PREDICTION OF ROAD PAVEMENT DAMAGE FOR LOCAL ROADS IN MALAYSIA

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ABSTRACT

The high wheel loads of heavy trucks are a major source of pavement damage by causing fatigue, which leads to cracking and permanent deformation, which produces rutting. Malaysia, as one of the developing country has high level of road pavement damage. In addition to the cost of rehabilitating the pavement, serious safety issues occurs especially when the heavy trucks using U2/U3 roads, which not design to be use by heavy trucks. With aim to develop an analysis method and corresponding tool for local authorities to evaluate the impact of heavy trucks on local access roads, an observation was carried out to determine the characteristics of the trucks and operating conditions on local roads, from February, 2013 until July, 2014 at the Taman Kosas Utama Ampang Selangor and Taman Tas Kuantan Pahang (Malaysia). The mechanics of truck movement on the local access roads were studied to identify relationships between truck properties and road damage and to develop an appropriate method of data collection for these local roads. The WarpPLS is used as 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 been established with a coefficient of determination (R) at value of 0.71.

ABSTRAK

Muatan berlebihan bagi trak muatan berat merupakan penyebab utama kerosakan jalan. Muatan berlebihan mengakibatkan struktur jalan menjadi lemah dan membentuk rekahan yang menyebabkan kerosakan serta pembentukan alur. Malaysia sebagai sebuah negara membangun mempunyai kadar kerosakkan jalan yang tinggi. Selain dari pertambahan kos pembaikan jalan, isu keselamatan juga menjadi perkara utama kerana jalan jenis U2/U3 tidak direka bagi kegunaan trak muatan berat. Pemantauan terhadap trak muatan berat yang menggunakan jalan-jalan yang telah dipilih dilakukan dari bulan Febuari 2013 hingga Julai 2014 Taman Kosas Utama Ampang Selangor dan Taman Tas Kuantan Pahang (Malaysia). Ini bertujuan mengenalpasti cara analisis kajian dan alatan yang bersesuai untuk kegunaan pihak berkuasa tempatan bagi menilai kesan penggunaan jalan-jalan tersebut oleh trak muatan berat. Pemantauan juga dilakukan bagi mendapatkan ciri-ciri trak muatan berat dan keadaan semasa jalan-jalan tersebut. Kajian berkaitan pergerakan mekanikal trak pada jalan-jalan ini juga dilakukan bagi mengenalpasti hubungan antara ciri-ciri trak dan kerosakan jalan yang terjadi. Ini penting bagi membangunkan cara pengumpulan data yang bersesuaian dengan objek kajian. WarpPLS digunakan bagi pembangunan cara kajian dan SPSS digunakan bagi menghasilkan model kajian. Hasil kajian mendapati terdapat hubungan regresi antara kerosakkan jalan raya dan faktor-faktor yang dikaji dengan koefisien determinasi dengan nilai 0.71.

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LIST OF ABBREVIATIONS

PMLOA	Pan Malaysia Lorry Owners Association
AASHTTO	American Association of State Highway and Transportation Officials
JKR	Jabatan Kerja Raya
ESAL	Equivalent Standard Axle Load
FHWA	Federal Highway Administration
HPU	Highway Planning Unit
MAL	Maximum Axle Loads
MGVM	Permissible Gross Vehicle Weights
VLF	Vehicle Load Factors
PMS	Pavement Management System
HDM	Highway Development and Management
ANN	Artificial Neural Network
OLS	Ordinary Least Squares
PWD	Public Working Department
PERS	Performance and Economic Rating System
SMP	Strategic Management Plan

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Malaysia is moving towards becoming a developed country. Roads play an important part in the trade and transportation planning throughout the cosmos, and it has became rapidly increased in the pavement infrastructure development in Malaysia, mostly road linking the state capitals, airports, railroad stations and ports, gazetted under Federal Roads Ordinance. Presently, Malaysia has more than 80,300 km roads, and the roads are divided into three primary classes, namely toll expressway 1,700 (km), federal roads 17,500 (km) and state roads 61,100 (km) and the life spans are between 10 to 15 years (Zakaria, 2005). Local authority road (city mall, municipal or local council) or village (district office) street depend on the areas and naturally kept up by the responsible local authority (Haron, 2004).

Yearly, the increases of heavy vehicles due to the high demand from industries, subjected the pavements to heavy axle loads. Yet, conflicting to the prevailing literature and the other road users' speculations, the Pan Malaysia Lorry Owners Association (PMLOA) objects to the fact that its trucks bearing any danger to other road users or damage to the (Golias I., 2001).

The heavy vehicle load on the pavement subjects it to high stresses causing damage. However, not all tracks have the same harmful effects; the damage to the road pavement depends on wheel loads, number and location of axles, load distributions,

number of wheels, tire types, inflation pressure and other factors (Gillespie T.D., 1993). Heavy truckloads are the major cause of pavement damage. The size and configuration of vehicular loads together with the environment have an important impact on induced tensile stresses within flexible pavement (Yu H.T., 1998).

The length of the bulge front/rear, Height of vehicles, impacts on the increasing carrying capacity of vehicles. Furthermore, this will immediately increase load axis of the vehicle making the axle load greater than is permitted. This produces the problem of excessive load or overloading. The impact of overload conditions on the road pavement is premature failure, that is, a condition that the damage can shorten the lifespan of roads before the design lifetime of the road is reached, (Badan Litbang Kementerian Pekerjaan Umum, 2004).

Wheel load on the pavement results in distribution and reduction of stresses throughout the Pavement structure, specifically for flexible pavement, stresses induced in a pavement structure by traffic loads are highest in the upper layers and diminishes with depth. A stress acting on an elemental cube of the pavement system experience normal and shear stresses along the opposite sides of the block, as the paving material is subjected to traffic load, the principal stresses are independent of the chosen coordinate system. When a pavement structure is subjected to loads induced by traffic wheel, it is classed as a dynamic load. The resultant stress consists of horizontal, vertical and shear component. These stresses are routinely changed as the wheel load pass (Lekarp, 1999).

This improves a comprehensive theoretical framing of driver performance, stating the relations amongst the dissimilar factors of driving performance. Several sources of information must be used in order to estimate models based on the framework. This study uses the observation method to gather information. Heavy vehicles also led to the Damage of the road; there were 19.3 million registered vehicles on the Malaysia's road, and the government spent RM5 billion between 2001 and 2010 to continue its sustenance on all the Federal roads (Kordi et al., 2010).

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

1997). The repetition of load and overloading of heavy trucks allegedly affect the road pavements; the design life of the pavements becomes shorter, although the same quality standard is used during design and construction (Mulyono, 2010), as much research confirms that the Roads are damaged by heavy trucks, and every researcher has implements different method from another to reach this conclusion. Although most of those methods are time consuming, costly, unsecure, can't be done individually; none of them had confirmed when and how these roads got damaged. This thesis will present a sample method to measure the road damage and to confirm when and how these roads got damaged.

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

1.2 PROBLEM STATEMENT

Statistics is the mathematical science involving the data collection, analysis and interpretation of data. A number of specialties have evolved to apply statistical theory and methods to various disciplines. Certain topics have "statistical" in their name but relate to manipulations of probability distributions rather than to statistical analysis. To think statistically is to know that the measurements taken in an experiment are subject to systematic and random sources of variation, and that it is beneficial to base methods of data analysis on probabilistic models. For many types of data analysis problems, there are no more than a couple of general approaches to be considered on the route to the problem's solution. Within the different approaches for a specific problem type, there are usually at most a few competing statistical tools that can be used to obtain an appropriate solution. The most type of data analysis problems is that selection of the best statistical method to solve the problem is largely determined by the goal of the analysis and the nature of the data. Model building, however, is different from most

other areas of statistics with regard to method selection. There are more general approaches and more competing techniques available for model building than for most other types of problems. There is often more than one statistical tool that can be effectively applied to a given modeling application. The large menu of methods applicable to modeling problems means that there is both more opportunity for effective and efficient solutions and more potential to spend time doing different analyses, comparing different solutions and mastering the use of different tools. The remainder of this section will introduce and briefly discuss some of the most popular and well established statistical techniques that are useful for different model building situations. Linear least squares regression is by far the most widely used modeling method. It is what most people mean when they say that they have used "regression", "linear regression" or "least squares" to fit a model to their data. Not only is linear least squares regression the most widely used modeling method, but it has been adapted to a broad range of situations that are outside its direct scope. It plays a strong underlying role in many other modeling methods, including the other methods like nonlinear least squares regression extends linear least squares regression for use with a much larger and more general class of functions. Almost any function that can be written in closed form can also be incorporated in a nonlinear regression model. Unlike linear regression, there are very few limitations on the way parameters used in the functional part of a nonlinear regression model. The biggest advantage of nonlinear least squares regression over many other techniques is the broad range of functions that can be fit. Although many scientific and engineering processes can be described well using linear models, or other relatively simple types of models, there are many other processes that are inherently nonlinear. For example, the strengthening of concrete as it cures is a nonlinear process. Research on concrete strength shows that the strength increases quickly at first and then levels off, or approaches an asymptote in mathematical terms, over time. Linear models do not describe processes that asymptote very well because for all linear functions, the function value can't increase or decrease at a declining rate as the explanatory variables go to the extremes. There are many types of nonlinear models that well describe the asymptotic behavior of a process. Like the asymptotic behavior of some processes, other features of physical processes can often be expressed more easily using nonlinear models than with simpler model types.

1.3 RESEARCH QUESTION:

1. Is road pavement damage on the access road to the residential area caused by the presence of unwanted heavy vehicles?
2. Are there any specific times and days that heavy vehicles frequently used these roads?
3. What is the type of heavy truck (Number of Axle) that caused damage to the road pavement?
4. Is the frequency and the volume of heavy vehicle using the road related to the severity of the road damage?

1.4 RESEARCH OBJECTIVES

1. To investigate and analyze the effect of different factors on the pavement damage of local roads at selected site; and

2. To develop and validate statistical relationship between different factors on the pavement damage of local roads in selected site;

1.5 SCOPE OF RESEARCH

The study was carried out in a residential area that has a JKR U2/U3 road network with high volume of heavy vehicle. This research was conducted from an engineer's perspective dealing with mathematical models and statistical methods. However, the most important contribution of this research study is in statistics.

1.6 LIMITATIONS OF THIS STUDY

- The low corporation rate experienced in this study was a concern. Follow-up observation utilized to encourage responses. These observation follow-ups did lead to a higher response rate than that which was initially received. Even so, a higher response rate would potentially have led to more statistically significant results.

- The collected statistics were limited to a certain chamber of the study area. The reason for selecting areas within this chamber was to make them readily available in the Taman Kosas Utama 1 area.

- This study was undertaken by a first-time researcher, which might also be seen as a limiting factor.

1.7 RESEARCH CONTRIBUTIONS

The primary contribution of this research is not the growth of a Damage model, rather the demonstration of the feasibility of using joint estimation and its many advantages, such as:

1. Identification and quantification of new variables,

2. How the road damage data should be collected/arrange

3. Efficient parameter estimates,

4. Identification of the JKR U2/U3 Roads Damage Index when every single variable involved,

5. The statistics method to be used for Nonparametric Data.

6. The use of WarpPLS as tool to develop the research model

1.8 SIGNIFICANCE OF RESEARCH

It is expected that the models created in the course of this research will help the local authority to monitor issues related to road Damage in residential areas (JKR U2/U3 Roads). Specifically the study will help improve original designs on the road, suggest better material types, advice quality construction, determine the threshold of traffic volume and axle loading, examine the road geometry and pavement age. Also, the study will contribute to results positively, and they are better environmental

conditions and maintenance policy towards roads.

1.9 VARIABLES INVOLVED

1. Road Damage: -this variable is the Dependent Variable, and the road damage explains the Damage caused by the heavy trucks with different types of damage to the Road.

2. Duration of Following: - this variable is independent variable, and this variable will check from where the truck come and to where it is heading by going through a residential area and writing down the time that the observer spend to follow this truck.

3. Frequency: - this variable is independent variable, and this variable will check if the same truck has gone through the residential area (study area) frequently.

4. Type of Access:- this variable is independent variable, and this variable will check if the truck has gone through the residential area (study area) for the purpose of passing through or trip end.

5. Number of Road: - this variable is independent variable, and this variable will check from where the truck comes and to where it goes through a residential area and to count how many roads that the driver used until reached the residential area.

6. Number of Trucks:- this variable is independent variable, and this variable will allow the observer to count how many trucks were at residential area (study area), as an observer and everyone know that the road damage comes from the heavy truck, but not in a residential area, where the road design not to carry those types of trucks.

7. Number of Axle: - this variable is independent variable, and this variable will allow the observer to check the type the trucks found in the residential area (study area), by looking weather these trucks are one axle, two axle three axle four axles and so on.

1.10 LAYOUT OF THE THESIS

Chapter 1 Provides the Background to the research, including problem Statements, objectives of the study, the scope, hypothesis of research, limitations of the study.

Chapter 2 Contains the comprehensive review on the literature review in this research field, offering definitions of positions from the perspectives of several researchers.

Chapter 3 Presents the detailed description of the research methodology for the

site selection, data collection.

Chapter 4 Explains the result and discussion as well as the statistical method employed in objective 1.

Chapter 5 Explains the result and discussion as well as the statistical method employed in objective 2.

Chapter 6 Concludes the study with some recommendation for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter highlights the road network in Malaysia and road standards and the Application of road standards. This is followed by discussion of the data characteristics that need to be considered for developing deterioration models. The empirical and mechanistic approaches to model development are briefly discussed, and their advantages and disadvantages are highlighted. Finally, this chapter reviews the existing deterioration models with focus on explanatory variables used and the conditions under which the models were developed.

2.2 ROAD NETWORK IN MALAYSIA

2.2.1 Federal Roads

Federal roads are all roads declared under the Federal Roads Ordinance (1959) and the major interurban roads joining the state capitals and roads leading to points of entry to and exit from the country.

2.2.2 State Roads

State roads comprise of the primary roads providing intrastate travel between the district administrative centers. Other roads included in this class are the urban collector roads under the municipalities and other minor roads within the hamlets and the rural inhabited areas under the Districts Offices.

2.3 ROAD STANDARDS IN MALAYSIA

2.3.1 Standardization

According to JKR manual, the geometric design of all roads needs to be standardized for the following reasons:

a) To maintain stability in the design of roads according to their performance demands.

b) To offer a consistent, dependable and reliable road facilities for the movement of traffic;

c) To provide a guide for less subjective decisions on road design;

According to JKR manual, Rural and Urban Areas the Urban areas are defined as areas having a population of at least 1,000 where buildings and houses gathered, and business activity is prevalent. It covers all areas within the gazette Municipality limits and also includes areas expected to become urbanized within the program period. Rural areas can be regarded as areas other than urban areas (Arahan Teknik (Jalan) 5/85, 1985).

There is no essential difference in the ideologies of design for rural and urban roads. Roads in urban regions are considered busy due to the pedestrian activities and frequent stopping of vehicles owing to short intersection spacing's and congested built-up areas. Lower design speeds usually adopted for urban roads, and different cross-sectional elements are applied with reference to the nature of traffic and adjoining land use. It is for these reasons that variations in certain views of geometric design incorporated for these two broad groups of roads.

2.3.2 Application of road standards

According to JKR manual (Arahan Teknik (Jalan) 5/85, 1985), the design standard is classified into seven groups (R6, R5, R4, R3, R2 and R1) for rural areas and seven groups (U6, U5, U4, U3, U2 and U1) for urban regions. These are arranged in their descending order of hierarchy. Roads that provide long distance travel will require a higher design speed whilst road which serves local traffic, where the issue of speed is less significant can have a lower design speed. Also roads with heavier traffic will be

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CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The research methodology adopted is the general pattern of organizing the procedure for collecting valid and reliable data for an investigation. It gives a detailed description of the research procedures that are followed during the investigation. The research methodology followed for the present investigation is discussed in detail in this chapter.

The research method used in the present study evolved five (5) stages. The first is the ***Desk top 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 also road maps from ***Jabatan Perancangan Majlis Bandaraya Ampang***. The second stage is the ***Site Selection Criteria***, which is used as the bases to select the right residential for this study. Next is the ***Preliminary Site observation*** where each selected residential JKR U2/U3 roads which have been deteriorated is identified and vetted through to finalize a suitable sample. The fourth stage is the ***Data Collection*** where the data were recorded while travelling on the selected roads JKR U2/U3 using the observation method. Finally, ***Statistical Analysis*** using a multiple regression is conducted to develop the models. The developed models need to be validated to evaluate the accuracy of the models. Figure 3.1 presents the flowchart of the research methodology.

The main focus of this chapter is to present a systematic flow of the entire design of the research process. Researcher present a case study of the experiences of heavy trucks as they conduct their daily routine of using local roads (JKR U2/U3 Roads)

Simply put, this study is an attempt to understand how pavement damage experience and respond to trucks drivers behavior.

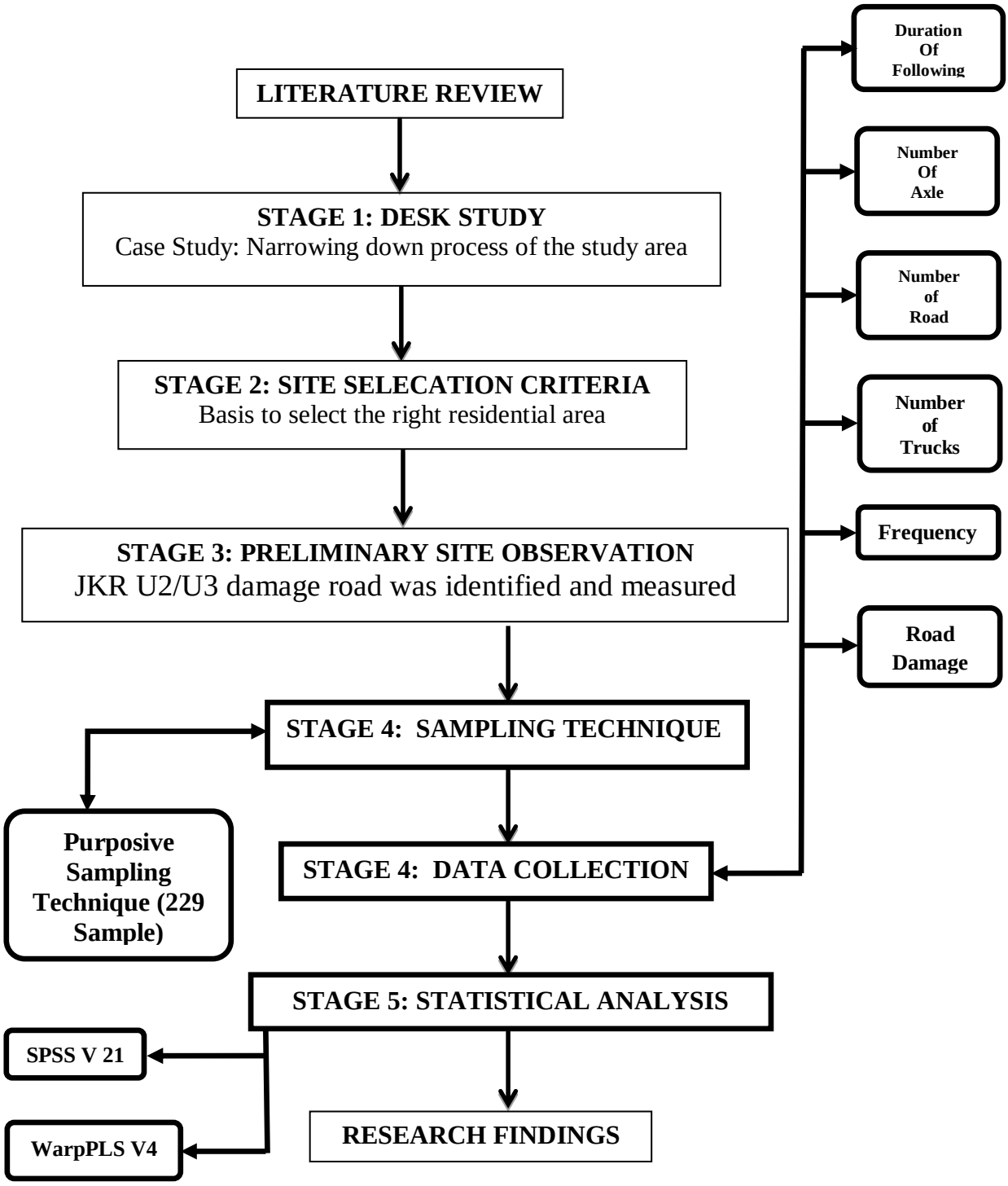

Figure 3.1 Flowchart Illustrating the Research Methodology

3.2 DESKTOP STUDY

From the desktop study finding, it was found that the trucks came from Access/intercity roads to enter the local roads/Ampang area, and 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. The figure 3.2 below shows Access/Intercity from these roads to Ampang area. Meanwhile, the result from the study could be effectively used to research the effect of heavy vehicle trafficking from the perspective of 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 3.3 Residential Area and other Facilities for the Study Area, JKR U2/U3 Roads in this area were selected as listed in the table 3.1 below.

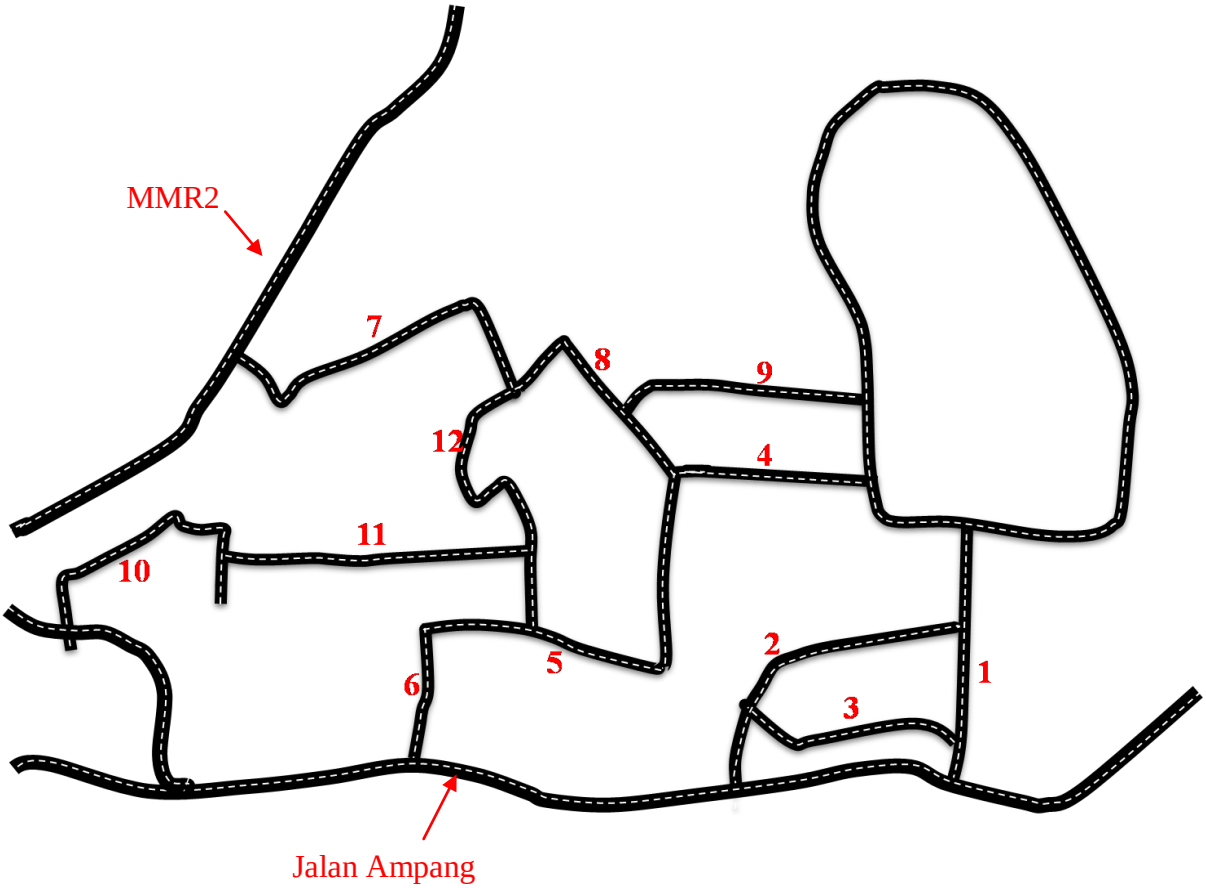

Figure 3.2 shows the Access to the Ampang area from both MMR2 and Elevated Highway