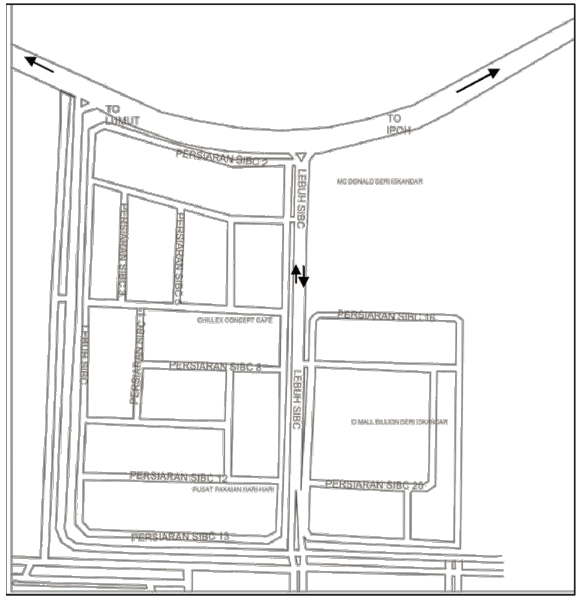

Figure 2: Study Area at Bandar Seri Iskandar Business Centre
Source: Author

Table 2: Profile of Road Junction

Location	No of Movements	Lane Width	Number of Junction
Entrance to Mc Donald	2	7 ft.	1
Entrance to BHP Petrol Station	2	7 ft.	1
Exit to BHP Petrol Station	1	7 ft.	1
Persiaran SIBC	6	15.37 ft.	1
Persiaran SIBC 12	7	15.38 ft.	1
Persiaran SIBC 13	6	15.38 ft.	1
Persiaran SIBC 15	8	15.12 ft.	1
Persiaran SIBC 16 (ECO)	13	15.66 ft.	1
Persiaran SIBC 2	4	15 ft.	1
Persiaran SIBC 20	11	15.12 ft.	1
Persiaran SIBC 22	6	15.12 ft.	1
Persiaran SIBC 4	6	10.48 ft.	2
Total	72	-	13

Source: Author

RESULTS AND DISCUSSIONS

Introduction

Result for the study was analysed in two stages. In the first stage, scores of all junctions were summarised in a table in order to explain the trend across variables. At this stage, percentage of variables in each score was observed and analysed. These data and parameters were then scrutinised in order to assess suitability of each variable with driver visibility at road junction.

Performance of Junction and Road

Table 3: Percentage of Road Junction Based on Parameter Scale

Category	Variables	Percentages (%)		
		Poor	Moderate	Good
Landscape	Availability	38.5	15.4	38.5
	Distance	15.4	69.2	7.7
	Height	15.4	69.2	7.7
	Maintenance	7.7	7.7	76.9
	Suitability	-	7.7	61.5
Signage	Signage Size	-	30.8	30.8
	Distance to Junction	38.4	15.4	46.2
	Retro reflectivity	38.5	7.7	53.8
Geometry	Junction to Junction Distance	38.5	46.2	15.3
	Design	-	38.5	61.5
Street Light	Availability	15.4	-	84.6
	Colour	23.1	-	76.9
	Night Visibility	30.8	-	69.2

Source: Author

Assessment made to all junctions were based on four categories; landscape, signage, geometry and street light, which were identified as mixed findings. As for variables in landscape category, the analyses involved distance, height and suitability of landscape elements that were ranked moderate, while, landscape maintenance received good average score. The landscape variables ranked were in such a way due to the location of the study area within city centre. Therefore, trees and landscape elements were under regular maintenance by the city council resulted in decent landscape condition.

Contrary, findings based on the signage category were quite differ even across scores. The study identified scores in this category concentrated either in poor or good score. Distance and Retro reflectivity received highest score that were mostly 46.2 percent and 53.8 percent, respectively.

Assessment made on variables in the geometry category showed elements of design and surface that were ranked between moderate and good, while none of the junction in the study area was ranked poor. As for assessment made on distance between junctions, ranks were identified skewed to left with most of the junctions received score between moderate and poor.

For variables listed in street light, most were ranked good or poor. These patterns were mainly influenced by the availability of street light at junction. The study identified unavailability of street light at road junction have resulted in poor score for road junction. Therefore, high collinear may exist between variables in this category.

Variable Suitability

Analyses using suitability matrix aims to determine each variable and entailed parameters capability in assessing driver visibility at road junction. During these analyses, suitability of each variable and entailed measurement were assessed based on two main aspects which are availability of element on ground condition and suitability of each scale to measure ground condition.

Table 4: Suitability Matrix Analyse

Category	Variables	Element Availability	Scale Suitability	Comments
Landscape	Availability	Present of landscape element in most junctions	Present of elements in each scale	Variable able to capture environmental condition at the study area, therefore are suitable for inclusion
	Height	Present of landscape with different height in most junctions	Present of elements in each scale	
	Maintenance	Variable was available in all junctions	Present of elements with different scale	
	Types/ Suitability	Variable was available in all junctions	No element received Poor scale	Scale require some modification
	Distance	Various distance was recorded	Present of elements in each scale	Measurement able to capture environmental condition at the study area, therefore are suitable for inclusion
Signage	Size of signage Distance of signage.	Variable was available in all junctions	No element received Poor scale	Scale require some modification
	Retro reflectivity- o show the same shape and similar color by both day and night		Present of elements in each scale	Measurement able to capture environmental condition at the study area, therefore are suitable for inclusion
Junction Design	Junction to Junction Distance	Variable was available in all junctions	Present of elements in each scale	
	Junctions Design		No element received Poor scale	Scale require some modification

Street Light	Availability	Variable was available in all junctions	No element received Medium scale	Measurement primally subjected to availability of street light.
	Street Light Colour		No element received Medium scale	
	Night Visibility		No element received Medium scale	

Source: Author

Suitability analyses identified that most of the variables and measurement used were suitable to measure driver visibility at road junction. However, there were some variables and entailed measurements that require modification to improve the assessment process.

Variables in the landscape category were mostly identified to be able to capture the ground condition with both availabilities of the variable and suitability of parameters which show variation of observations. However, measure of type/suitability in this category that was identified with no road junction was given poor score. This situation is anticipated since road junctions in the study area are managed by a local authority. Therefore, selection and maintenance of tree are scheduled and regularly conducted.

Variables in the signage category were also identified to determine the suitability of assessing road junction visibility. The assessment made would identify variables used and existed in the study area. Thus, elements at the ground were able to be arranged using the scale. However, the study should also consider the availability of signage in the measurement, since the availability of signage will determine the score for signage size, clarity and distance.

For variables in the geometry category, both variables were identified able to capture ground condition by using the established parameters. The measure could also be improved by including distance of straight road measured between junctions to curve road (Jamson, Benetou, & Tate, 2015) and surface condition as to determine the degree of road abrasion, fatigue performance of asphalt or road aging (Roesler, Jeffery, Hiller, & Brand, 2016).

The street light measurement is also greatly subjected by the availability of street light at the study area. The study identified unavailability of street light has also contributed to no observation. This was also recorded to colour and night visibility. Observation of type of light displayed little variation in the findings. The study assumes light types will result in illumination of quality e.g led street light produce – blue colour, low/high pressure sodium – yellow/orange; metal halide – white light. However for the case on the study area, only low/high pressure sodium that produces yellowish illumination were detected ("Types of Light," n.d.). Thus, high subjectively of night visibility on availability and type of street light, the measurement category and parameters entailed are considered as uni-dimensional and imperil to high similarity. Although, Rashid (2013) recorded uni-dimensional variable is capable to capture multi facets of a complex phenomenon and explained most of the variance of the dimension under study, however such application in this study should be reconsidered as the unavailability of observation resulting in poor observation data. These findings however should not dictate the measurement used since the application of various light types could be found in a larger study area.

CONCLUSION

Relation between driver visibility and the state of transportation sustainability are apparent and well documented in the literature. Primarily and worth to mention is the association between driver's visibility and accident cases. Therefore, good visibility while driving need to be given attention during transportation system planning, provision and monitoring stages. However, the lack of assessment criteria that consider physical and spatial elements such as landscape, street light, junction design, geometry and signage make monitoring, has caused safety of driving especially at road junctions agitated.

This research proposed assessment criteria to determine the driver visibility by considering both physical and spatial arrangement surrounding a road junction. Applying this method as a case study is not primarily to make generalisation, instead the capability of the variables to capture key physical features that form road or junction environment and the suitability of the parameters used are of primary concern.

To address this notion, the analyses were conducted in two stages. First, performance analyses based on each variable category. The findings showed that variables in landscape and street light, perform better compared to variable in signage and street geometry, whereas most road junctions were given good and moderate score for this category. This also suggests that variable and measures used were able to clearly reflect condition on the ground.

Secondly, each variable was used to assess and determine each parameter scale suitability in assessing driver's visibility at road junction. For this reason, comparison was made between data collected with the availability of variables at ground and suitability of parameters used to capture all possible ground conditions. Although, most variables and parameters used were capable to capture most environmental conditions that form a road junction at the study area, some of the parameters i.e types/ suitability, size of signage and junctions design require modification in ensuring all conditions are considered in the parameters.

Application of the assessment criteria to determine driver visibility is envisioned to produce safer driving environment in Malaysia. Considering the continuous challenges in providing safer driving environment, future research on driver's visibility at junction or roads should consider application of listed criteria in other city centres, primarily areas with high traffic volumes. In addition, it is recommended inclusion of other elements that determine driver's visibility such as driver's health condition, and visibility during harsh weather condition are worth for exploration.

The findings of the study have contributed to a better understanding on the importance of physical environment forming a junction or road and visibility of driver. Thus, the assessment will certainly benefit the local transport agencies during planning and monitoring stages of road and junctions.

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