EFFECT OF HEAVY VEHICLES PERFORMANCE TOWARDS FEDERAL ROAD : A CASE STUDY OF FEDERAL ROAD 3

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EFFECT OF HEAVY VEHICLES ON THE PERFORMANCE OF FEDERAL ROAD : A CASE STUDY OF FEDERAL ROAD 3

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Thesis submitted in fulfillment of the requirements
for the award of the
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ABSTRAK

Walaupun bilangan kenderaan berat dalam aliran lalu lintas hanya sedikit peratusan, kesannya menonjol. Kenderaan berat mengenakan kesan fizikal dan psikologi ke atas aliran lalu lintas yang disebabkan oleh ciri-ciri panjang dan saiz (fizikal) dan percepatan / penurunan (operasi) ciri-ciri. Kajian ini dijalankan untuk mengkaji keseriusan kemerosotan jalan raya dan untuk menilai tahap Perkhidmatan (LOS) bagi kemudahan untuk menampung permintaan kenderaan berat bagi keadaan semasa (2018) dan keadaan ramalan masa depan (2020). Kajian ini dijalankan dengan menggunakan kaji selidik pengamatan visual dan tinjauan jumlah lalu lintas. Untuk mencapai ini, Federal Road 3 dipilih sebagai lokasi pengajian. Terdapat dua lokasi yang dikenal pasti yang menghubungkan ke wilayah pantai timur untuk Stesen 1 dan menghubungkan ke pelabuhan untuk Stesen 2. Kemudian, data akan diperoleh dari dianalisis menggunakan kaedah penilaian penilaian jalan raya dan analisis prestasi operasi. Hasilnya menunjukkan bahawa tahap kecacatan dan penarafan jalan adalah (Kedudukan A: sangat memuaskan) untuk Stesen 1 dan (Kedudukan C: kurang memuaskan) untuk Stesen 2. Walaupun untuk analisis prestasi operasi keputusan tersebut menunjukkan bahawa LOS diperolehi di Stesen 1 dalam keadaan sekarang adalah LOS C manakala untuk masa depan adalah LOS D.. Berbanding dengan Stesen 2, kedua-dua hasil mendapatkan keadaan sekarang dan masa depan menunjukkan LOS A.

ABSTRACT

Although the number of heavy vehicles within the traffic stream is only a small percentage, their impact is prominent. Heavy vehicles impose physical and psychological effects on surrounding traffic flow because of their length and size (physical) and acceleration/deceleration (operational) characteristics. Prior to these issues, this study is conducted to investigate the seriousness of road pavement deterioration and to evaluate the Level of Services (LOS) of the facilities to accommodate traffic demand of heavy vehicle for both present condition (2018) and future forecast condition (2020). This study was conducted by using visual observation survey and traffic volume survey. To achieve this, Federal Road 3 was chosen as study location. There will be two identified locations which is link to east coast region for Station 1 and link to port for Station 2. Then, data obtained from the sites were analyzed using road rating assessment method and operational performance analysis. The result revealed that the disability level and road rating for Station 1 was (rating A : very satisfactory) and (rating C : less satisfactory) for Station 2. While for operational performance analysis the result revealed that LOS obtain at Station 1 in present condition is LOS C while for future condition is LOS D. Comparing to Station 2, the both result obtain for present and future conditions show LOS A..

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FFS	Free Flow Factor
LOS	Level of Services
D	Density

LIST OF ABBREVIATIONS

FFS	Free Flow Factor
LOS	Level of Services
HCM	Highway Capacity Manual
BFFS	Base Free Flow Speed
fLW	Adjustment of lane width
fLC	Adjustment of lateral clearance
fM	Adjustment of median
fA	Adjustment of assess point
Vp	Flow Rate
fHV	Factor Heavy Vehicles
PHF	Peak Hour Factor
D	Density

CHAPTER 1

INTRODUCTION

1.1 Research Background

Malaysia has identified mineral resources of barite, bauxite, clays, coal, copper, gold, ilmenite, iron ore, limestone, monazite, natural gas, petroleum, silica, silver, struverite (tantalum), tin, and zircon (Tse, 2016). During the 20th century, mineral production played an important role in Malaysia's national economy after many years of exploitation. Malaysia has a long past of mining, exclusively tin, but until very recent times it scarcely listed on global markets as a source of mineral. That changed suddenly in January 2014, when, in an attempt to enhance its own aluminium-smelting industry (Wan Junaidi Tuanku Jaafar, September 2016).

In Kuantan, the active mineral mining is located in Gebeng, Pahang. The mine while strengthening the economy and as well helping as a profitable source of earnings for many people, is also bring about intense suffering to the local people. Mineral activity indeed has causes the pollution around Bukit Goh, Gebeng and Kuantan Port. For months, certain areas in the district, particularly Bukit Goh, have underwent serious air pollution from mineral dust and residue released by the processing plants or leaked during transportation to Kuantan Port. Mineral dust and residue also has polluted and damaged the road (Malaysiakini, January 2016).

Other than that, few fatal accidents also happened caused by lorries transporting of mineral. Lorries for transporting mineral also has caused traffic congestion as the drivers parked their lorries on the road. Other than that, many potholes have occurring because of mineral transportation activity on the road surface where it can cause an accident to road user. Moreover 24 accident have been recorded since it operation. About 200 trips are made in a day, from the mines to Kuantan which has make the roads are badly damaged by the lorries (Andansura Rabu, January 2016). This is happening because most of the lorries are carrying more than they should. This activity has caused the roads heading to the port are pockmarked with potholes and it is dangerous for the user (Khaidir Ahmad, June 2014). Even though they may be using the designated routes, these public roads go through neighborhoods and urban areas. Some of the accidents are caused by lorries driver that trying to rush their loads to the port, as they are paid according to the number of trips they make. Therefore, this research is done by evaluated the impact of heavy vehicles distribution towards road pavement deterioration and determine the performance of existing level of service multilane highways when being generated by the heavy vehicles operation.

1.2 Problem Statement

Malaysia's basically unregulated mineral mining industry has boomed in the past two years to encounter the demand from top aluminum producer China, filling in a resource gap after Indonesia banned exports (Reuters, September 2016). The development of the mineral industry has made Kuantan also led to the growth of new industries that generate state and population revenues. Along with these developments, the increase in the number of vehicles for the transportation of bauxite has also increased. Problems arising from the development of this industry have posed a danger to road accidents and road surface. This activity has caused the roads heading to the port are pockmarked with potholes and it is dangerous for the user.

Moreover, the boomed of this industry has causes several road accidents involving lorries transporting mineral, which some of it were fatal. The changes of road surface such as potholes also occur along with these developments where it has changed the condition of the road surface. The reason to this changed is due to high demand from outside the country and also caused by lorries driver who trying to hurry to freight their mineral to the port, as they are rewarded according to the number of journeys they make. This research will focus on the impact of heavy vehicles distribution towards road pavement deterioration and determine the performance of existing level of service multilane highways when being generated by the heavy vehicles operation. There will be two station chosen to represent the effect of heavy vehicles distribution towards federal road performance.

1.3 Objective

The aim and objective of this case study is to analyses the effect of heavy vehicles distribution along Federal Route 3 Jalan Pintasan Kuantan – Pelabuhan (AH18). To achieve the aim of this study, the following objectives have been set follow:

i. To assess the impact of heavy vehicles distribution to road pavement deterioration
ii. To evaluate the LOS of the facilities to accommodate traffic demands of heavy vehicles for both present and future condition

1.4 Scope of Study

The scope of this research has been determined to ensure the literature study is focusing at certain field. This research will be focus on:

1. The location selected is Kuantan Baypass Federal Route 3 (AH18), a main highway baypass
2. The starting point for visual observation for road deterioration will be 3 km at Station 1and 3 km at Station 2
3. Metro count will be installed at Station 1 and Station 2 to obtained traffic volume data
4. Highway Capacity Manual (HCM 2010) was used to determine the Operational Analysis in terms of LOS

1.5 Research Methodology

To make this study work, several research methodologies were used. There is initial discussion, proposal, literatures review, collecting data, analysis data and conclusion. The **Figure 1.1** below showed the flow chart of research methodology in this study.

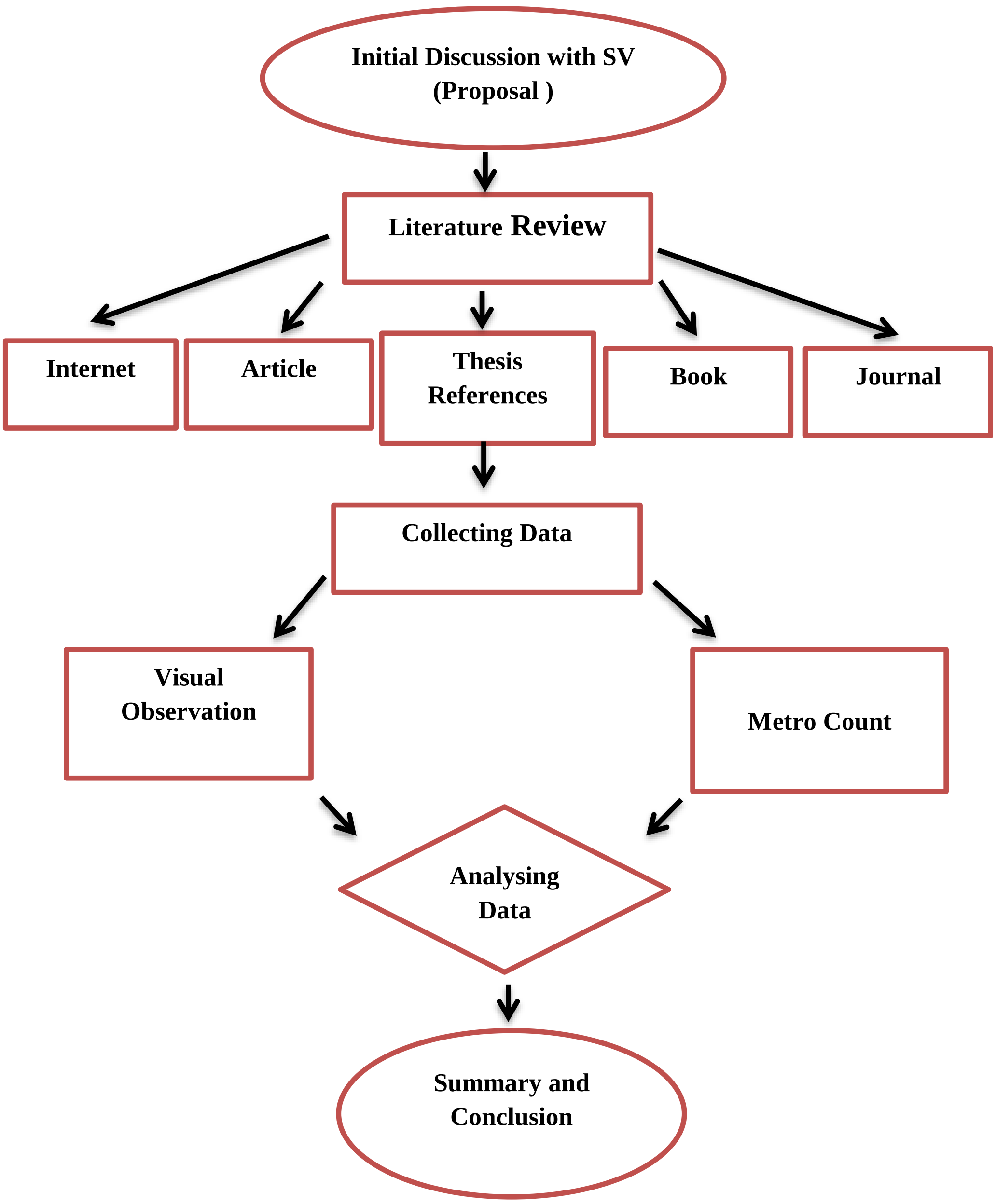


Figure 1.1 : Research Methodology Flow Chart

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Mineral could be the potential sources of wealth creation for resources-rich nation and mining is still the primary method of extraction. With the increasing demand from raw material thriving global manufacturing sector, the mining industry is seeing the revival from its sunset day (Professor Datuk Dr Asma Ismail, FASc, 2017). A mineral is a naturally occurring chemical compound, usually of crystalline form and not produced by life processes. A mineral has specific chemical composition, whereas a rock can be aggregates of different mineral or mineraloids. Minerals are classified by variety, species, series and group, in order of increasing generality. Rock mineral such as dimension and crushed stones and sand and gravel are indispensable material for the building and construction industries. The growth in demand for these resources causes intensification of mining operation and transport problems in regions abundant in rock minerals. According to reports, Malaysia's exports to China rose, rising steeply from just 343,000 tonnes in January 2015 to 3.72 million tons in September 2015.

2.2 Mineral in Kuantan

Recent mineral mining activities in the vicinity of Kuantan, Pahang, have been associated with apparent to transportation. Malaysian mining industry is expected to remain on a growth path driven by the ongoing demand for mineral supply both nationally and globally. Metallic mineral sector in Malaysia includes bauxite, iron ore, manganese, gold, tin, and other by products of tin and gold mining (Majid et al. 2013). As of 2013, mineral production has greatly increased and the only mineral mine in operation was in Pengerang, Johor. Kuantan, Pahang, a district in eastern Peninsular Malaysia, has become a hot spot for new mineral mines in Malaysia when mineral mining in Indonesia ceased operation.

Mineral in Kuantan area is formed from basalt. The area in Kuantan including Bukit Goh occupied by basalt is about 18,000 ha (Paramananthan 2000). A mineral is a naturally occurring chemical compound, usually of crystalline form and not produced by life processes. A mineral has one specific chemical composition, whereas a rock can be an aggregate of different minerals or mineraloids. The study of minerals is called mineralogy. However, mineral mining is not without its challenges, especially the open cast mining activity. Mineral is usually strip mined because it is typically found below soil layer, 1 or 2 m below the surface. Mining mineral may cause great disruption as it has detrimental impacts on water, air, land, aquatics, wildlife, transportation and other biological resources as well as human life if the mining activities are not properly controlled (Saxena and Singh 2000: Abdullah et al. 2016)

2.3 Mineral Freight Distribution

Kuantan District (2960 km2) is the state capital of Pahang, which is located at latitude 3° 45′ 0″ N, and longitude 102° 30′ 0″ E. The National Physical Plan 2005 has identified Kuantan as one of the future growth centres and a hub for trade, commerce, transportation, and tourism in Malaysia. Kuantan is considered a social, economic, and commercial hub for the East Coast of Peninsular Malaysia due to its strategic location, while rapid development has transformed and modernized the city. The mineral mining operation is progressively occurring in the vicinity of Bukit Goh Kuantan, but the ore deposits were then transported to temporary storage area within Kuantan Port prior to being exported to China for mineral processing. Figure 2.1 show the active route of mineral mining in Kuantan.

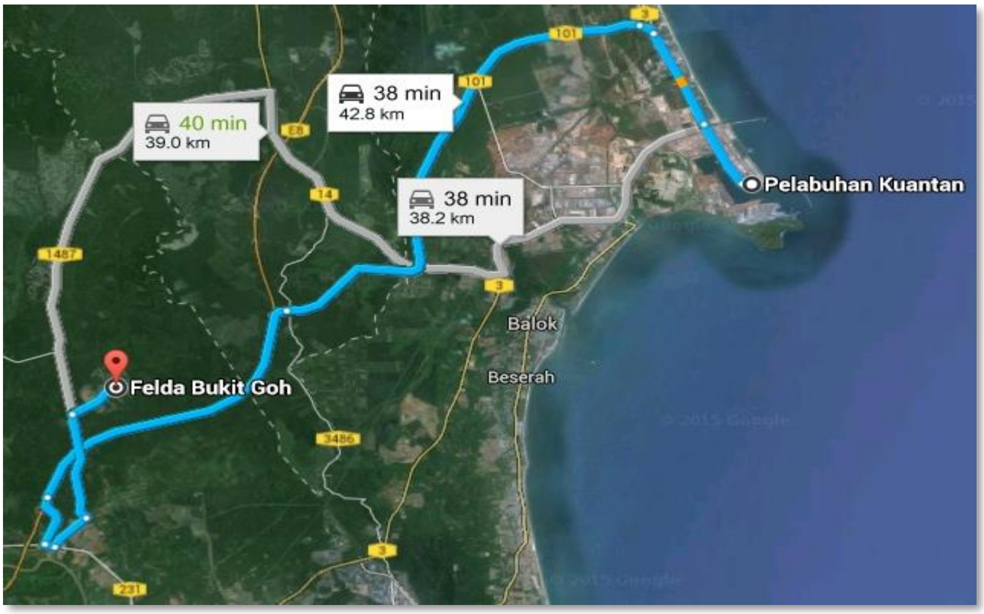


Figure 2.1 : Active route in Kuantan

2.4 Effect of Mineral

Mineral mining activities have caused lots of environmental impact and accident. These were caused by the methods of operation by the mining companies that can cause an effects towards our natural environment and as well as surrounding communities. Communities who live near mineral mining area experience social, psychosocial and health impact from the environmental activities. Some of the problems identified were the nuisance by noise emanating from bauxite lorries, traffic congestion, road damage with red mud, deforestation, increase of erosion, air pollution such as dust which resulted in bad vision during hot dry days, dusty homes and properties, respiratory and skin problem, soil and water pollution (The Star Online, 2016). From the previous research that has been done by (Norazura Ismail and Junaidah Zakaria, 2016) one hundred and sixty two residents within the mineral mining area has been selected randomly for a face to face interview. This study was conducted from June 2015 until June 2016 and the data collection were carried out from the 7th January to 28th February 2016.

Based on the pie chart from Figure 2.2 that obtain from the interview show that road damage is the second biggest issue that should be monitor, where about 13% of the

113 respondents agree that road damage is causes by mineral freight distribution. Reason that lead to this causes is because most of the lorries are carrying more mineral that what should the carried. Due to this activity the roads heading to the port are pockmarked with potholes and it is dangerous for the user. Moreover, some of the accidents also caused by lorries driver that trying to rush their loads to the port, as they are paid according to the number of trips they make.

On the other hand, another effect that causes by mineral industry on traffic problems is when lorries transporting the material often fill overload so that spills occur on roads and also on other vehicles and also turn the road becoming dusty in the summer and is in the rainy season. Furthermore, the lorry also often makes U rounds in places that are not allowed to quickly reach the port causing a lot of accident events. Another effect that lead to this problem is a dirty truck which make it difficult for enforcement because the vehicle registration number is not easy to see and recorded by the authorities.

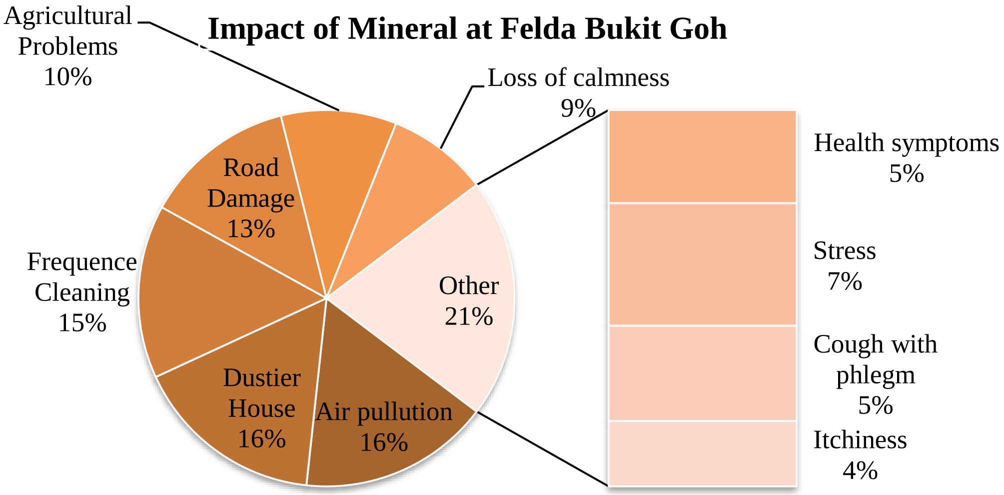


Figure 2.2 : Pie chart for Impact of Mineral at Felda Bukit Goh

2.5 Traffic & Accident

Between April 2 and May 23, about 43,278 lorries were inspected. And 1134 lorries have been seized. It has even resulted in the collection of offense compounding amounting to RM 2.1 million. This is due to the excessive number of lorries and the enforcement scale seen less effective. Among the mistakes seen frequently performed by this bauxite truck are :

1. Bringing and overloading the cargo which can interfere with other vehicle drivers. This happens because when the mineral is excessive in excess of the bauxite it spills into the road and triggers dirty roads.
2. Trucks do not follow road rules. Most mineral lorries make U- turn laps in unauthorized places to heavy vehicles resulting in highway congestion
3. Drive the lorry beyond the prescribed limit, especially the empty trucks after the mineral is cast in the port
4. Dirty mineral truck has causes the number plate of the lorry does not seem can cause a lot of trouble, especially when there is an accident and the complaint should be made to the authorities.

As the mining activities has becoming worse at Pahang, the standard operating procedure (SOP) for bauxite mining activities in Pahang has been produced in order to control the activities. Environment Minister Datuk Seri Wan Junaidi Tuanku Jaafar said the SOP was prepared after taking into account environmental impact assessments by several agencies involved, as well as input from the Malaysian Anti-Corruption Commission (MACC).The SOP will ensure that bauxite mining and export comply with the set regulations and not cause pollution.

The SOPs include the gazette of special routes for lorries carrying bauxite from all mining sites to the port, so that they do not pass through residential areas, public places, crowded routes, and comply with the load limit,(Hamim Samuri,2016). Another SOP is include preparing suitable lorries to transport mineral to ensure that the mineral is contained properly and does not spill on the road during the transportation process, limited and carrying the bauxite at given amount, operation hour within the time given from 8.00 am to 6.00 pm and restricting the vehicles speed to 60 km per hour.

2.6 Road Pavement Deterioration

A road is a thoroughfare, route, or way on land between two places that has been paved or otherwise improved to allow travel by foot or some form of conveyance, including a motor vehicle, cart, bicycle, or horse (Shalini, Puchika, Bhupali, Pooja N., Ajit, & A.K.Sarkar, 2016). Road has played an important role in the trade and transportation system throughout the world. Despite to this activity, sometimes these roads not able to carry the load with the specified design life especially in industry areas because heavy lorries always using these road to move their good. Therefore, the road is not only to form a simple road surface to ensure the vehicle ride comfort, but also must be strong enough to support the vehicle.

2.6.1 Heavy Traffic

One of the defects caused by heavy traffic on the road is the deformation of the pavement surface due to overloading that is more than the design load. As stated by (Sharad.S.Adlinge & Gupta, 2012) that deterioration of pavement arises from deformation generally associated with cracking under heavy commercial vehicles. The increased traffic loading will then cause failures such as cracks and depression on the pavement.

Pavement deterioration is the process by which distress develop in pavement under the combined effect of traffic loading (M.E.Zumrawi, 2016). Deterioration of pavement greatly affects serviceability, safety and riding quality of the road. The pavement deterioration over time is caused by a combination of factors however, traffic loads play a key role in consumption of pavement life. Several factors such as traffic, environment, material and design considerations affect the pavement damage over time. Traffic loads play a key role in pavement deterioration. As trucking has become the most popular mode of freight transportation because of its efficiency and convenience it has contributed to most of pavement deterioration (Bai, Schrock, Mulinazzi, Hou, Liu, & and Firman, 2010). Trucks are the major consumers of the pavement network as they apply the heaviest loads to the pavement surface. Moreover, increased demands due to economic growth have led to changes in the designs of heavy vehicles and in their weights.

2.6.2 Overloading Vehicles

Overloaded vehicles have a significant impact on pavement fatigue life and distress. Overloaded vehicles especially freight vehicles destroying roads and impacting negatively on economic growth because the damage caused grows exponentially as the load increases (Bai, Schrock, Mulinazzi, Hou, Liu, & and Firman, 2010). Every vehicle has a specific limit to which it can carry passengers or cargo. Road transportation is a dominant mode of freight transportation in Malaysia that accounts for about 80% of the freight movement. The number of heavy vehicles is continuously increasing on the road network. Overloading is growing up, and it is a major cause for significantly accelerating the rate of pavement deterioration.

Paved roads involving both asphalt and concrete usually carry the bulk of road traffic and cause of road pavement deteriorates (Pretoria, 2008). This is because every vehicle which passes over a road causes a momentary, very small, but significant deformation of the road pavement structure. Moreover the passage of many vehicles has a cumulative effect which gradually leads to permanent deformation and road surface deterioration. One of the defects caused by heavy traffic on the road is the deformation of the pavement surface due to overloading that is more than the design load. Besides that, deterioration of pavements arises from deformation generally associated with cracking under heavy commercial vehicles. The increased traffic loading will then cause failures such as cracks and depressions on the pavement.

2.6.3 Pavement Deterioration

The pavement deterioration over time is caused by a combination of factors however, traffic loads play a key role in consumption of pavement life (Karim Chatti, 2018) Pavement deterioration is the process by which distresses develop in pavement under the combined effects of traffic loading and environment conditions (Zumrawi, 2016). Deterioration of pavement greatly affects serviceability, safety and riding quality of the road. Moreover, road deterioration can be contributed in much way such as excessive load, climates changes, poor drainage and low quality pavement materials. The most common road distress are cracks, potholes, rutting, ravelling, depressions and damaged edges (Sharad.S.Adlinge).

2.6.3.1 Causes of Pavement Deterioration

In Malaysia, there are many causes that lead to road deterioration due to traffic loading and climate change. Below is the common cause that lead to road deterioration :

1. Sudden increase in traffic loading especially on new roads where the design is based on lesser traffic.
2. Provision of poor shoulders lead to edge failures
3. Provision of poor clayey subgrades results in corrugation at the surface and increase in unevenness
4. Poor drainage condition especially during raining season, force the water to enter the pavement from the sides as well as from the top surface.

2.6.4 Heavy traffic impact on pavement deterioration

Pavement deterioration is the process by which distress develop in pavement under the combined effect of traffic loading (Magdi M. E. Zumrawi, 2016). Deterioration of pavement greatly affects serviceability, safety and riding quality of the road. The pavement deterioration over time is caused by a combination of factors however, traffic loads play a key role in consumption of pavement life. Several factors such as traffic, environment, material and design considerations affect the pavement damage over time. Traffic loads play a key role in pavement deterioration. As trucking has become the most popular mode of freight transportation because of its efficiency and convenience it has contributed to most of pavement deterioration. Trucks are the major consumers of the pavement network as they apply the heaviest loads to the pavement surface. Truck loads are transferred to the pavements through various combinations of axle configurations depending on the truck type.

2.7 Type of Road Damage

In general, the road damages can be caused by the water flow, pavement construction materials, climate, unstable soil conditions and poor compaction process on layer above the subgrade (Achmad Wicaksono, 2015). In Malaysia, normally road are designed until ten to fifteen years design life to support load. However, from time to time these roads not able to carry the load with the specified design life especially at industry areas because heavy lorries always using these road to move their goods. Due to this activity, a lot of distress on the flexible pavement and it became uncomfortable approaches to the driver. The common causes of pavement deterioration and degradation are overloading, seepage, improper or poor road surface drainage, lack of proper road maintenance, lack of proper design, adverse climatic conditions and some other factors. In Malaysia there are three common road deterioration which is:

a. Cracking

One of the common types of road damages is cracking. Cracking is a load associated structural failure. The failure can be due to weakness in the surface, base or sub grade, a surface or base that is too thin, poor drainage or the combination of all three. It often starts in the wheel path as longitudinal cracking and ends up as alligator cracking after severe distress. Figure 2.3 below shows type of cracking damages on road surfaces.

Figure 2.3 : Types of cracking damages

b. Pot Holes

Small bowl - shaped depressions in the pavement surface that penetrate all the way through the asphalt layer down to the base course. They generally have sharp edges and vertical sides near the top of the hole. The remaining hole after the pavement chunk is dislodged is called a pothole. Figure 2.4 below show the potholes damages on road surfaces.

Figure 2.4 : Potholes

c. Rutting

Rutting in asphalt pavements are channelized depressions in the wheel-tracks. Rutting results from consolidation or lateral movement of any of the pavement layers or the subgrade under traffic. It is caused by insufficient pavement thickness, lack of compaction of the asphalt, stone base or soil, weak asphalt mixes or moisture infiltration. Figure 2.5 show rutting on pavement surface.

Figure 2.5 : Rutting

2.8 Capacity Analysis

Highway Capacity Manual (HCM 2010) define capacity analysis as a set of procedures for estimating the traffic carrying ability of facilities over a range of defined operational conditions which it provides tools to assess facilities and to plan and design improved facilities. A principal objective of capacity analysis is to estimate the maximum number of persons or vehicles that a facility can be accommodate with reasonable safety during a specific time period. However facilities generally operate poorly at or near capacity they are rarely planned to operate in this range. Accordingly, capacity analysis also estimates the maximum amount of traffic that a facility can accommodate while maintaining its prescribed level of operation.

In another words capacity is the maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions. Moreover, capacity also can be depends on traffic condition and geometric design. In addition, the capacity is a probabilistic measure and it varies with respect to time and position. Hence it is not always possible to completely derive analytically the capacity.

2.9 Levels of Service

A term closely related to capacity and often confused with it is service volume. When capacity gives a quantitative measure of traffic, level of service of LOS tries to give a qualitative measures. Level of service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience.

The intention of LOS is to relate the traffic service quality to a given flow rate of traffic. It is a term that designated a range of operating conditions on a particular type of facility. Highway capacity manual (HCM) developed by the transportation research board of USA provides some procedure to determine the level of services. It divides the quality of traffic into six levels ranging from level A to level F. Figure 2.6 the range of operational condition based on LOS.

LOS	Typical operating conditions
	Roadways
A	Free flowing traffic conditions
B	Still free flowing traffic conditions
C	Traffic flow is still under stable conditions
D	Approaching unstable flow and vehicle movement are constrained by high volume of traffic
E	Unstable flow
F	Congested flow

Figure 2.6 : Definition of LOS, as defined by American HCM

A : Free flow

Traffic flows at or above the posted speed limit and motorists have complete mobility between lanes. The average spacing between vehicles is about 550 ft (167 m) or 27 car lengths. Motorists have a high level of physical and psychological comfort. The effects of incidents or point breakdowns are easily absorbed. LOS A generally occurs late at night in urban areas and frequently in rural areas.

B : Reasonably free flow

LOS A speeds are maintained, manoeuvrability within the traffic stream is slightly restricted. The lowest average vehicle spacing is about 330 ft (100 m) or 16 car lengths. Motorists still have a high level of physical and psychological comfort.

C : Stable flow, at or near free flow

Ability to manoeuvre through lanes is noticeably restricted and lane changes require more driver awareness. Minimum vehicle spacing is about 220 ft (67 m) or 11 car lengths. Most experienced drivers are comfortable, roads remain safely below but efficiently close to capacity, and posted speed is maintained. Minor incidents may still have no effect but localized service will have noticeable effects and traffic delays will form behind the incident. This is the target LOS for some urban and most rural highways.

D : Approaching unstable flow

Speeds slightly decrease as traffic volume slightly increase. Freedom to maneuver within the traffic stream is much more limited and driver comfort levels decrease. Vehicles are spaced about 160 ft (50m) or 8 car lengths. Minor incidents are expected to create delays. Examples are a busy shopping corridor in the middle of a weekday, or a functional urban highway during commuting hours. It is a common goal for urban streets during peak hours, as attaining LOS C would require prohibitive cost and societal impact in bypass roads and lane additions.

E : Unstable flow, operating at capacity

Flow becomes irregular and speed varies rapidly because there are virtually no usable gaps to maneuver in the traffic stream and speeds rarely reach the posted limit. Vehicle spacing is about 6 car lengths, but speeds are still at or above 50 m/h (80 km/h). Any disruption to traffic flow, such as merging ramp traffic or lane changes, will create a shock wave affecting traffic upstream. Any incident will create serious delays. Drivers' level of comfort become poor. This is a common standard in larger urban areas, where some roadway congestion is inevitable.

F : Forced or breakdown flow

Every vehicle moves in lockstep with the vehicle in front of it, with frequent slowing required. Travel time cannot be predicted, with generally more demand than capacity. A road in a constant traffic jam is at this LOS, because LOS is an average or typical service rather than a constant state. For example, a highway might be at LOS D for the AM peak hour, but have traffic consistent with LOS C some days, LOS E or F others, and come to a halt once every few weeks.

2.10 Factors Affecting Capacity and LOS

2.10.1 Base Conditions

Many of the procedures in this manual provide a formula or simple tabular or graphic presentations for a set of specified standard conditions, which must be adjusted to account for prevailing conditions that do not match. The standard conditions so defined are termed base conditions. Base conditions assume good weather, good pavement conditions, users familiar Base conditions defined with the facility, and no impediments to traffic flow. Examples of base conditions for uninterrupted-flow facilities and for intersection approaches are given below. Base conditions for uninterrupted-flow facilities include the following:

- Lane widths of 3.6 m
- Clearance of 1.8 m between the edge of the travel lanes and the nearest obstructions or objects at the roadside and in the median
- Free-flow speed of 100 km/h for multilane highways
- Only passenger cars in the traffic stream (no heavy vehicles)
- Level terrain
- No no-passing zones on two-lane highways
- No impediments to through traffic due to traffic control or turning vehicles.

Base conditions for intersection approaches include the following:

- Lane widths of 3.6 m
- Level grade
- No curb parking on the approaches
- Only passenger cars in the traffic stream
- No local transit buses stopping in the travel lanes
- Intersection located in a non-central business district area
- No pedestrians.

In most capacity analyses, prevailing conditions differ from the base conditions and computations of capacity, service flow rate, and level of service must include adjustments. Prevailing conditions are generally categorized as roadway, traffic, or control.

2.11 Road Condition

Roadway conditions include geometric and other elements. In some cases, these influence the capacity of a road in others word they can affect a performance measure such as speed, but not the capacity or maximum flow rate of the facility. Roadway factors include the following:

- Number of lanes
- The type of facility and its development environment
- Lane widths
- Shoulder widths and lateral clearances
- Design speed
- Horizontal and vertical alignments
- Availability of exclusive turn lanes at intersections

The horizontal and vertical alignment of a highway depend on the design speed and the topography of the land on which it is constructed. In general, the severity of the terrain reduces capacity and service flow rates. This is significant for two-lane rural highways, where the severity of terrain not only can affect the operating capabilities of individual vehicles in the traffic stream, but also can restrict opportunities for passing slow-moving vehicles.

2.12 Traffic Conditions

Traffic conditions that influence capacities and service levels include vehicle type and lane or directional distribution.

2.12.1 Directional and Lane Distribution

- Directional distribution
- Lane distribution

Directional distribution has a dramatic impact on two-lane rural highway operation which achieves optimal conditions when the amount of traffic is about the same in each direction. Capacity analysis for multilane highways focuses on a single direction of flow. Nevertheless, each direction of the facility usually is designed to accommodate the peak flow rate in the peak direction. Typically, morning peak traffic occurs in one direction and evening peak traffic occurs in the opposite direction. Lane distribution also is a factor on multilane facilities. Typically, the shoulder lane carries less traffic than other lanes.

2.12.2 Multilane

In the context of traffic control, a lane is part of a carriageway that is designated for use by a single line of vehicles, to control and guide drivers and reduce traffic conflicts. A highway is a public road especially a major road connecting two or more destinations. A highway with at least two lanes for the exclusive use of traffic in each direction, with no control or partial control of access, but that may have periodic interruptions to flow at signalized intersections not closer than 3.0 km is called as multilane highway. They are typically located in suburban areas leading to central cities or along high-volume rural corridors that connect two cities or important activity centres that generate a considerable number of daily trips.

Multilane highways generally have posted speed limits between 60 km/h and 90 km/h. They usually have four or six lanes, often with physical medians or two-way right turn lanes (TWRTL), although they may also be undivided. The traffic volumes generally varies from 15,000 - 40,000 vehicles per day. It may also go up to 100,000 vehicles per day with grade separations and no cross median access. Furthermore this multilane can be categorized into tow which is divided and undivided multilane. Figure 2.7 and Figure 2.8 below show the condition of the multilane.

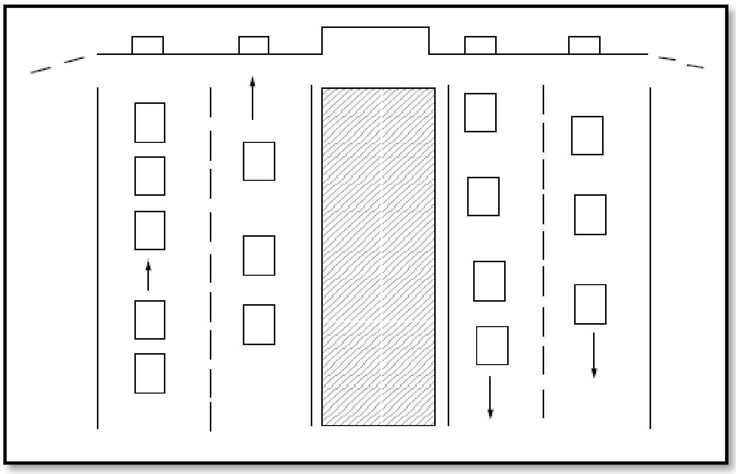


Figure 2.7 : Divided multilane

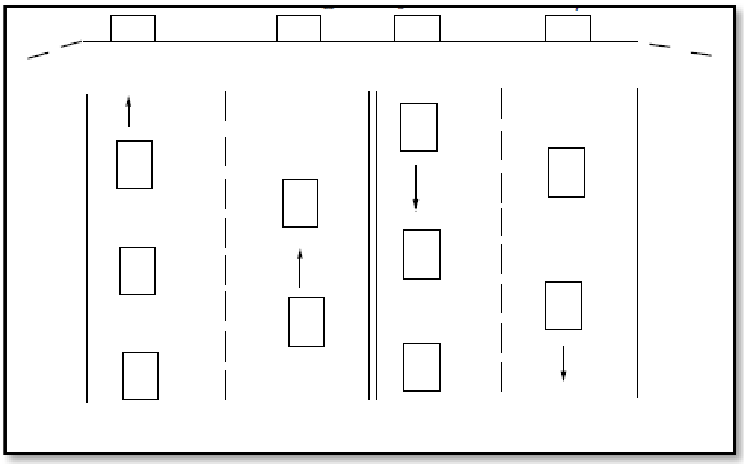


Figure 2.8: Undivided multilane

2.12.3 Vehicle Type

In addition to the distribution of vehicle types to other traffic characteristics affect capacity, service flow rates, and level of service. The entry of heavy vehicles that is vehicles other than passenger cars into the traffic stream affects the number of vehicles that can be served. Heavy vehicles are vehicles that have more than four tires touching the pavement. Trucks, buses, and recreational vehicles (RVs) are the three groups of heavy vehicles addressed by the methods in this manual. Heavy vehicles adversely affect traffic in two ways:

- They are larger than passenger cars and occupy more roadway space
- They have poorer operating capabilities than passenger cars, particularly with respect to acceleration, deceleration, and the ability to maintain speed on upgrades.

Heavy vehicles also can affect downgrade operations, particularly when downgrades are steep enough to require operation in a low gear. In these cases, heavy vehicles must operate at speeds slower than passenger cars, forming gaps in the traffic stream. Trucks cover a wide range of vehicles, from lightly loaded vans and panel trucks to the most heavily loaded coal, timber, and gravel haulers. An individual truck's operational characteristics vary based on the weight of its load and its engine performance. Table 2.1 0 below show the vehicles class in Malaysia.

Table 2.1 : Vehicles class

Class	Type of Car
C1	Car, Taxi
C2	Small Van, Medium Lorry
C3	Heavy Lorry
C4	Bus
C5	Motorcycle

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

In this chapter, the case study will focus on the effective methods to get more detailed information. Through this chapter, it will develop a better understanding about the research in detail, particularly how research is conducted and the information that will be discussed. In a research, the important thing is a process and how the way to interpret the correct data so that the research will do smoothly and the information provided are true and have their evidence. In general, there are two methods of carrying out the research which is qualitative methods and quantitative methods but there is some research that carries both methods. In this research, the author uses qualitative methods in which the authors work on site by planting the devices to get data. The data is very useful to the study to gain more information. This chapter will discuss briefly about the methodology that has been used in this study. It will also describe the locations of case study data collection, the equipment used, the equations used, the statistical and mathematical analysis and the Highway Standard.

3.2 Chart Review Methodology

In this study, the first step is to provide a flow chart of the study as shown in Figure 3.1 for the implementation of the study. This study will be begin which the related research has been studied to find the scope of case study which is relate with this topic. After that the location of this case study is determined. The next process is by doing the site observation on road condition and obtaining the data from metro-count which is needed to accomplished this study. Results of observation data gathered and analysed**.**

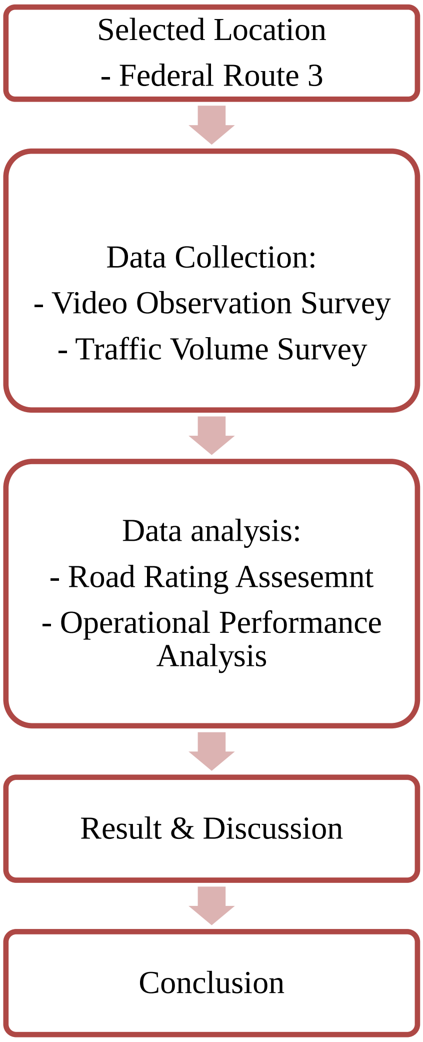


Figure 3.1 : Flow Chart Methodology

3.3 Site Location

In this study, the following criteria were applied in the site selection process:

i. This location has been chosen because it is significance as major road that used for mineral freight distribution heading to Kuantan Port
ii. The location selected is Kuantan Bypass Federal Route 3 (AH18) is a main highway bypass
iii. The selected site is on a multilane divided highway
iv. The specified location for this study is 3 km for Station 1and 3 km for Station 2.
v. Road defect inspection is done where the pavement is examined by eye, and the distress quantities will be measured by hand manually

3.4 Study Site

This study will be conducted at Kuantan Bypass Federal Route 3 (AH18) Kuantan, Pahang. The length of road for this study will be 3 km for Station 1 and 3 km for Station 2 for road defect inspection. This location can be representing the damaged due to vehicles distribution activity. For traffic volume analysis the site location choose for installation of metro count is at Station 1 and Station 2 which it will be represent the condition of road before and after mineral freight distribution activity. This research used quantitative methods for data collection in the field.

3.5 Data Collection

To obtain the data collection needed for this study is based on the objective. Based on the first objective, the data will be gain using visual observation survey which is video recorded and site observation. For objective two, the data will have obtained by using a metro-count to analyses the performance of existing level of service multilane highways when being generated by the heavy vehicles operation.

3.6 Site Observation

To achieving objective one, video recorded and site observation will be done in order to determine the road deterioration at study area. From the observation the data of road pavement damaged that occurs on Federal Route 3 will be categorized based on three categorized which is cracking, rutting and potholes. The data will be taken at Station 1 and Station 2. There will be 3 km road selected for both station which 3 km road will divided to 1 km section with 5 segment of 200 meter. By using site observation, the pavement will be examined by eye and the distress will be measured by hand manually. Figure 3.2 below show the illustration location and how procedure will be done for data taken.

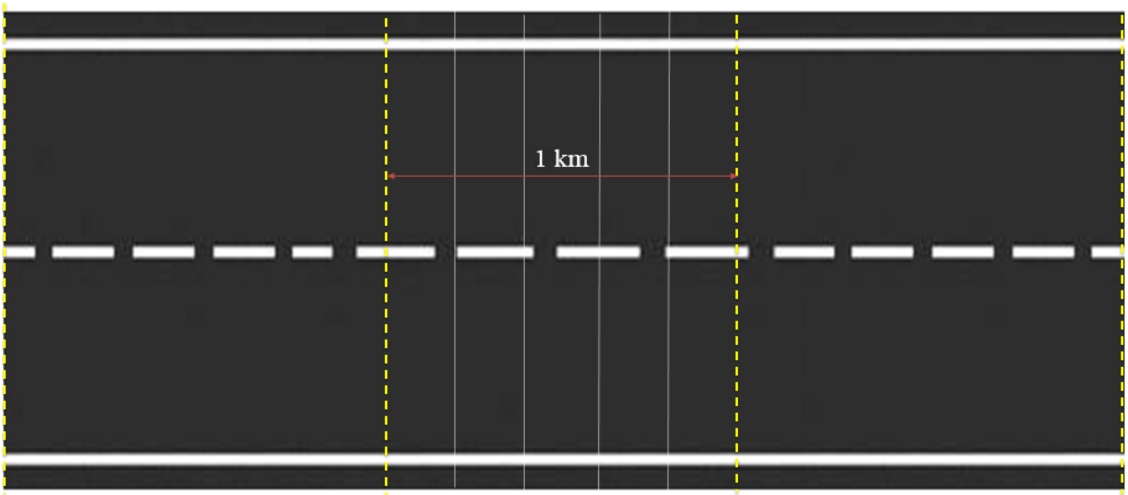


Figure 3.2 : Procedure done for data taking

The location of study will be 3 km at Station 1 and 3 km at Station 2. The pavement condition will be examined by eye and the road deterioration will be measured by using hand manually. For 3 km road, each 3 km will be divided to 3 section and in 1 km section will be contain 5 segments which its refer to 200 m for each segments.

For site observation, the apparatus used to accomplish this study is road defect table, measuring tape, trumeter and straight edge. In road defect table the data taken will be based on 1 km road with 5 segment of 200 m. In 200 m segment along the road, the road deterioration will be focusing at crucial area that consists of most higher percentage damages. Then the damages will be measured by using measuring tape and trumeter for it accuracy. Table 3.1 below show the table used for road defect analysis.

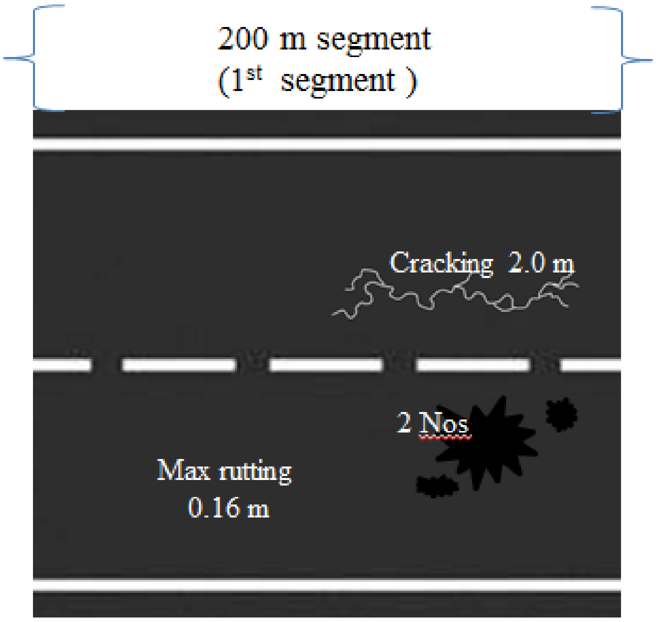
Table 3.1 : Road defect table

Section (KM)		Percent Crack (m)			**MARKS**	Maximum Indentation Rutting (m)			**MARKS**	Number of potholes			**MARKS**	**TOTAL MARKS**	**REMARKS**
Start	Finish	< 50	50 to 150	>150		<0.012	0.012-0.025	>0.025		0	1	> 1			
0.000	0.200														
0.200	0.400														
0.400	0.600														
0.600	0.800														
0.800	1.000														

The disability level of the road will then be classified in three stages which is low, medium and high based on the data obtain. After that, each of the disability level will be marks depend on the marks shows in Table 3.2. Figure 3.3 below show the example on how the calculation for road disability level will be conducted based on the value obtain from manual observation.

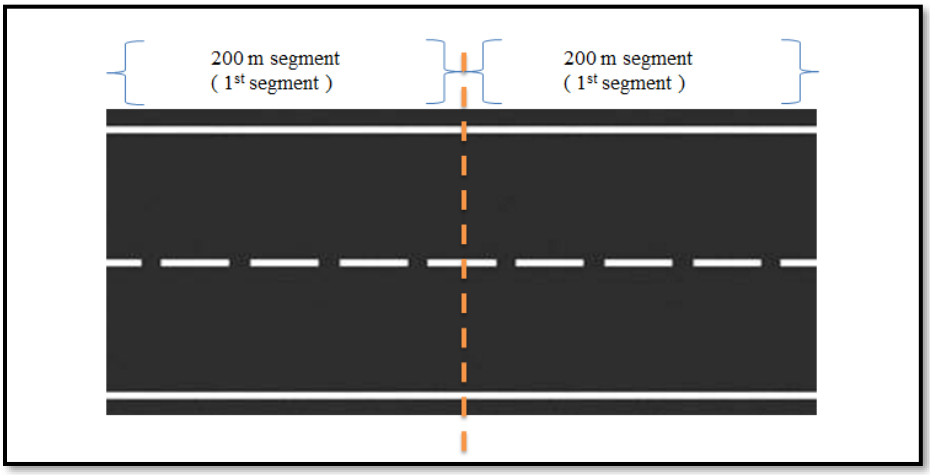
Table 3.2 : Marks for road disability level

Type of road defect	Mark for disability level		
	Low	Medium	High
Cracking (m)	< 50	50 -150	> 150
Rutting (m)	< 0.012	0.012 – 0.025	> 150
Potholes	0	1	> 1
MARKS	1	2	3



Damages	Damage measure	Marks
Cracking	2.0 m	1
Rutting	0.16 m	1
Potholes	2 Nos	1
Total Marks		3
Rating		A

Then by referring to the marks for each road segment, the classification of road damages will be determined by using road rating formula. After obtaining the averages marks for road rating, the road rating condition will be determined by using Table 3.3 either it very satisfying, satisfying and less satisfying.. Figure 3.3 below show the example of road rating calculation that will be used in this study.



$$\text{Road Rating} = \frac{Mark\ at\ 1st\ segment + Marks\ at\ 2nd\ segment}{Total\ segment}$$

Figure 3.3 : Road Rating Calculation

Table 3.3 : Road Condition Rating

Marks	Rating	Remarks
< = 3.00	Very Satisfying	A
3.00 – 6.00	Satisfying	B
> 6.00	Less Satisfying	C

3.7 Traffic Analysis

To achieving objective two, the traffic volume study will be conducted to determined free flow and flow rate of existing road. The location of this study that has been chosen will be the landmarks of before and after mineral freight distribution activity. There will be two places chosen for this study which is Sultan Haji Ahmad Shah Agricultural Park (Station 1) and Kuantan Port (Station 2). The location of Sultan Haji Ahmad Shah Agricultural Park after Kuantan Exit will be assumed as before mineral activity while the location of Kuantan Port will be assumed as after mineral freight distribution activity. The reason of this chosen is because to predict the traffic volume generated before and after mineral route if the mineral activity is still active.

3.8 Level of Services (LOS)

The parameter of data collection for level of services is a free slow speed and flow rate. The method to get data for free flow speed, speed, flow, headway, volume and density is observed using metro-count. Free flow speed is the theoretical speed of traffic density, when density approaches zero. It is the speed at which drivers feel comfortable travelling under the physical, environmental and traffic conditions existing on an uncongested section of multilane highway.

3.8.1 Determination of free flow speed

In this study free flow speed study will determined by performing traffic density studies during morning peak hours which started at 7.00 am until 10.00am for three days. This study will be done by installing metro – count at study area. The observation will be done for 3 hours continuously. The free-flow speed can be estimated indirectly as follows :

$$FFS = BFFS - fLW - fLC - fM - fA$$

where, FFS is the estimated FFS (km/h), BFFS= base FFS (km/h), fLW = adjustment for lane width Table 3.4 (km/h) , fLC= adjustment for lateral clearance from Table 3.5 (km/h), fM=adjustment of median Table 3.6, fA=adjustment of asses point Table 3.7.

Table 3.4 : Adjustment for lane width

Lane Width	Reduction in FFS (km/h)
3.6	0.0
3.5	1.0
3.4	2.1
3.3	3.1
3.2	5.6
3.1	8.1
3.0	10.6

Table 3.5 : Adjustment of lateral clearance

Four Lane Highway		Six Lane Highway	
Total Lateral Clearance (m)	Reduction in FFS (km/h)	Total Lateral Clearance (m)	Reduction in FFS (km/h)
3.6	0.0	3.6	0.0
3.0	0.6	3.9	0.6
2.4	1.5	2.4	1.5
1.8	2.1	1.8	2.1
1.2	3.0	1.2	2.7
0.6	5.8	0.8	4.5
0.0	8.7	0.0	6.3

Table 3.6 : Adjustment of median

Median Type	Reduction in Free flow speed
Undivided Highway	2.6
Divided Highway	0.0

Table 3.7 : Adjustment of assess point

Access Point per kilometre	Reduction in free flow speed (km/h).
0	0.0
6	4.0
12	8.0
18	12.0
>24	16.0

3.8.2 Determination of Flow Rate

The next step in the determination of the LOS is the computation of the peak hour factor. The fifteen minute passenger-car equivalent flow rate (pc/h/ln), is determined by using following formula:

$$Vp = \frac{V}{PHF\ X\ H\ X\ fHV\ x\ fp}$$

Where, vp is the 15-min passenger-car equivalent flow rate (pc/h/ln), V is the hourly volume (veh/h), PHF is the peak-hour factor, N is the number of lanes, fHV is the heavy-vehicle adjustment factor, and fp is the driver population factor. PHF represents the variation in traffic flow within an hour. Observations of traffic flow consistently indicate that the flow rates found in the peak 15-min period within an hour are not sustained throughout the entire hour. The PHFs for multilane highways have been observed to be in the range of 0.75 to 0.95. To accomplish this study the heavy vehicles factor (fHV)will be adjusted to reflect an equivalent flow rate in passenger cars per hour per lane (pc/h/ln) **Table 3.8** below show the table of passenger car equivalent on general highway segment (Sources : HCM,2000)

$$\mathbf{fHV} = \frac{\mathbf{1}}{\mathbf{1+PT(ET-1)+PR\ (ER-1)}}$$

Table 3.8 : Passenger car equivalent on general highway segment

Factor	Type of terrain		
	Level	Rolling	Mountainous
ET (Trucks and Buses)	1.5	2.5	4.5
ER (RVs)	1.2	2.0	4.0

3.8.3 Determination of Density

The third step to determine LOS is by computing density flow. Density flow can be computed as:

$$\mathbf{D} = \frac{\mathbf{VP}}{\mathbf{S}}$$

Where, D is the density (pc/km/In), *vp* is the flow rate (pc/km/In), and *S* is the average age passenger-car travel speed (km/h). The level of service then will be determined by using Speed Flow Curve with criteria of LOS.

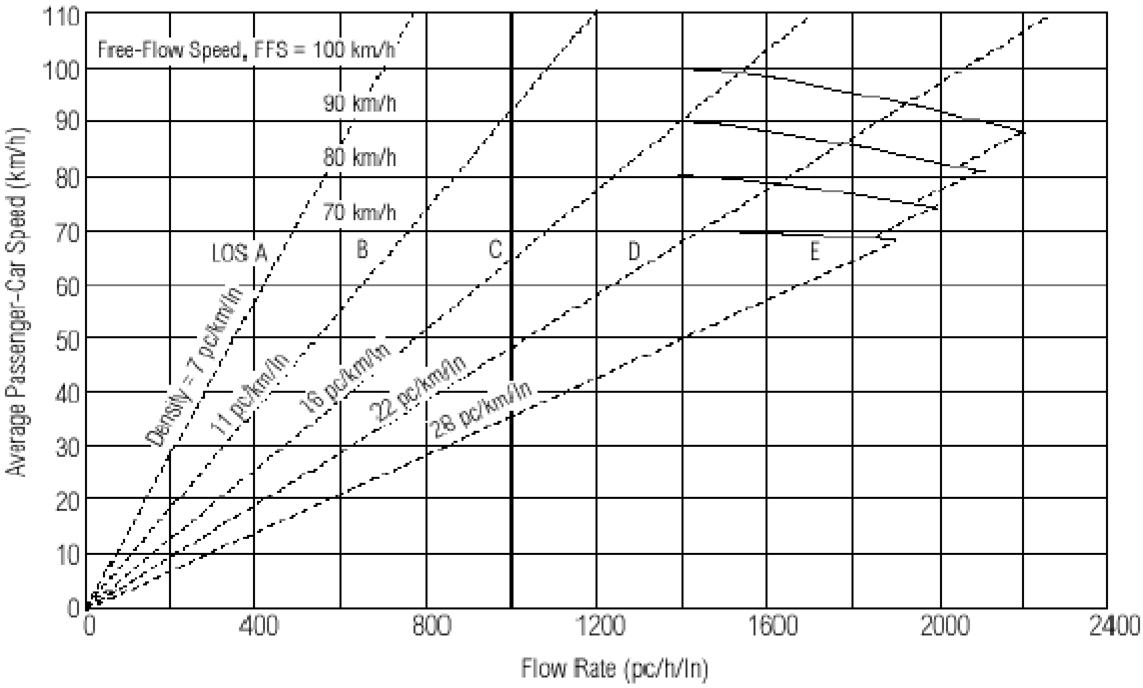


Figure 3.4 : HCM 2010 Basic Freeway Segments Speed-Flow Curve (National Research Council .Transportation Research, 2010

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter was discussed about the results that had acquired from the observation conducted to get the necessary data. Traffic composition were counted automatically during peak hour by using metro count and site observation. The collected data from metro count will provide the traffic composition, speed, flow and volume. For the road defect study, the video camera and site observation was used to determine type of disability level of road defect. The road defect study was performed by observing the road pavement condition 3 km at Station 1 and 3 km at Station 2 along Federal Route 3.

The analysis was conducted to view the real situation for the problem that occurs at Federal Route 3 due to heavy vehicles transportation. From the early observation that has been done, Federal Route 3 was identified as one of the critical road that has been used to go to Kuantan Port. The performance of this Federal Route 3 was analysed in terms of traffic volume and road defect. From the analysis that has been done, the performance of this Federal Route 3 can be identified either it is good or worst. Then, the recommendation was proposed to improve the performance of Federal Route 3. Therefore, the workability of Federal Route 3 can be improving in order to generated more traffic and reduce road defect.

4.2 Description of Study Area

The study areas from two places are considered in such a fashion that the road network give the required input data for analysing road defect. Federal Route 3 (AH18) with multilane lane is considered in the present study. This is because Federal Route 3 (AH18) is the main route used to heading to Kuantan Port. In this study, Federal Route 3 (AH18) is been consider as study area, for road defect analysis where it was a starting point where manual observation is taking part. The analysis of road defect will be based on method that has been stated in previous chapter. Each kilometre road will be interpreted based on disability road level and road rating level.

Two study area chosen for this study is in front of Sultan Haji Ahmad Shah Agricultural Park as (Station 1) and Kuantan Port as (Station 2). The reason of this site selection is to consider another interaction of mineral activities from other places such as Sungai Lembing and RTP Bukit Goh which it near to Kuantan Exit. Moreover, another reason of this selection is because the scattered location of logistic area and mineral transportation. As the rapid increase of industry activity at Kuantan Port this selection site will be considers as dominant heavy vehicles distribution activity.

In this study, the selection of road is determined along Federal Route 3 as study area to collect all data needed for the road defect analysis. The length of road for this study will be 3 km at Station 1 and 3 km at Station 2 for road defect inspection. This location selected is to represent the damaged of pavement due to heavy vehicles activity that link to east coast region and link to port. The Federal Route 3 (AH18) is selected based on the reasons that it was a crucial road used to heading to Kuantan Port. In this study Federal Route 3 will be consider as a study area for road defect analysis. The view of selection site chosen at Station 1 and Station 2 for data collection is shown in Figure 4.1 and Figure 4.2.

.

Figure 4.1 : Station 1

Figure 4.2 : Station 2

Along this Federal Route 3, the location of Station 1 and Station 2 study area was chosen. The Station 1 area for this study is in front of Sultan Haji Ahmad Shah Agricultural Park as shown in Figure 4.1 and the second study area is at Kuantan Port as shown in Figure 4.2. For Station 1 area, it is selected due to its position that near to Kuantan Exit and link to east coast region. The reason of this selection is because of another upcoming lorry from another industry location that transporting needs to Kuantan Port. Moreover, another reason of this site selection is because it's a main road that serve as service road, serving industrial, education institution and consist large residential communities. As for the second location, it is chosen because it was a main collect point for logistics activities in Kuantan. Furthermore, this site location is chosen because it more focused on logistic and domestic activities compared to Station 1. Both of this area is chosen in order to evaluate the Level of Service of the facilities to accommodate traffic demands of heavy vehicles for both present and future conditions.

4.3 Data Analysis on Road Deterioration

The rapid increases of the mineral industry are concern due to its significant effects to traffic conditions. Subsequently, the uncontrolled heavy vehicles activities have affected traffic performance on the road accordingly. These roads are located in the regular road that used to head to Kuantan Port. Because of this, the route of heavy vehicles activity and traffic should not be neglected. Due to this problem, the analysis will be used to determine road rating level either its satisfying to use or not.

For manual observation analysis, there will be 3 km road consider as stated in previous chapter for Station 1 and Station 2. Station 1 result will represent condition of road that link to east coast region and Station 2 result will used to represent condition of road that link to port. The interpretation of this result will based on disability level and road rating condition. The road defect analysis will be calculated based on each 1 km road segment with five road segment with 200 m as stated in previous chapter.

For each 1 km road, the illustration of road with defect is provided for clear understanding. Based on the illustration the road selection will be showing the defect occur on the road surface. As the asphalt road is exposed to many distresses due to the high stress of axle loading, the pavement has causes cracks, potholes and rutting. Due to heavy vehicles activity these defect causes a lot of problems for many road users such as discomfort and the road will not be safe. For each 200 m segment, the analysis obtain from manual observation will be interpret in the table based on the disability level and road condition rating.

Stretch of road at Station 1 is study as stated in previous chapter. As been show in Figure 4.3 below in 1 km road analysis for Station 1 based on the illustration of road condition the highest cracking that occurring along 1 km road is 113.0 m with 1 nos of potholes. During first segment of 200 m none of road damages occur.

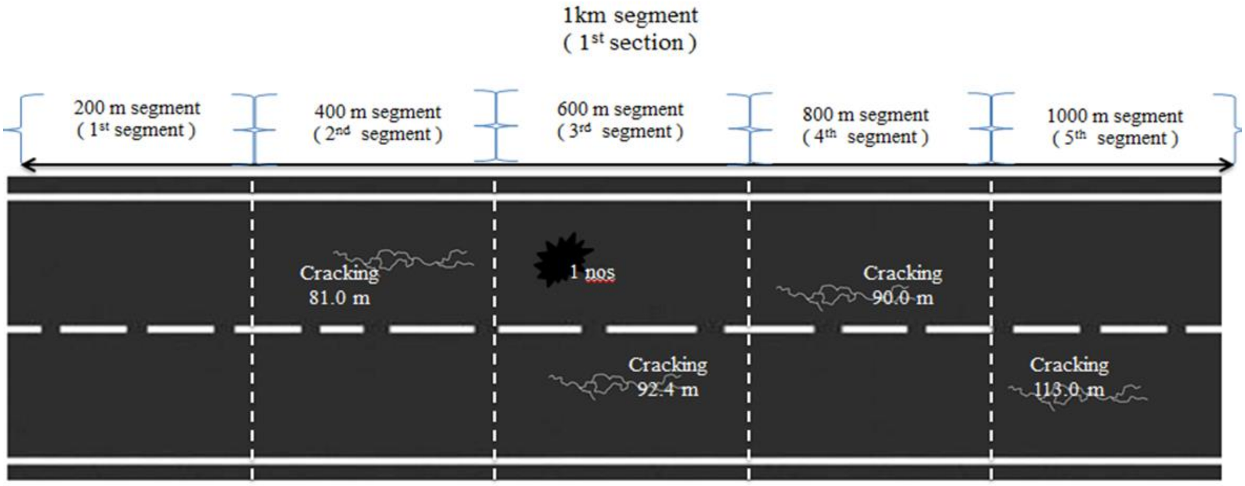


Figure 4.3 : 1 km road defect

In Figure 4.4 below, based on the illustration of road condition the lowest cracking value that occurring along 1 km road is not more that 10 m at second and fourth segment which is 2.0 m and 6.0 m respectively for second 1km in Station 1 . During first and fifth segment none of road damages occur.

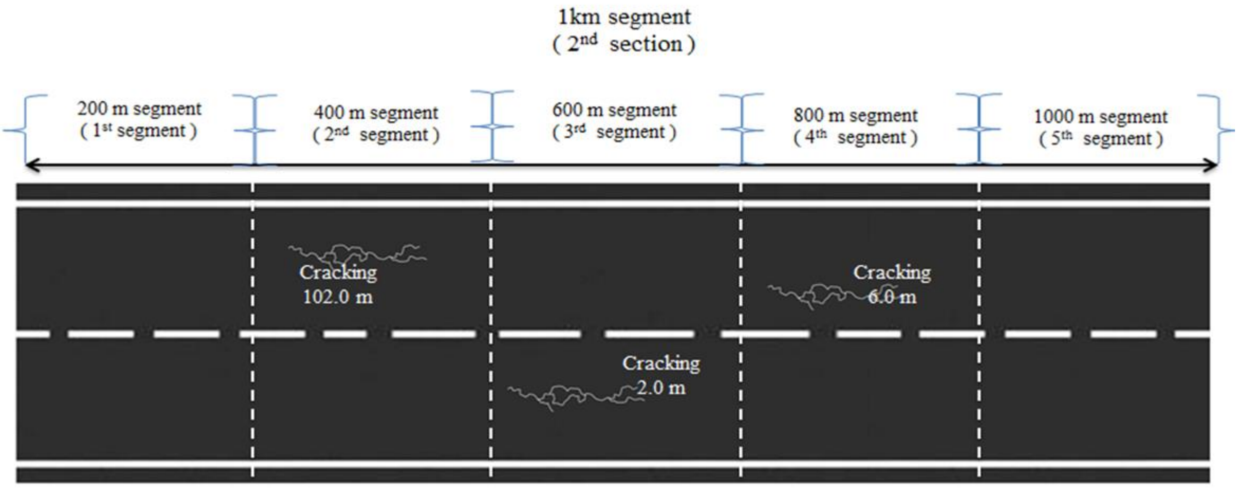


Figure 4.4: 1 km road defect

While for third 1 km at Station 1 as show in Figure 4.5 below, based on the illustration of road condition the lowest cracking value that occuring along 1 km road is 2.0 m and the highest cracking occur is 24.0 m. In this segments it show that the highest nos of potholes occur is 4 nos at fifth segment.

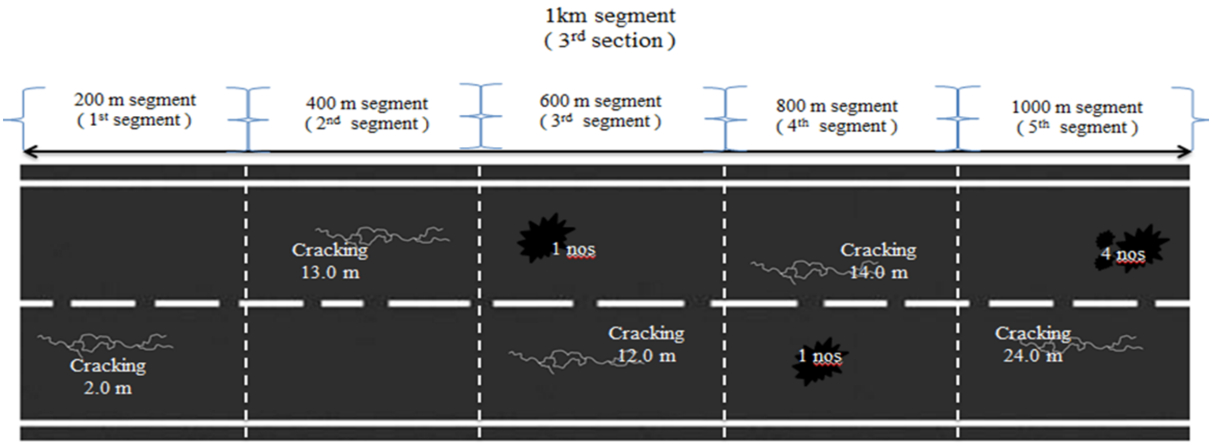


Figure 4.5 : 1 km road defect

Average for 3 km road defect for Station 1

Road Rating

$$= \frac{1 + 3 + 4 + 3 + 3 + 1 + 3 + 2 + 2 + 3 + 2 + 3 + 2 + 2 + 4}{15}$$

= 2.5 (Rating A : Very Satisfying)

As show in road rating calculation above, the avearge result form road rating obtain is 2.5 with A rating which is very satisfying. From the result obtain, we can conclude that the defect occur at Station 1 is less. Moreover, as we can see in the illustration provided, most of the cracking occurs less than 150 m and the number of maximum potholes occur only with 4 nos of potholes. From the result obtain, we can see that the pavement is in the good condition for road user. Other than that, based on this analysis, the transportation of lorry without mineral and comparing with daily streams does not affecting the workability of road.

As for Station 2, a strecth of raod is show in Figure 4.6 below. As we can see from the figure the highest cracking occur along 1 km road for three segments is more that 150 m and the maximum cracking is 200 m along the fitht segments. Along this segments, the highest potholes occuring is 20 nos of potholes.

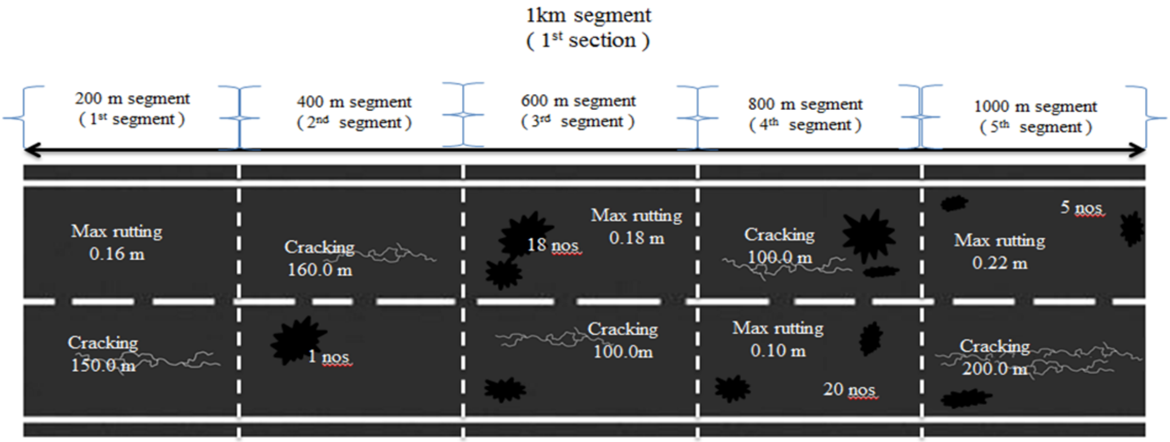


Figure 4.6 : 1 km road defect

While for second stretch of road at Station 2 as shown in Figure 4.7 below, we can see that lowest cracking occur along the segments is 2.0 m and the highest cracking occur is 200.0 m. Other than that, the maximum potholes occuring along the road is at the fifth segment with 7 nos of pothole and 0.40 m maximum rutting.

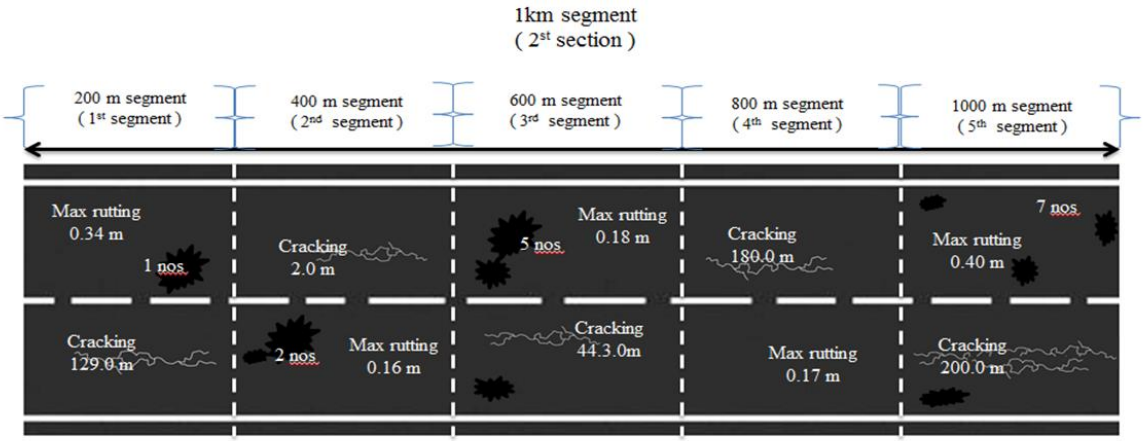


Figure 4.7 : 1 km road defect

Lastly for the third strech as road at Station 2 as shown in Figure 4.8 below, based on the illustration of road condition the highest cracking occur along 1 km road is 200.0 m, 0.42 m for rutting and 6 nos of pothloes at first road segments. While the lowest cracking and potholes occur is at fourth segments which is 40.0 m and 2 nos of potholes.

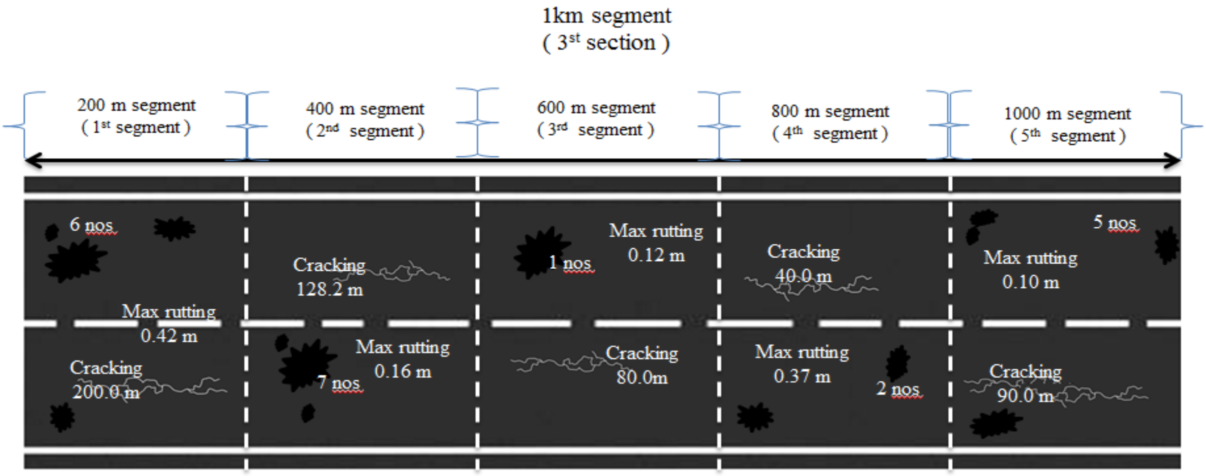


Figure 4.8 : 1 km road defect

Average for 3 km road defect for Station 2

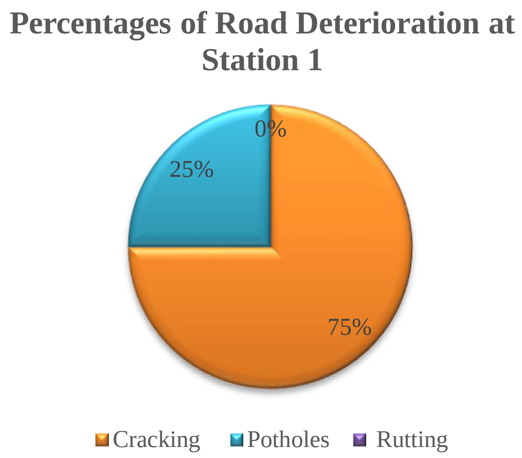
Road Rating

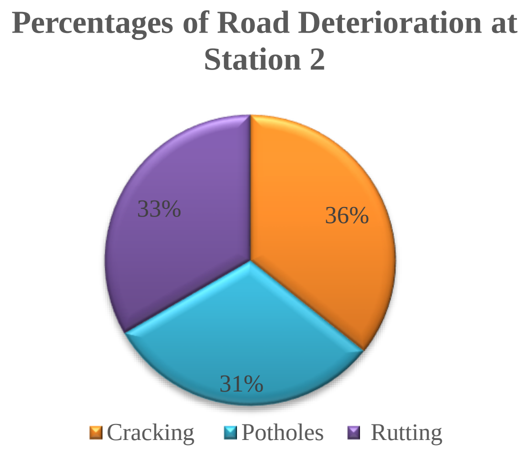
$$= \frac{5 + 5 + 7 + 6 + 7 + 7 + 6 + 6 + 6 + 9 + 9 + 7 + 5 + 6 + 6}{15}$$

= 6.45 (Rating C : Less Satisfying)

As show in road rating calculation above, the avearge result form road rating obtain is 6.45 with C rating which is less satisfying. From the result obtain, we can see that the defect occur due to mineral transportation and daily traffic is very high. The most significant road defect observed is cracking, potholes and rutting. Moreover, as we can see in the illustration provided, most of the cracking occurs is maximum 200 m in road segment and the number of maximum potholes occur is 20 nos of potholes. Other than that, one of the defect causes by heavy traffic on the road is deformation of pavement surfaces due to overloading vehicles plus with daily traffic activities.

4.3.1 Precentages Result Of Road Defect





Types of Damages	Frequency	Percentages %
Cracking	12	75
Potholes	4	25
Rutting	0	0

Types of Damages	Frequency	Percentages %
Cracking	15	36
Potholes	13	31
Rutting	14	33

As we can from the graph above, it show the percentages result of road defect for both Station 1 and Station 2. From the table, we can see that the percentages of damage frequency is higher at Station 2 compared to Station 1. From the table, the potholes frequency happened at Station 2 is 13 while 4 at Station 1. Meanwhile for rutting frequency, it show that 14 frequency for Station 2 while none for Station 1.

As main highway bypass, Federal Route 3 has to accommodating daily traffic expanses to meet the needs and activities of surrounding communities. Due to this in - flight activity and overload traffic from overpassed, road surfaces along Federal Route 3 has undergone many changes. One of the reasons due to this problem is the increases of vehicles. Along Federal Route 3 (AH18) the most common types defect occur is alligator crack, longitudinal crack, edge crack and block crack. It happens because of the repeated traffic loading movement. Cracking is where the damages occur in the surfaces layer of the road.

Based on this study analysis, most of the frequency cracking that been seen in the study location is alligator cracking, longitudinal cracking and edge damages and block cracking. Cracking can be integrated because the soil road base is not good paving material, which exceeds the load capacity of road traffic. In general, the location of occurrence of cracking is not extensive. Based on the Figure 4.9 below, it show the road defect due to cracking. The main cause of this crack is due to stress. Other than that, this crack also occur due to the weakness of the base lack of lateral support and heavy vehicles.

Figure 4.9 : Cracking

Other than cracking, rutting also is one of the road deterioration factors. Based on the manual observation that has been done, rutting usually occur near to the patching area and at the edge of the road. Based on the Figure 4.10 below, it show the road defect because of the rutting. Based on the manual observation that has been done, rutting usually occur near to the patching area and at the edge of the road.

Figure 4.10 : Rutting

Numerous potholes also occur along this Federal Route 3. Generally, potholes are the end result of cracking (Rafeeq Ameen Kattiparuti, 2017). As alligator cracking becomes severe, the interconnected cracks create small chunks of pavement, which can be dislodged as vehicles drive over them. Moreover, along the road also consist a lot of crack seal and patching. Based on the Figure 4.11 below, it show the road defect due to potholes. For this study the size of potholes that been considering is 200 mm to 1000 mm (L) depth > 25 mm.

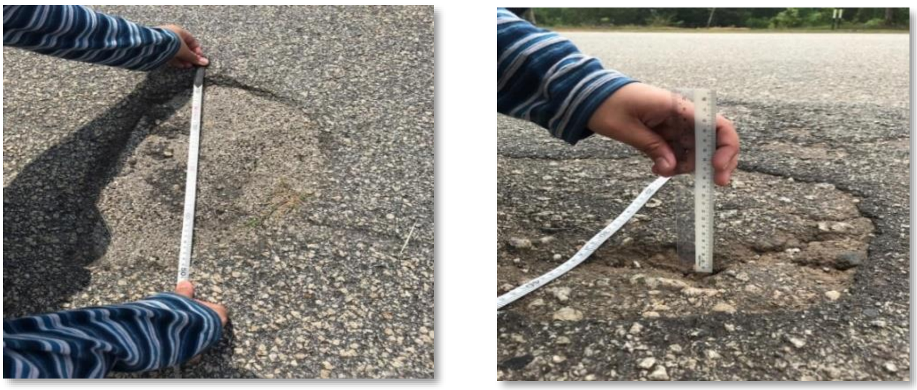


Figure 4.11 : Potholes

4.5 Operational Performance analysis for multilane used in term of Level of Service (LOS)

4.5.1 Traffic Characteristics

The transport of heavy vehicles from the field to the port is an important step in the overall operation of heavy vehicles distribution. In this study, the traffic characteristics along Federal Route 3 were observed such as the number of lane, speed limit, volume, density and flow. The equipment was used in this study are metro count. The speed limit for the free flow speed at this site as follow the JKR are 90 km/h. From the observation, the free flow speed data are taken after Kuantan Exit at Federal Route 3. The free flow speed for this site shown at Figure 4.12.

Figure 4.12 : Free Flow Speed

The traffic counting was done in peak hour during AM (7.00am – 10.00am) which is 3 hours. The data was collected in three working days which is on Monday, Wednesday and Friday with metro count. In this part, the speed, flow and density was taken using metro count with an interval 15 minutes and five types of vehicles. The types of vehicle as shown in Table 4.4. Then, the data were tabulated and presented by using histogram graph. For Table 4.5 shows the total of traffic volume was collected at each peak hour on Monday, Wednesday and Friday. Based on the table, total traffic volume was presented in Figure 4.16.

Table 4.4 : Type of Vehicle Classes

Class	Type of Car
C1	Car, Taxi
C2	Small Van, Medium Lorry
C3	Heavy Lorry
C4	Bus
C5	Motorcycle

4.5.2 Total of Traffic Flow

Table 4.5 shows the total of traffic flow was collected for three days at peak hour (7.00 am – 10.00 am) for Station 1 and Station 2. Based on the table, the total of traffic flow is 20701 vehicles. The histogram graph for traffic flow was presented in Figure 4.13. From this data observation, the highest traffic flow is on Monday. Figure 4.16 shows the pie chart for types of vehicle classes for three days at peak hour.

Table 4.5 : Traffic Flow for three days

Days	Station 1	Station 2
Monday	6421	816
Wednesday	5159	783
Friday	5819	558

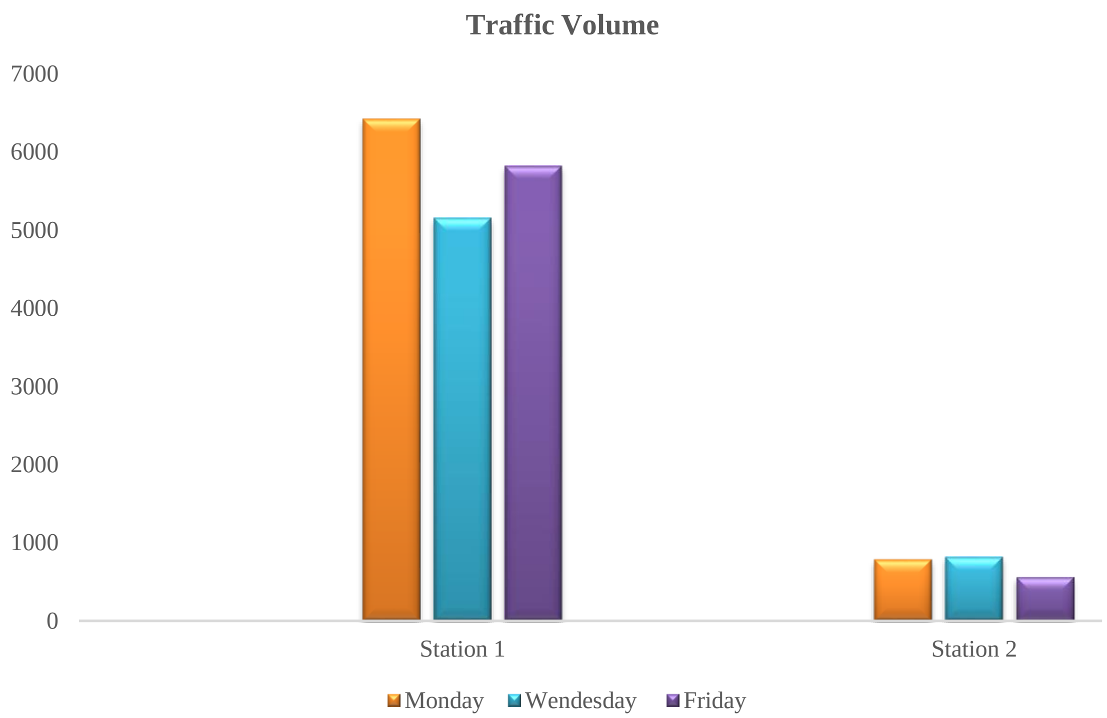


Figure 4.13 : Histogram graph for traffic volume during three days

Table 4.6 : Percentages of vehicles based on class types for three days

Types of Vehicle	Station 1	Station 2
C1	78%	25%
C2	7%	36%
C3	2%	14%
C4	1%	0%
C5	12%	25%

Table 4.6 above, show the total number vehicle at Federal Route 3 (AH18) for three days. Based on Table 4.7 and Table 4.8 below show the traffic composition at Federal Route 3 from two study area.

Traffic Composition at Sultan Haji Ahmad Shah Agricultural Park (Station 1)						
Time	Class 1	Class 2	Class 3	Class 4	Class 5	Total
7.00 - 7.15	536	40	5	6	77	664
7.15 - 7.30	510	32	0	6	85	633
7.30 - 7.45	511	21	5	4	94	635
7.45 - 8.00	492	29	4	7	84	616
8.00 - 8.15	428	33	11	10	69	551
8.15 - 8.30	392	33	7	3	70	505
8.30 - 8.45	321	29	8	6	54	418
8.45 - 9.00	294	39	10	7	48	398
9.00 -9.15	279	37	14	5	43	378
9.15 - 9.30	248	37	17	7	38	347
9.30 - 9.45	234	31	8	5	95	373
9.45 - 10.00	232	35	14	9	32	322
TOTAL	4477	396	103	75	789	5840

Table 4.7 : Traffic Composition for Station 1

Traffic Composition at Kuantan Port (Station 2)						
Time	Class 1	Class 2	Class 3	Class 4	Class 5	Total
7.00 - 7.15	34	8	9	0	24	75
7.15 - 7.30	30	8	9	0	18	65
7.30 - 7.45	35	5	10	0	22	72
7.45 - 8.00	28	4	11	1	20	64
8.00 - 8.15	26	20	8	1	19	74
8.15 - 8.30	26	7	11	0	27	71
8.30 - 8.45	22	7	15	0	18	62
8.45 - 9.00	20	2	7	1	19	49
9.00 -9.15	21	2	9	2	16	50
9.15 - 9.30	25	1	10	0	13	49
9.30 - 9.45	25	1	13	0	14	53
9.45 - 10.00	23	1	12	0	14	50
TOTAL	224	315	124	5	224	734

Table 4.8 : Traffic Composition for Station 2

Table above show the result gain for 3 days by using metro-count at Sultan Haji Ahmad Shah Agricultural Park and Kuantan Port. Based on the Table above, we can see that traffic composition for Agricultural Park is higher than Kuantan Port in total which is 5840 and 2487 respectively. It happened because of the traffic activity where

Federal Route 3 is the main road used to heading to Kuantan Port and Semambu which it serves as a service road, serving industrial, educational institutions, large residential communities, domestic activity, logistic activity and port. Figure 4.14 below show the installation of metro count.

Figure 4.14 : Metro – count installation

As the study was conducted for 3 days, data from metro count is analysed by using Microsoft Excel to determine the maximum volume of vehicle. In this part, the maximum volume of vehicle from two study area was used in determination of Level of Services. Table 4.9 below show the maximum volume of vehicle for Agricultural Park while Table 4.10 below show the maximum volume of vehicle for Kuantan Port for 1 hour. The calculation of Level of Services then will be calculated for present condition and the projected 5% increment of vehicles will be calculated to predict the future conditions of road in 2020.

Table 4.9 : Existing volume for Station 1

Traffic Composition at Sultan Haji Ahmad Shah Agricultural Park (Station 1)						
Time	Class 1	Class 2	Class 3	Class 4	Class 5	Total
7.00 - 7.15	536	40	5	6	77	664
7.15 - 7.30	510	32	0	6	85	633
7.30 - 7.45	511	21	5	4	94	635
7.45 - 8.00	492	29	4	7	84	616
Total	2049	122	14	23	340	2548

Table 4.10 : Maximum volume for Station 2

Traffic Composition at Kuantan Port (Station 2)						
Time	Class 1	Class 2	Class 3	Class 4	Class 5	Total
7.00 - 7.15	34	8	9	0	24	75
7.15 - 7.30	30	8	9	0	18	65
7.30 - 7.45	35	5	10	0	22	72
7.45 - 8.00	28	4	11	1	20	64
Total	127	25	39	1	84	276

4.6 Free Flow Speed

In this study free flow speed study is determine by performing traffic density studies during morning peak hours which started at 7.00 am until 10.00am for three days. The observation will be done for 3 hours continuously. For free flow speed, the formula used is based on the Figure 4.15 below.

$$FFS = BFFS - fLW - fLC - fM - fA$$

Figure 4.15: Free flow speed formula (Source Highway Capacity Manual 2010)

For this study FFS that will be used is based on JKR which is 90 km/h for designated road (Source JKR). The lane width for Federal Route 3 (AH18) is 3.6 m and the lateral clearance is 1.8 m. As the lane width is 3.6 m, the reduction in FFS will be 0.0 km/h. As the lane width is 1.8 m, the adjustment of lane width for four lane highway is 0.0 (km/h), adjustment for median for divided highway will be 0.0 and the adjustment of interchange will be 16.0 as the access point is more than 25 per kilometre along study area. The calculation of free flow spends is show as below:

FFS = BFFS − fLW − fLC − fM – fA

FFS = 90 – 0.0 – 0.0 – 0.0 – 16.0

= 74 km/hr

4.7 Flow Rate and Density

The next step in determined the LOS is computation of the peak hour factor. The fifteen-minute passenger car equivalent flow rate (pc/h/In) is determine by using formula below. The flow rate will be calculated for two study area which is Agricultural Park and Kuantan Port. As the type of terrain at study area is level, the value for ET will be 1.5 and the driver population factor will be 1.0 for all regular commuters.

$$Vp = \frac{V}{PHF\ x\ N\ x\ fHV\ x\ fdp}$$

Figure 4.16: Flow rate formula (Source Highway Capacity Manual 2010)

fHV $= \frac{1}{1+PT(ET-1)+PR\ (ER-1)}$

$$= \frac{1}{1+0.1\ (1.5-1)+0}$$

= 0.95

Flow rate and density will be calculated as show in formula above. The calculation will be made based on two places chosen which is Station 1 and Station 2. The value obtain from flow rate then will be used to calculated density. Then the result from density calculation will be used to determine Level of Services for present condition 2018.

As show in Table 4.10 the result obtains from present conditions 2018. Form the calculation the peak hour value for Station 1 is 2.24 while the value of peak hour factor for Station 2 is 2.4. From this peak hour value, the flow rate can be determined. By using flow rate formula, the value gain for Station 1 is 1396 pc/hr/ln and for Station 2 is 157 pc/hr/ln. Then density for two roads will be determined by using density formula. As we can see form the calculation above, the value for Station 1 and Station 2 will be 19 and 2 respectively. Then the value obtain from density calculation will be used in Speed Flow curves with LOS criteria. From the graph, the LOS for Station 1 is LOS D and the LOS for Station 2 is LOS A.

Sultan Haji Ahmad Shah Agricultural Park (Station 1)	Kuantan Port (Station 2)
PHF $= \frac{\text{V}}{\text{4 x Vmin 15}}$	PHF $= \frac{\text{V}}{\text{4 x Vmin 15}}$
$= \frac{2548}{4 \text{ x } 664}$	$= \frac{276}{4\ x\ 75}$
= 0.96	= 0.92
Vp $= \frac{\text{V}}{\text{PHF x N x fHV x fdp}}$	Vp $= \frac{\text{V}}{\text{PHF x N x fHV x fdp}}$
$= \frac{2548}{0.96 \text{ x } 2 \text{ x } 0.95 \text{ x } 1.0}$	$= \frac{276}{0.92\ x\ 2\ x\ 0.95\ x\ 1.0}$
= 1396 pc/hr/ln	= 157 pc/hr/ln
D $= \frac{\text{VP}}{\text{S}}$	D $= \frac{VP}{S}$
$= \frac{1396}{74}$	$= \frac{157}{74}$
= 19 ~ LOS C	= 2 ~ LOS A

Table 4.11 : Flow rate and density calculation

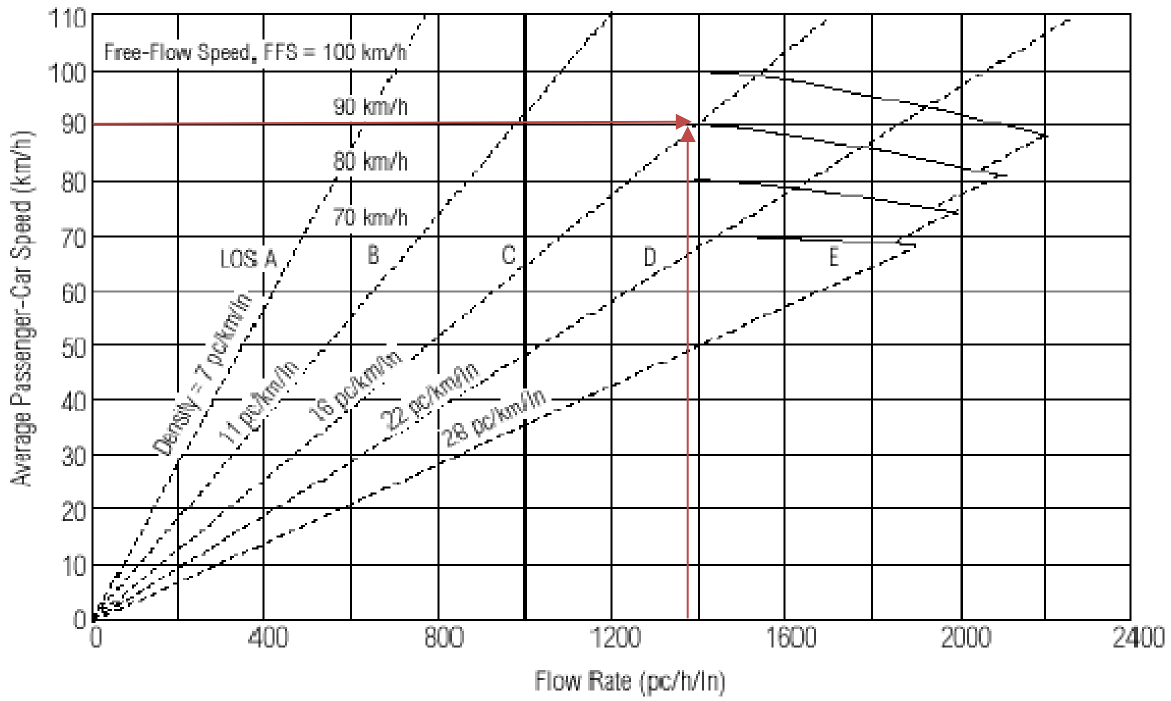


Figure 4.17: HCM 2010 Basic Freeway Segments Speed-Flow Curve (National Research Council Transportation Research, 2010)

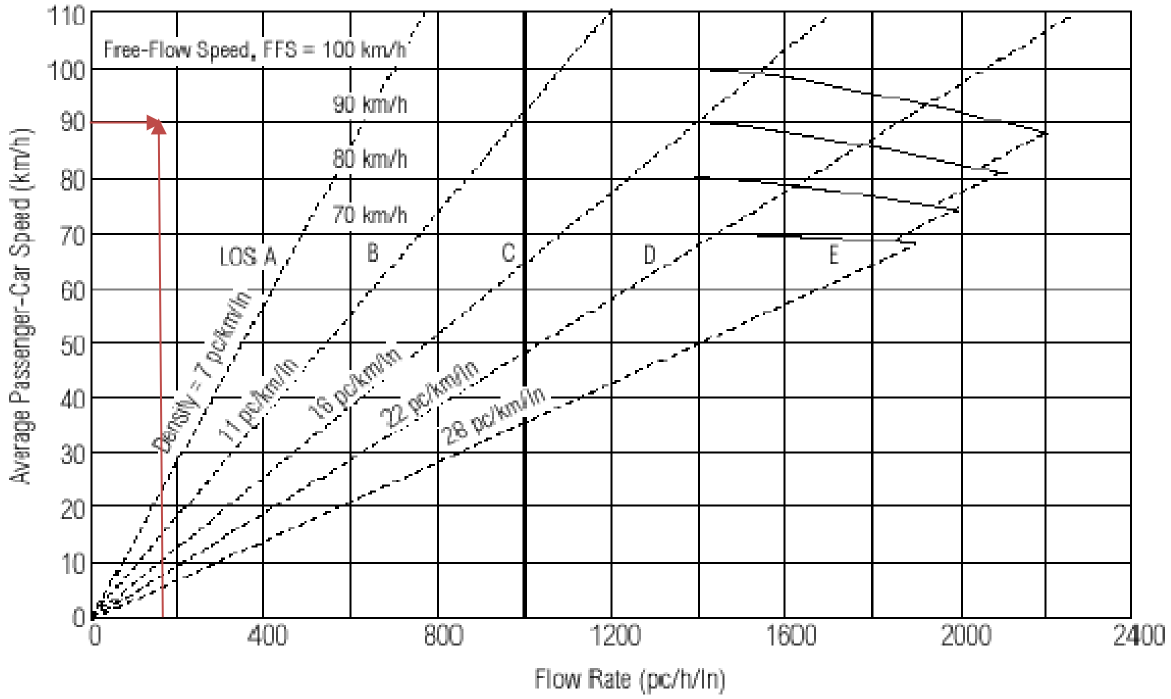


Figure 4.18: HCM 2010 Basic Freeway Segments Speed-Flow Curve (National Research Council Transportation Research, 2010)

For future condition, the projected 5% increment of vehicles will be calculated to predict the future conditions forecast of road in 2020. By using traffic forecast equation, the volume of vehicles for Station 1 and Station 2 has be determined. From the calculation, the prediction of 5% for future condition has shown that 6439 vehicles can be accommodate at Station 1 and 809 vehicles at Station 2. Table 4.12 and Table 4.13 show the future traffic composition with 5% increment of vehicle at 1 hour.

Station 1

$$P_{2020} = P_{2018}\ (1 + r)^2$$
$$= 5840\ (1 + 0.05)^2$$
$$= 6439$$

Station 2

$$P_{2020} = P_{2018}\ (1 + r)^2$$
$$= 734\ (1 + 0.05)^2$$
$$= 809$$

Table 4.12 : Forecast volume for Station 1

Traffic Composition at Sultan Haji Ahmad Shah Agricultural Park (Station 1)						
Time	Class 1	Class 2	Class 3	Class 4	Class 5	Total
7.00 - 7.15	563	42	6	6	81	698
7.15 - 7.30	536	34	0	6	85	661
7.30 - 7.45	537	22	6	4	99	668
7.45 - 8.00	517	31	4	7	88	647
Total	2153	129	16	23	353	2674

Table 4.13 : Forecast volume for Station 2

Traffic Composition at Kuantan Port (Station 2)						
Time	Class 1	Class 2	Class 3	Class 4	Class 5	Total
7.00 - 7.15	36	8	14	0	25	83
7.15 - 7.30	32	8	15	0	19	74
7.30 - 7.45	37	5	11	0	23	76
7.45 - 8.00	9	4	15	1	21	50
Total	114	25	55	1	88	283

As the increment of 5% vehicles**,** the value for population truck (PT) will be 0.05. As the type of terrain at study area is level, the value for ET will be 1.5 and the driver population factor will be 1.0 for all regular commuters.

$$fHV = \frac{1}{1+PT(ET-1)+PR\,(ER-1)}$$

$$= \frac{1}{1+0.05\,(1.5-1)+0}$$

= 0.98

By using new fHV value, the calculation will be made to calculated future condition in 2020 at Station 1 and Station 2. The value obtain from flow rate then will be used to calculated density. Then the result from density calculation will be used to determine Level of Services for future condition 2020. The calculation step is show in Table 4.21. By using flow rate formula, the value gain for Station 1 is 1421 pc/hr/ln and for Station 2 is 170 pc/hr/ln. Then density for two roads will be determined by using density formula. As we can see form the calculation above, the value for Station 1 and Station 2 will be 20 and 2 respectively. By using Speed Flow curves with LOS criteria show Station 1 with LOS D and Station 2 with LOS A.

Sultan Haji Ahmad Shah Agricultural Park (Station 1)	Kuantan Port (Station 2)
PHF $= \frac{\text{V}}{\text{4 x Vmin 15}}$	PHF $= \frac{\text{V}}{\text{4 x Vmin 15}}$
$= \frac{2674}{4 \text{ x } 698}$	$= \frac{283}{4\ x\ 83}$
= 0.96	= 0.85
Vp = $\frac{V}{\text{PHF x N x fHV x fdp}}$	Vp = $\frac{\text{V}}{\text{PHF x N x fHV x fdp}}$
$= \frac{2674}{0.96 \text{ x } 2 \text{ x } 0.98 \text{ x } 1.0}$	$= \frac{283}{0.85\ x\ 2\ x\ 0.98\ x\ 1.0}$
= 1421 pc/hr/ln	= 170 pc/hr/ln
D = $\frac{\text{VP}}{\text{S}}$	D = $\frac{VP}{S}$
$= \frac{1466}{74}$	$= \frac{158}{74}$
= 20 ~ LOS D	= 2 ~ LOS A

Table 4.14: Flow rate and density calculation

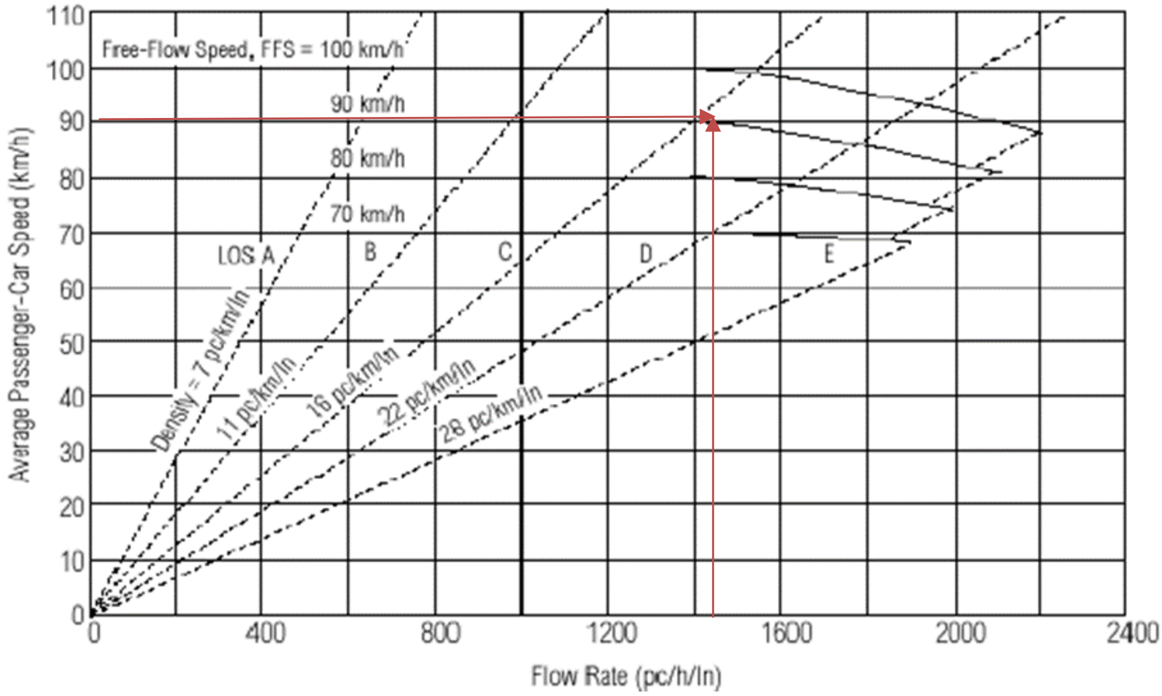


Figure 4.19: HCM 2010 Basic Freeway Segments Speed-Flow Curve (National Research Council Transportation Research, 2010)

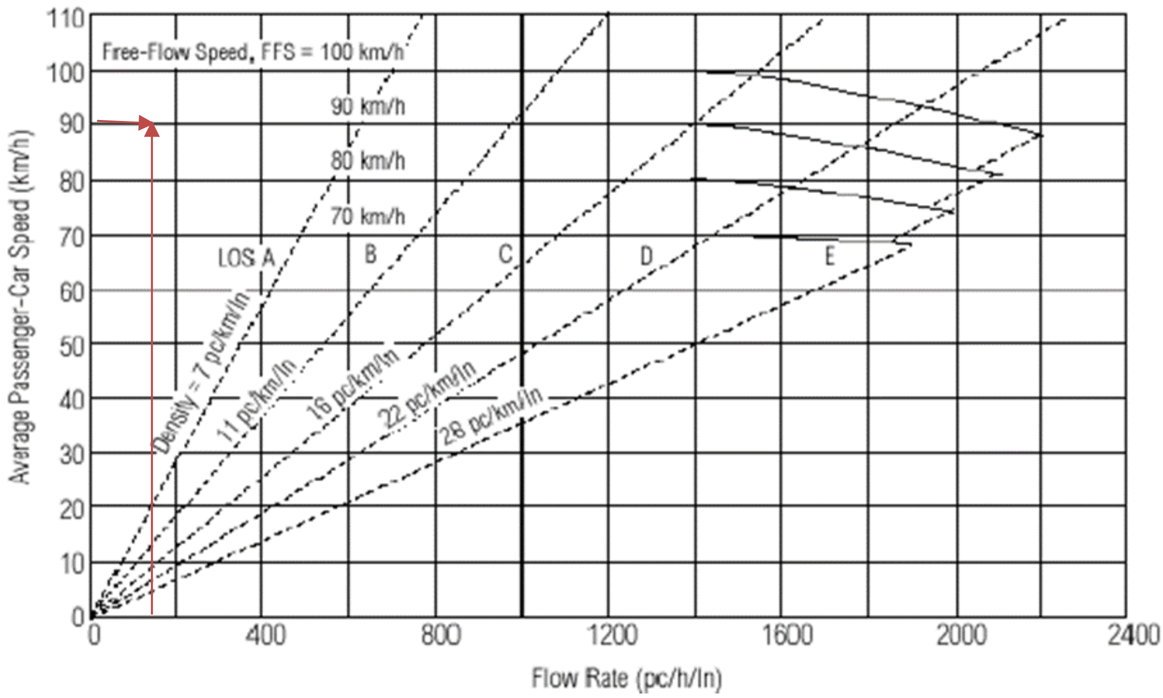


Figure 4.20: HCM 2010 Basic Freeway Segments Speed-Flow Curve (National Research Council Transportation Research, 2010)

LOS	TYPICAL OPERATING CONDITIONS
	Roadways
A	Free flowing traffic conditions
B	Still free flowing traffic conditions
C	Traffic flow is still under stable conditions
D	Approaching unstable flow and vehicle movement are constrained by high volume of traffic
E	Unstable flow
F	Congested flow

As we can see from the result obtain from Level of Service (LOS) calculation, we can see the different result obtain at Station 1. As we can from the result, the LOS obtain at Station 1 in present condition is LOS C while for future condition is LOS D. Based on the definitions of Level of Services (LOS), As Defined by American HCM for LOS C the traffic flow is still under stable conditions in present conditions while the traffic have approaching unstable flow and vehicles movement are constrained by high volume of traffic at LOS D in future conditions 2020. Comparing to Station 2, the both result obtain for present and future conditions show LOS A which traffic is free flowing traffic conditions. From this result, we can see that Station 1 generate more traffic volume comparing to Station 2, as it serves as service road, serving industrial, education institutions and consist of larger residential community's area. Moreover, the location of station itself show the interaction of traffic is different because of traffic domination.

CHAPTER 5

CONCLUSION

1.1 Introduction

This chapter will summarize the studies that have been conducted and concluded based on the analysis and the results obtained. Traffic on a road pavement is characterized by a large number of different vehicle types, and these can be considered in pavement design by using truck factors to transform the damage they apply to the pavement. Analysis based road rating assessment and operational performance analysis has chosen in this study. For road rating assessment each of the 3 km road segment has been consider for both Station 1 and Station 2 as stated in previous chapter. Based on the result obtained from visual observation survey, we can see a huge different between both Station that link to east coast region and link to port. This situation could arise due to new commercial facilities bringing additional vehicles on a permanent basis, the temporary additional heavy vehicles required for some major construction activities, the location of new mining activities and associated haul routes, or for other cause.

Moreover, most of our local roads were never designed to take either the weight or the volume of heavy goods for which they now have to cater and that is a key reason why many show signs of road deterioration. One of the largest challenges facing towards federal road 3 is the rapidly growing amount of heavy commercial vehicle (HCV) traffic being carried on the roads which were not designed to carry this increase in traffic. As a road surface is damaged and cracked by heavy axle loads, water can enter the underlying pavement layers, which weakens the pavement and can result in premature failure. While for the operational performance analysis the traffic demand of heavy vehicles for both present and future condition show a different result obtain for Station 1 while same for Station 2. This happen because of the existing activity consist at the Station 1, where the road is serve as a service road, serving industrial area, consist of education institution and larger residential community's area.

5.2 Conclusion

This study was done to explore on road deterioration and level of services of multilane highway using road rating assessment and operational performance analysis. As stated before in chapter one, the objective of this study were:-

i. To assess the impact of heavy vehicles distribution towards road pavement deterioration

ii. To evaluate the Level of Services (LOS) of the facilities to accommodate traffic demands of heavy vehicles for both present and future conditions

It can be concluding that this study was achieved all of the objectives. Based on the analysis that was discussed before in chapter four, from the result obtained for road rating assessment, we can see that the road condition at Station 2 that link to port is worse compared to road that link to east coast region Station 1 due to existing vehicles plus with additional loading vehicles from mineral activities, physical factors at surrounding area and daily traffic activity at study area. While for the traffic demands of heavy vehicles for both present and future condition show we can see the different result obtain at Station 1. As we can from the result, the LOS obtain at Station 1 in present condition is LOS C while for future condition is LOS D. Comparing to Station 2, the both result obtain for present and future conditions show LOS A. In the nutshell, the effect of heavy vehicles performance toward Federal Route 3 is successfully determined.

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APPENDIX A