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Factors Influencing Local Road (JKR U2/U3) Damage in Malaysia

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ABSTRACT

This study configures the high loads of heavy trucks as a major source of pavement damage by causing fatigue, which leads to cracking and permanent deformation, producing rutting. Malaysia, as one of the developing countries, has a high level of road pavement damage.

Through examining the cost of rehabilitating pavements, serious safety issues occur, especially when heavy trucks use local roads (JKR U2/U3), which are not designed to be used by heavy trucks. This study aims at discussing the factors influencing local road (JKR U2/U3) damage in Malaysia, from February 2013 until July 2014 at the selected area.

The overall results show a positive significant interaction using WarpPLS as a tool to develop the method and SPSS is used to examine the data and generate the model. Results indicated that regression relationships between road damage and other research factors have been established with a coefficient of determination (R) of 0.71. The limitations of the study are that the observation was done according to purposive sampling technique, time was just adequate and there was no accurate measurement of truck weight.

This paper highlights not only the important statistical relationship between different factors influent on local road damage, but the mechanics of truck movement on local access roads was also studied to identify relationships between truck properties and road damage and to develop an appropriate method of data collection for these local roads.

KEYWORDS: Statistical relationship, Local road (JKR U2/U3) damage, Observation method.

INTRODUCTION

Yearly, increases of heavy vehicles due to high demand from industries subject pavements to heavy-axle loads. Yet, conflicting to the prevailing literature and the other road users' speculations, the Pan Malaysia Lorry Owners Association (PMLOA) does not agree with the fact that its trucks are causing danger to other road users (Golias and Karlaftis, 2001).

Damages on roads are mainly caused by heavier-axle loads associated with large commercial trucks (Croney and Croney, 1991). For this reason, every state has legislated maximum axle-load limit and maximum gross vehicle weight to be followed (Ramadhan, 1997).

The repetition of loading and overloading of heavy trucks allegedly affect road pavements, causing the design life of pavements to become shorter. Although

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the same quality standard is used during design and construction (Mulyono et al., 2009), much research confirms that roads are damaged by heavy trucks and researchers have implemented different methods to reach this conclusion. Although most of those methods are time-consuming, costly, insecure and can't be individually implemented, none of them had confirmed when and how these roads were damaged. This study will present a sample method to measure road damage and confirm when and how these roads got damaged.

The causes of pavement failure are separated into two types, which are: internal and external. Internal pavement failures are frequent because of lack of pavement mixture, weaknesses of component materials and poor construction. In the meantime, external failures occur because of overloading, diesel spillage, flooding, sinkholes and other unforeseen reasons, such as earthquakes, volcanoes, among others. Failures of flexible pavement are separated into four categories, which are: surface deformation, surface defects, cracking and patching and potholes (AASHTO, 2001; AASHTO, 2001).

The objective of this paper is to develop a model with respect to heavy trucks on local roads (JKR U2/U3). The WarpPLS 4.0 applies the partial least-square (PLS) method-based SEM technique (PLS-SEM). WarpPLS 4.0 software is a powerful statistical tool, because it has added seven new model-fit and quality-fit indices to the previous version of WarpPLS 3.0 which has already three fit indices: Average path coefficient (APC), average r-squared (ARS) and average variance inflation factor (AVIF), thereby bringing them to a total of ten indices. The new model-fit and quality-fit indices added to WarpPLS 4.0 are: average adjusted R^2 (AARS), average full collinearity VIF (AFVIF), Tenenhaus GoF (GoF), Sympson's paradox ratio (SPR), R-squared contribution ratio (RSCR), statistical suppression ratio (SSR) and nonlinear bivariate causality direction ratio (NLBCDR) (Kock, 2013). PLS-SEM was favorably selected in this study, because it is better suited for complex models with large numbers of constructs and links (Ahuja et al., 2007; Au et al., 2008; Pavlou and El Sawy, 2006; Pavlou and Fygenson, 2006). Equally important is that PLS-SEM is more suitable than other statistical tools for testing the effects of moderators (Limayem et al., 2007) as in the case of the current study. Furthermore, WarpPLS 4.0 is equipped with measures related to the quality of the model, such as the ten powerful goodness-of-fit indices, p-values and multicollinearity estimates (Kock, 2013).

METHODOLOGY

The research method used in the present study is composed of five (5) stages. The first is the *desktop study*, which is the identification process or the narrowing down process of the study area through various maps, such as land use maps, topographical maps and roadmaps from *Jabatan Perancangan Majlis Bandaraya Ampang*. The second stage is the *Site Selection Criteria*, used as the basis to select the right residence for this study. Next is the *Preliminary Site Observation*, where each selected residential local road (JKR U2/U3) which has been deteriorated is identified and vetted through to finalize a suitable sample. The fourth stage is the *Data Collection*, where data was recorded while traveling on the selected local roads (JKR U2/U3) using the observation method. The models developed need to be validated to evaluate their accuracy. Figure 1 presents the flowchart of the research methodology.

The focus of this study is to present a systematic flow of the entire design of the research process. The researchers present a case study on the experiences of heavy trucks as they conduct their daily routine of using local roads (JKR U2/U3). Simply put, this study is an attempt to understand how pavements experience damage and respond to truck drivers' behavior.

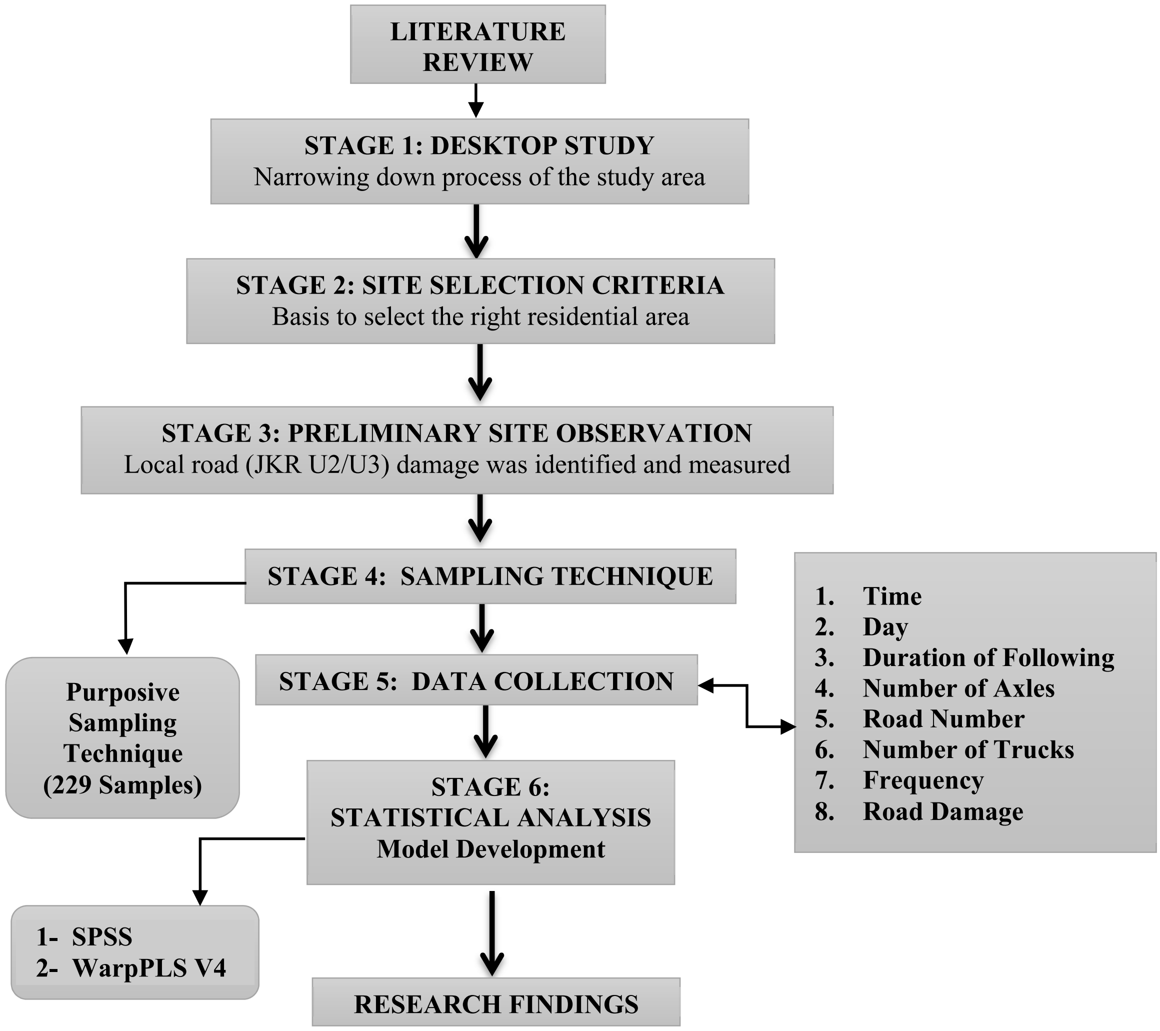

Figure (1): Flowchart illustrating the research methodology

Desktop Study

From the desktop study findings, it was revealed that the trucks came from Access/Intercity roads to enter the local roads/Ampang area. By looking at the Google map and driving through the Ampang area, it was found that the MMR2, Ampang Kuala Lumpur Elevated Highway and Jalan Ampang were the reason behind accessing the local roads. Figure 2 shows Access/Intercity from these roads to Ampang area. Meanwhile, the results from the study could be effectively used to research the effect of heavy vehicle trafficking relying on various drivers' perceptions and behaviors. The desktop study also revealed that the targeted locations are suitable, as the sample and the deteriorated road areas are residential areas that occupy most of the city. Figure 3 shows the residential area and other facilities for the study area. Local roads (JKR U2/U3) in this area were selected as listed in Table 1.

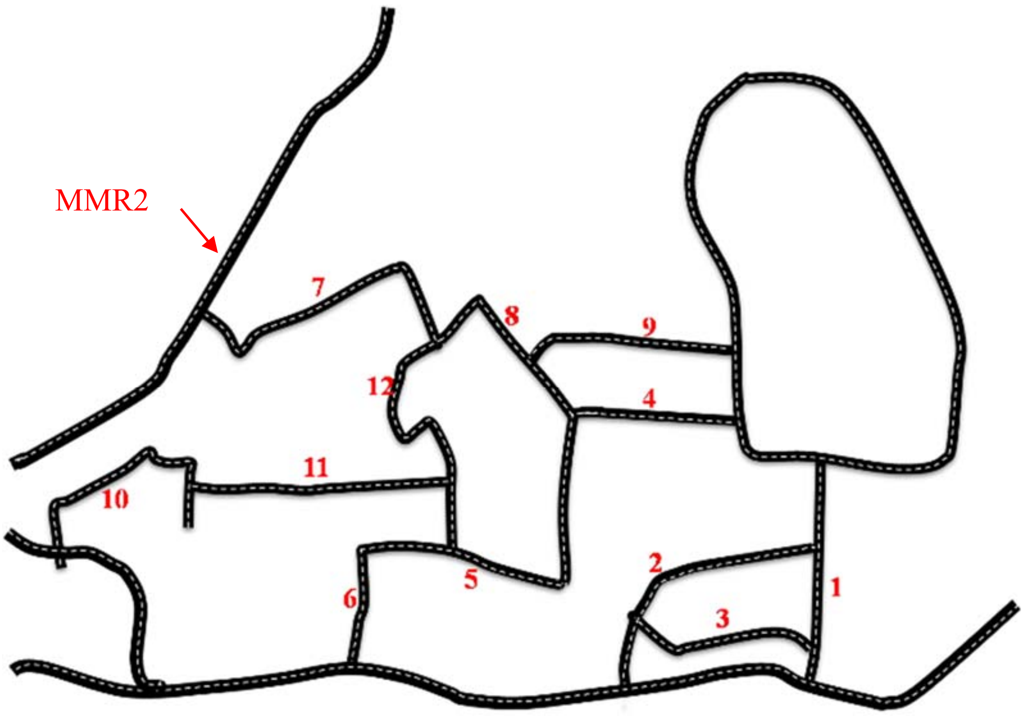

Figure (2): Access to Ampang area from both MMR2 and elevated highway

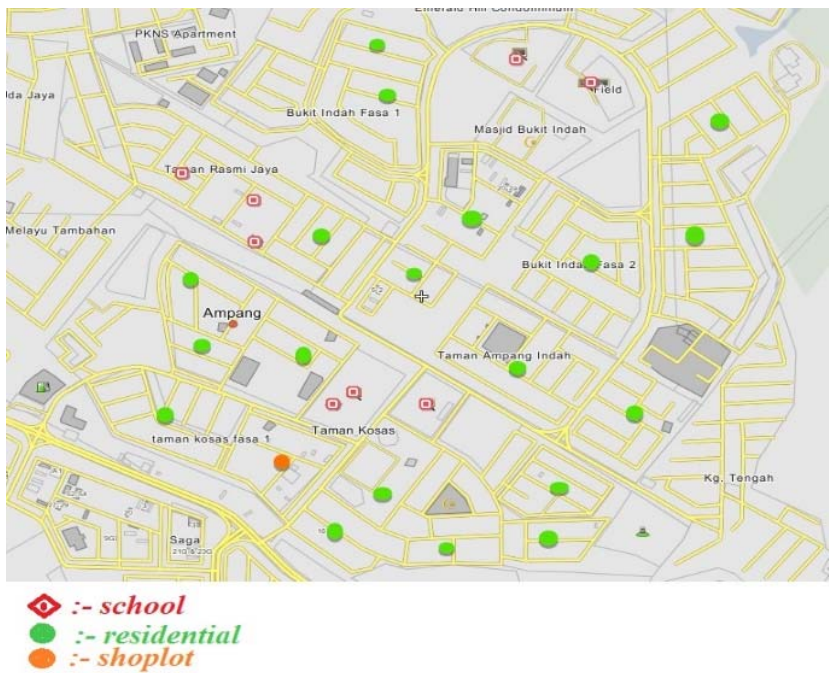

Figure (3): Residential area and other facilities in the study area

Table 1. Selected local road (JKR U2/U3) details for inspection/observation

No.	Road Name	Road Standard	Length (km)
1	Jalan Kosas Utama	Local Roads (JKR U3)	0.59
2	Jalan Kosas 2	Local Roads (JKR U3)	0.79
3	Jalan Kosas 1/1	Local Roads (JKR U3)	0.59
4	Jalan Rasmi 14	Local Roads (JKR U2)	1.00
5	Jalan Kempas	Local Roads (JKR U3)	0.63
6	Jalan Merbau	Local Roads (JKR U2)	0.28
7	Jalan Anggerik	Local Roads (JKR U2)	0.96
8	Jalan Dedap	Local Roads (JKR U2)	0.59
9	Jalan Rasmi	Local Roads (JKR U2)	0.73
10	Jalan Mamanda	Local Roads (JKR U2)	0.73
11	Jalan Seraya	Local Roads (JKR U2)	0.82
12	Jalan Wira	Local Roads (JKR U2)	0.81

Site Selection Criteria

Site selection criteria are set as a guide to select a suitable area among the residential areas in Ampang.

Selection criteria have been established in accordance to the following conditions:

A. The selected residential area should have an existing "Local Road (JKR U2/U3)" with a design speed of not more than 50 km/hr according to the Public Working Department's Guidelines (Jalan, 1986).
B. The selected residential area must be free of any traffic control devices, such as signalized intersections or construction and infrastructure works that will eventually disturb the free flow of traffic.

Preliminary Site Observation

In the preliminary site observation, different characteristics of the local road (JKR U2/U3) pavement damage are measured and identified. The first characteristic was potholes, including type and dimensions, as well as type of pavement. The second characteristic was the control mechanism that includes posted speed limit, warning signs and traverse bar/road making. The third characteristic was reflective joint cracking that is due to occur with composite pavement construction. The fourth characteristic was thermal movement as a result of temperature change. The last characteristic was traffic operation that includes the specific site requirements and traffic flow.

Sampling Technique

According to Kumar and Phrommathed (2005), sampling can be divided into probability random sampling, non-probability non-random sampling and mixed sampling. Stratified non-probability non-random sampling collection was used in this this study, as well as judgmental sampling, also known as purposive sampling. Purposive sampling is an informant selection tool which is widely used in ethnobotany. However, the use of this method is not adequately explained in most studies. The purposive sampling technique, also called judgmental sampling, is the deliberate choice of an informant selection tool due to qualities that informant selection possesses. It is a non-random technique that does not need underlying theories or a set number of informants. Simply put, the researcher decides what needs to be known and sets out to find people who can and are willing to provide the required information by knowledge or experience (Bernard, 2017; Lewis and

Sheppard, 2006). Purposive sampling is especially exemplified through the key informant technique (García, 2006; Gustad et al., 2004; Jarvis et al., 2004; Lyon and Hardesty, 2005), wherein one or a few individuals are solicited to act as guides to a culture. Key informants are observant, reflective members of the community of interest who know much about the culture and are both able and willing to share their knowledge and experience.

The research is based on purposive sampling technique, where the sample is a representative portion of the population of interest. A sample is used in research when it is not feasible to study the whole population from which it is drawn. Sampling technique is defined as the method used in drawing a sample from a population, usually in such a manner that the sample will facilitate the determination of some hypotheses concerning the population. The process of sampling makes it possible to accept generalization to the intended population based on careful observation of variables within a relatively small proportion of the research population.

In the present investigation, the sample is drawn from the population of heavy trucks. The sample was drawn by purposive sampling technique. In this technique, the sample comprises the heavy trucks contributing to the pavement damage on local roads (JKR U2/U3).

Sample Size

There were 229 samples in this study at Taman Kosas from roads; namely, Jalan Kosas Utama, Jalan Kosas 2, Jalan Kosas 1/1, Jalan Rasmi 14, Jalan Merbau, Jalan Kempas, Jalan Seraya, Jalan Mamanda, Jalan Anggerik, Jalan Dedap, Jalan Wira and Jalan Rasmi. Data such as (day, time, duration of following, frequency, type of access, number of trucks, road number and number of axles), was collected from all these samples. The samples which did not meet inclusion criteria were not considered. Also, those samples which met exclusion criteria were not considered.

Data Collection

The area selected for this study is Taman Kosas Utama Ampang and the data was collected on local roads (JKR U2/U3): Jalan Kosas Utama, Jalan Kosas 2, Jalan Kosas 1/1, Jalan Rasmi 14, Jalan Merbau, Jalan Kempas, Jalan Seraya, Jalan Mamanda, Jalan Anggerik, Jalan Dedap, Jalan Wira and Jalan Rasmi within Selangor. Data collection was carried out by the observation method from 2 February 2013 until 18 July 2014 and all sampled local roads (JKR U2/U3) were observed during the time period mentioned above with the consideration of weather conditions. However, road damage represents a special case for data collection as it might be decreased or increased. Decrease is used to denote the type of damage found in the previous visit/inspection which was maintained by the local authority. As heavy-truck traffic increases in the residential area, the roads become more damaged, simply because local roads (JKR U2/U3) were not designed for use by heavy trucks. However, if on the second visit it was found that there was no reduction or increase at the road, the visit will be canceled and postponed to another visit. However, if in one of these sites it was found that there are no changes within the last visit, the scale considered is (zero). Normally, visits are scheduled daily at each of the selected roads in the study area for a total time period of one year and six months.

STATISTICAL ANALYSIS

Profile analytical methods are employed to explain the mass of quantitative data collected over a period of time. Researchers attempted to provide in-depth explanation of the analysis process to bring meaning, structure and order to their data. The focus of data analysis is to yield congruence between the reality of the phenomena studied and the emergent themes. This study is situated to entrench the concept that the form of data capture is ultimately in the form of text. Most data was converted into text and the text was the primary model for the object of interpretation (Schwandt, 1999).

All the empirical data was garnered through SPSS version 22.0 and WrapPLS version 4.0 (Kock, 2013). Data from observation was coded and analyzed through multi-nomial logistic regression, ordinal logistic regression, hierarchical ordinary least-square regression and WrapPLS from theory methods as espoused by Charmaz (2005). The goal was not to develop theory, but rather to present a viable interpretation of the findings obtained. The following sections describe the detail phases involved in the data analysis.

There are several steps before a model can be developed. The first step is data screening to check validity and normality. The second step is to calculate the basic descriptive statistics for each variable to identify the mean, median, maximum, minimum, standard deviation, skewness and kurtosis values. The third step is the selection of variables to consider possible independent, dependent and mediation variables using correlation analysis and significance values. The fourth step is to develop models based on the possible independent, dependent and mediation variables using WrapPLS. Finally, validation processes are conducted to verify the absolute developed models. The model development process is shown in Figure 4.

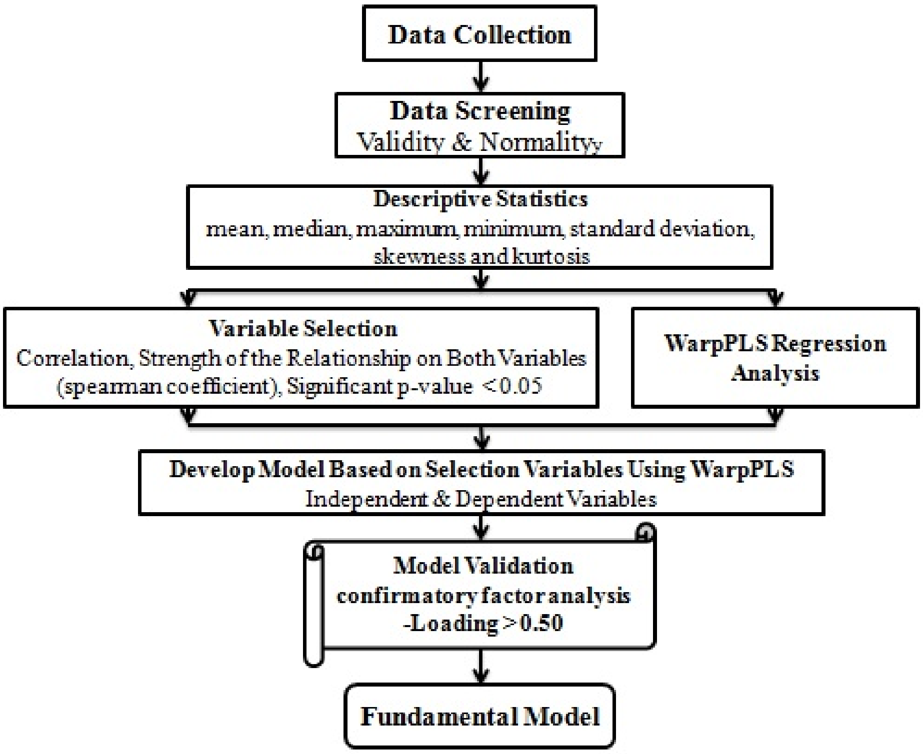

Figure (4): Model development process

Observation Method

The observation method research is one of the most popular non-experimental research methods. In research design, observation helps reduce complexities and make research projects more useful. Observation has become a scientific tool for data collection. It serves for a formulated research design. Under the observation method, the information is sought by the way of one's own direct observation. The advantage of this process is that information is obtained through observations relating to current happenings. The limitations of this process are as follows: the information provided is insufficient, some obstacles may be created by unforeseen factors, thereby restricting data collection efficiently if related resources are not directly accessible and the information is collected directly. Quantitative data gathered will be summarized through statistical analysis (Kothari, 2004).

The unstructured observation method is used to foreground the importance of context and co-construction of knowledge between the researcher and the researched (Mulhall, 2003). The reason for using observational methods in this study was to determine whether what participants say is exactly what they do in practice. Unstructured observation (Mulhall, 2003) allows to capture not only the process of policy implementation, but also the context. In using unstructured observation, researchers assumed the role of reactive observers (Angrosino, 2005). Researchers acknowledged that the role as reactive observer is part of the social setting under study (Giacomini et al., 2000). Reactive observations are controlled settings which assume that participants are mindful of being observed and are amenable to interacting with researchers only in response to the elements in the research design. Researchers purposefully chose this role because of the useful source of data that this approach may yield, where the researcher was positioned as a reactive observer (Angrosino, 2005).

Researchers structured the observations by using three procedures as delineated by Angrosino (2005), inherent in observational research. In terms of descriptive observation, researchers tried to eliminate preconceptions and noted (field notes) detailed descriptions of everything that took place. Then, researchers employed focused observation, in which they chronologically documented field notes on the observations and materials that were significant to the study, focusing on well-defined categories of pedagogy. Lastly, the researchers in this research performed selective observation (Angrosino, 2005) of a general nature, recording field notes on (JKR U2/U3) roads. The reflection below indicates some aspects relative to the design of the observation field notes.

In this study, the researchers chose to locate themselves within the local roads (JKR U2/U3) to engage in limited interaction and intervening only when further clarification of actions was needed (Schatzman and Strauss, 1973). Where and when possible, provision was made to set up the equipment prior to trucks entering the local roads (JKR U2/U3), allowing the researchers to record all data needed from the commencement of the observations. The researchers usually positioned themselves at the centre, so as not to become obtrusive. This observation position offered the opportunity to collect data that satisfied ethical issues of data collection, as the researchers could capture images of trucks without compromising their identity.

RESULTS AND DISCUSSION

Reliability and Validity

The reliability and validity of the measurement instrument were assessed through WarpPLS 4.0. These important statistical issues are conducted by assessing the convergent validity and reliability of each measure, followed by the discriminant validity. The convergent validity and reliability aspects have been evaluated by the combination of factor loading, Cronbach's alpha, composite reliability (CR) and average variance extracted (AVE), as shown in Table 2. Factor loading measures the strength of linear correlation between the measuring items and the latent variable. In fact, high factor loadings indicate excellent convergent validity (Fornell and Larcker, 1981a). Cronbach's alpha was used to examine the internal consistency (reliability) of the scale measurement items and research variables. The results of Cronbach's alpha presented in Table 2 suggest that all measures in this study ranged around 1.000 and are therefore reliable as recommended by Hair et al. (2010), being well above the required threshold of 0.6 (Goffee and Jones, 1996). In order to validate the measurement model, convergent validity was assessed by investigating composite reliability and average variance extracted (AVE) values from the measures. Chin et al. (2003) suggested that acceptable values for composite reliability should be above 0.70 and this minimum value of composite reliability estimate has also been recommended and used by most studies in the field. Indeed, the current study has reported that composite reliability values for all variables of the model exceeded the recommended value of 0.70. Also, AVE measured values should be greater than the generally accepted cut-off value of 0.50, which means that 50% or more of the items' variance should be accounted for (Fornell and Larcker, 1981a, 1981b). Table 2 shows that all variables of the current model have achieved AVE values above the minimum recommended value of 0.50. Apparently, all values for composite reliability and AVE calculated in this study meet the recommended threshold values. In conclusion, the statistical analyses obtained here suggest that the model exhibits adequate convergent validity and reliability. About discriminant validity, the AVE value for each variable in the current model was computed to test discriminant validity. As shown in Table 2, the square root of AVE for each variable is greater than the correlations between the variable and all other latent variables, demonstrating that all variables of the current model have adequate discriminant validity (Fornell and Larcker, 1981a, 1981b). However, factor loadings for all measurement items in the current model were significant and ranging around 1.000, noting that high factor loadings are an indication of possible multicollinearity. Therefore, a statistical test of importance, called the multicollinearity test, must be performed whenever factor loadings exceed 0.70 (the threshold for possible multicollinearity). By definition, multicollinearity is a measure of the correlation between the predictors of a variable which falsely inflates the standard errors and therefore, certain model parameters may sometimes become unstable (Kock, 2011). To assess the degree of multicollinearity, variance inflation factors (VIFs) are evaluated for each of the predictor variables. VIFs lower than 5 suggest no multicollinearity (Hair et al., 2010). Table 2 summarizes the results. It is clear that VIF values meet the recommended threshold values which points to the nonexistence of multicollinearity among the predictors of this model. Moreover, it is important to examine both AVIF and AFVIF calculated values (see Table 3) to further affirm the absence of multicollinearity. The current statistical analysis computed that AVIF and AFVIF values are 1.583 and 1.769, respectively, which are less than the restrictive threshold value of 3.30 (Cenfetelli and Bassellier, 2009; Petter et al., 2007). Finally, based on the estimated statistical parameters of this model, this study demonstrates that the current model exhibits adequate reliability and construct validity, which makes the model liable for further statistical analysis, such as hypothesis testing.

Table 2. Alpha coefficients, composite reliability, VIFs and AVE values

Variable	Alpha Coefficient	Composite Reliability	VIF	AVE
Duration of Following	1.000	1.000	1.953	1.000
Number of Trucks	1.000	1.000	1.424	1.000
Road Damage	1.000	1.000	3.429	1.000
Number of Axles	1.000	1.000	1.379	1.000
Road Number	1.000	1.000	2.050	1.000
Frequency	1.000	1.000	1.279	1.000
Type of Access	1.000	1.000	1.329	1.000

General Results

The model includes 229 items describing latent constructs: road damage, duration of following, road number, frequency, type of access, number of trucks and number of axles (see Figure 5). Structural equation modeling (SEM) using the WarpPLS 4.0 software was used to provide the necessary analysis to serve the objectives of this study. The measurement model test resulted in statistically accepted goodness-of-fit between the data and the proposed measurement model. The various goodness-of-fit statistics are shown in Table 3. Consequently, in accordance to (Kock (2013), the model has a good fit to the data.

Table 3. Model evaluation overall fit measurement

Measure	Value	P-values
Average path coefficient (APC) (<0.05)	0.214	P=0.001
Average R-squared (ARS)	0.708	P<0.001
Average adjusted R-squared (AARS)	0.700	P<0.001
Average block VIF (AVIF)	1.400	acceptable if <= 5, ideally <= 3.3
Average full collinearity VIF (AFVIF)	1.834	acceptable if <= 5, ideally <= 3.3
Tenenhaus GoF (GoF)	0.842	small >= 0.1, medium >= 0.25, large >= 0.36
Sympson's paradox ratio (SPR)	1.000	acceptable if >= 0.7, ideally = 1
R-squared contribution ratio (RSCR)	1.000	acceptable if >= 0.9, ideally = 1
Statistical suppression ratio (SSR)	1.000	acceptable if >= 0.7
Nonlinear bivariate causality direction ratio	1.000	acceptable if >= 0.7

Assessment of Proposed Hypotheses

The test of each hypothesis is achieved by looking at the sign, size and statistical significance of the path coefficient (b) between the latent variable and its dependent variables. The higher the path coefficient, the stronger the effect of the independent variable on the dependent variable. Almost all of the proposed relationships show significance at $p<0.00$. The significance of the path coefficients was assessed using the stable function of WarpPLS 4.0 with 100 resamples (default values). Table 4 shows each proposed hypothesis and its results, whether supported or not.

Table 4 presents the significant structural relationships among the research variables and the standardized path coefficients with their respective significance levels. Only 8 out of 19 hypotheses proposed are found significant.

The hypotheses (H1, H2, H3 and H6) are strongly supported. However, (H4 and H5) are not supported. The model has explained substantial variance in perceived usefulness (R^2=0.71). The overall fit indices, including APC, ARS and AVIF, indicate that the hypothesized model best fits the data with (H1, H2, H3 and H6). Appendix C shows the full results of analysis using WarpPLS 4.0 software.

Table 4. The significant structural relationships among the research variables

Hypothesis	Pathway (IV-DV)	B	P- Value	Remark
Hy1. Duration has a direct significant influence on road damage.	+	0.308	<0.001	Hypothesis Asserted
Hy2. No. of Trucks has a direct significant influence on road damage.	+	0.263	<0.001	Hypothesis Asserted
Hy3. No. of Axles has a direct significant influence on road damage.	+	0.184	0.001	Hypothesis Asserted
Hy4. Frequency has a direct significant influence on road damage.	+	0.161	0.002	Hypothesis Asserted
Hy5. Type of access has a direct significant influence on road damage.	-	-0.144	0.005	Hypothesis Asserted
Hy6. Road number has a direct significant influence on road damage.	+	0.222	<0.001	Hypothesis Asserted
All predictors have a significant influence on road damage in the structural model, R^2 = 0.71.				

Fundamental Model of Road Damage Measurements

Figure 5 presents the significant structure of the model based on Cohen (1988). The model shows a high level of influence of predictors on the endogenous variable (road damage) and is also confirmed as a significant valid model (Kock and Lynn, 2012). Road damage model was explained by heavy truck factors with a percentage of 71%; adjusted R^2 value= 0.71 = 71%.

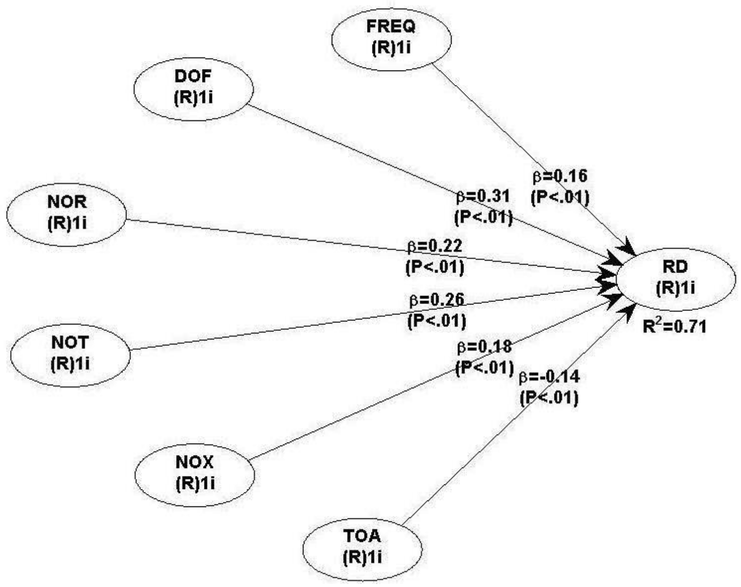

Figure (5): Fundamental model of road damage measurements

Regression Equation of Road Damage Model

The regression equation of the road damage model brings the researchers back to use the SPSS to generate the equation needs, like the B value and the constant. Table 5 shows the needs for the model equation shown under the Table.

Table 5. The equation model needs (coefficients)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.277	0.146		-8.724	0.000
	Duration of following	0.183	0.027	0.308	6.662	0.000
	Road number	0.127	0.028	0.222	4.470	0.000
	Frequency	0.078	0.019	0.161	4.063	0.000
	Type of access	-0.152	0.043	-0.144	-3.548	0.000
	No. of trucks	0.177	0.027	0.263	6.676	0.000
	No. of axles	0.115	0.026	0.184	4.505	0.000

a. Dependent variable: road damage.

Road Damage = -1.277 + 0.138 Duration of following+ 0.127 Road number + 0.078 Frequency – 0.152 Type of access + 0.177 Number of trucks + 0.115 Number of Axles

DISCUSSION

Motivated by the explanatory and predictive power of model development, this study has been launched to investigate the process of developing a model on road damage among local roads (JKR U2/U3) in Malaysia. This study intends to examine the applicable model for road damage in the Malaysian context within the domain. Indeed, to our knowledge, these types of analysis are missing from the literature of both developed and developing country perspectives. The empirical findings and conclusions of the current study offer many important perspectives.

As this study investigates the factors influencing local road (JKR U2/U3) damage in Malaysia, it has tested the relationships hypothesized in the model of this study. This study demonstrates that all variables have influences on the relationships tested in the current model. More clearly, the statistical analysis of this study has empirically demonstrated that variables have significant influences on road damage. However, the road damage model was explained by heavy truck factors with a percentage of 71%: adjusted R^2 value 0.71= 71%.

Based on Cohen (1988), the model has a high level of influence of the predictors on the endogenous variable (road damage) and confirmed to have a significant valid model (Gujarati and Porter, 2003; Kock, 2014; Seider et al., 2009).

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