

Exploration on Pavement Surface Conditions Attributed To Mineral Freight and Logistics Operations on Kuantan Road Network

A Ismail^{1,2}, M R Intan Suhana¹, K A Masri¹ and N H Rapar¹

¹Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia

²Earth Resources & Sustainability Centre, Universiti Malaysia Pahang, 26300 Kuantan, Pahang, Malaysia

Abstract. The most active mineral mining operations in Malaysia are located in Kuantan, Pahang. The rapid increases of the minerals operations are of concern due to its significant impacts on the environment and human health. While effects to the environment and human health are a great of concern, the effect to the transportation system also should not be neglected. With the continuous growth of these industries, there will be more heavy vehicles generated on road transporting minerals related products leading to several issues especially on road pavement damages. Pavement damages are always associated with its optimum function and may contribute to road crashes. There are several factors that influenced the pavement damages such as weather changes, quality of material use, improper maintenance and traffic operations. This study was conducted to explore the pavement damages occurrence based on traffic operation which focusing on heavy vehicles composition as centre for critical analysis. To achieve this study, the identification of regular routing used for minerals logistic operation from the mining source to the port was chosen as study location. This study was conducted by using visual observation survey and traffic volume survey. A set of historical data on route inspection supplied by Road Care also been used for analysis. Then, data obtained were analyzed using road disability level and road rating assessment. The result shows that the road rating leading to Kuantan Port was less satisfactory (rating C) with the marks of 7.27 and the highest type of damage found was cracking with 36% followed by rutting (33%) and potholes (31%). The outcomes from this study were hoped to bring some understanding on the impact of heavy vehicles towards transportation system within a local road network in Kuantan.

1. Introduction

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 2013 when bauxite mining in Indonesia ceased their operation. Kuantan, Pahang, a district in eastern Peninsular Malaysia, has become a hot spot for bauxite mineral mines in Malaysia to fill the supply gap after Indonesia barred exports of mineral ores in 2014. Since then, this industry continues to evolve over time from the early days to present times, is one of Malaysia's most important industries that has been debated for their pros and cons as widely reported by mainstream and social media.

Almost all minerals activities contribute to intense problems to the surrounding area. As in Kuantan, the boomed of this mineral mining industry has led to several issues between year 2013 to 2016 before moratorium of bauxite was implemented somewhere in June 2016. Several studies had been done especially on the impact of bauxite towards environmental quality degradation and health condition

among the public. [1] and [2] in their studies have investigated the impact of bauxite activities towards psychosocial and health conditions among communities that being affected.

While effects to the environment and human health are a great of concern, the effect to the traffic and transportation system also should not be neglected. The route of minerals freight distribution and their traffic affect the environment through which they pass. Consequently, it will also affect traffic performance on the roads accordingly. The complexity of the minerals hauling has indeed brought several issues to the surrounding areas especially environmental factors in terms of traffic and land use interactions that has been generated by the heavy trucks operations that transporting the minerals [3]. These issues include travel behaviour, environmental and health impacts, damage of pavement and other infrastructure and also road accident.

As in Kuantan, the development of the mineral industry has led to the growth of new industries that generate state and population revenues. Along with these developments, the increase in the number of vehicles especially for transporting the minerals has also increased. The significance growth of vehicular road traffic especially the heavy trucks will indirectly contributed to an increase of road safety issues. Moreover, if with uncontrolled mining activities will just lead to worsen the condition. Therefore, this study was conducted to explore on road condition and environment that focusing on pavement surface conditions attributed to heavy vehicles operation which perceived to have an association on pavement damage.

2. Literature Review

The transport of minerals from the field to the port is an important step in the overall operation of the minerals freight distribution. As for example, the typical bauxite freight distribution processes involved the loading onto trucks and hauling to a crushing facility. In this process trucks ranging in size from 30 to 180 tonnes are used depending on the size mines [4]. The mine site in Kuantan were located at Balok, Bukit Goh, Bukit Sagu and Sungai Karang where the most progressively mineral mining area occurred in the vicinity of Bukit Goh in about 18000 ha. Meanwhile, the minerals product storage areas were found to be located around Bukit Goh, Bukit Kuantan, Bukit Sagu, Kampung Bukit Kubang Badak, Jeram, and Beserah before transported to Kuantan Port before delivery to export or to local refineries. These mineral's product were transported to its stockpile areas mostly via Kuantan Bypass road (Federal Road 3) or through local state road penetrating Felda Bukit Goh. Due to the location of mining activities in Kuantan that totally different scenario comparing to the other common area in mining in other countries has led to intense suffering to the local even though on the other hands, it offers some exciting economic opportunities for various parties. In other country, remote locations and well defined zoning area are common for bauxite mining activities. While in Kuantan the location of mining activities is scattered and occurring near to and within community settlements without a clearly defined zone [3]. With the rapid developments of this industry especially in the freight and logistics operation are of concern due to its significant effects on the road condition and environment. Considering the scale of the minerals mining activities, it is not surprising that they also have a wide range of impacts on the road condition and environment such as air pollution, noise pollution, pavement damages, crashes and so on. This is especially true for the uncontrolled mining activities. As mention by [3] the extensive and uncontrolled mining activities have great potentials to cause adverse impacts on the environment, health and quality of life of the people living in the affected areas. Local newspaper had reporting the news regarding traffic issues caused by minerals transportation by highlighting fatal accident cases and congestion that linked to the heavy trucks generated on the road to transporting the minerals. The changes of road surface such as potholes also occur along with these developments where it has changed the condition of the road surface. As stated by [5] damage of pavement are considered among the main contributing factors to fatal accident. This is also in line with statement pointed out by Peter Larsson from The Swedish Transport Agency during his presentation to Ministry of Work (MOW) Malaysia, which more than 29% of road crashes factors are caused by road condition and environment. Road condition and environment itself covers many aspects of the physical elements of the road system such as roadside conditions, road surface conditions traffic volumes, operational speed and not to be missed out the driving ambience itself.

An extensive research done by [1] reported on the environmental problems arises due to bauxite mining activities as shown in Table 1 that involved community in Felda Bukit Goh Kuantan which is within 5 km radius from the boundary of the mining site. The finding shows that road damages were among the top five serious issues that have been reported by the respondents (69.8%). This was believed associated with the heavy trucks since they were heavily used the route for transportation of minerals.

Table 1. The environmental problems reported by the respondents

Environmental Problems	Frequency (n)	Percentage (%)
Increased air pollution	142	87.7
Dustier house	142	87.7
House cleaning problem	129	79.6
Road damage	113	69.8
Agricultural problem	86	53.1
Loss of calmness	75	46.3
Land erosion/landslide	60	37.0
Water resource problem	50	30.9
Food resource problem	12	7.4

N=162

As mentioned by [6], damages on the roads are primarily caused by the heavier axle loads associated with large commercial vehicles. One of the defects caused by heavy trucks on the road is the deformation of the pavement surface due to overloading that is more than the design load. As stated by [7], the deterioration of pavement arises from deformation generally associated with cracking under heavy trucks. The increased traffic loading will then cause failures such as cracks and depression on the pavement. Other than that, the issue of overloading solely also causes roads in Malaysia to have their mending period earlier than the expected lifespan. Vehicle overloading has been identified as one of the major contributors to road pavement damage in Malaysia [8]. Overloaded vehicles produce higher kinetic energy, resulting in greater impact forces and damages to other vehicles or to the infrastructure.

3. Methodology

Analysis of traffic data often begin with some type of statistical analysis and often involves some type of graphical display. These data should be transformed in appropriate way in order to provide information. In this report, the data collected provide an overview of traffic volumes and pavement surface conditions.

3.1 Field Data

To accomplish research objectives, two routes have been chosen to serve as a study area namely Station 1 and Station 2. Station 1 was on Kuantan Bypass Federal Route 3 and Station 2 was on Route Jalan Kuantan heading to Kuantan Port. Station 1 was an urban arterial of dual two-lane carriageway similar to the East Coast Expressway in the number of lanes but a rank lower in the hierarchy of roads in Malaysia. Meanwhile for Station 2 was a main distributor road that connects Kuantan Port with the outside areas. These two routes were selected as a study area by considering the function of both routes as a main route that provide essential link to and fro Kuantan Port where high volume of heavy trucks could be expected travelling on these routes. Having said that, it clearly shows that the traffic flow catered along both routes was relatively heavy and becoming much heavier especially due to the traffic generated from the growth of the mineral industry in Kuantan in combination with the rapid development along the road. The data collection processed has been performed during weekdays in September and October 2018.

Before proceed with the data collection, a historical data that contain information on pavement damage and traffic volume data from 2014 to 2016 has been collected to provide a basis for further analysis. The pavement damages data was supplied by Road Care Sdn. Bhd. and the peak hour traffic volume data was obtained from Road Traffic Volume Malaysia.

3.2 Traffic Volume Data

Traffic volume is defined as the number of vehicles that pass a given section of road during a given time under prevailing roadway and weather conditions. The purposes of traffic volume study are to evaluate the present traffic flow condition for document planning activities in highway usage and also for design and operation analysis. Traffic volume counts by vehicle class have been conducted for three days on Monday, Wednesday and Friday for AM peak from 7.00 am to 10.00 am at Station 1 and Station 2. An electronic device called Metro Count was used to assist the data collection process. As to achieve the objective of this study, the traffic volume was segregated into vehicle classification as to look in detail the pattern compositions of heavy vehicles on both stations 1 and 2.

3.3 Visual Observation and Physical Measurement

This research employed a quantitative approach to achieve the study's aim. A survey to identify the pavement surface conditions was done by visual observation and physical measurements was made at both location stated above. Only the common type of road damage was considered in this study which were cracking, rutting and potholes. Observation was made within 3 km around the identified stations. Meanwhile the traffic volume based on vehicles class also was taken as to explore the heavy trucks operation which perceived to have an association on pavement damage.

3.3 Road Rating Assessment

Data obtained from the site was then analyzed to identify the frequency of each damage type and road rating assessment was used to determine the seriousness of the road damaged based on road disability level and rating as shown in Table 2 and 3 below.

Table 2. Road Disability Level

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

Table 3. Road Rating

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

4. Results And Discussion

4.1. Traffic Volume Characteristic

As shown in Table 4 below was a volume variation characteristic of site location on weekday basis of Monday, Wednesday and Friday for AM peak from 7.00am to 10.00 am. Basically from the data collected it is found that there was a little different in traffic flow on each weekday for both station with maximum volumes observed was on Monday. However, the volume pattern for both stations was distinctly different with the maximum average volume was at Station 1. This was resulting from the function characteristics of route mention as preceded that station 1 was operated as trunk road that

connecting Kuala Lumpur and Johor to East Coast region meanwhile Station 2 was a main distributor road form Kuantan Port to the outside area.

Table 4. Traffic Volume Counts

Days	Station 1	Station 2
Monday	6421	816
Wednesday	5159	783
Friday	5819	558
Average	5800	719

In order to achieve the objective of this study, the traffic volume was then segregated into vehicle classification as to have a detail overview on the pattern compositions of heavy vehicles on both stations during those 3 days period. In Table 5 indicated the average traffic volume that was separated according to its vehicles class. C1 class is referred to cars/van/pick up, C2 for medium lorry, C3 for heavy lorry, C4 for bus while C5 is for motorcycle. Based on the tables 5, a total of 10% commercial vehicles of C2, C3 and C4 were observed in Station 1 meanwhile in Station 2 was about 50%. This was especially true because Station 2 was somehow the main distributor route for logistics activities as this route connecting outside areas to Kuantan Port where heavy vehicles were expected using this road more regular compare to the other vehicles class.

Table 5 Average Percentage of Vehicles Composition

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

4.2 Pavement Disability Level and Road Rating

The distress on the pavement surface at Station 1 and Station 2 has been conducted by visual observation and physical measurement. From the observation, the frequency and percentage of pavement damages within 3 km of identified station was recorded as shown in Table 6 and 7. The highest frequency of damages was seen on Station 2 (42) compare to Station 1(16). This is corresponding to several literature stated above where heavy vehicles have a significant impact on pavement fatigue life and distress. As in Station 2, where 50% of the volume of vehicles was significantly commercial vehicles with C2 36%, C3 14%, meanwhile in Station 1 the commercial vehicles only comprises of 10% with the C2 7%, C3 2% and C3 1%. The pattern of damage of both stations was quite similar where cracks were found to be the main type of damage with 75% in Station 1 and 36% in station 2. Cracks are one of the common types of road damages especially on federal roads [9]. There was no rutting found in station 1 but potholes were observed about 25%. Meanwhile in station 2 rutting was about 33% followed by potholes 31%. Based on the observation that has been done, rutting usually occurred near to the patching area and at the edge of the road.

Table 6. Pavement Damage at Station 1

Types of Damages	Frequency	Percentages %
Cracks	12	75
Potholes	4	25
Rutting	0	0
Total	16	100

Table 7. Pavement Damage at Station 2

Types of Damages	Frequency	Percentages %
Cracks	15	36
Potholes	13	31
Rutting	14	33
Total	42	100

The pattern of pavement of damages in this study was further assess to determine the seriousness of the road damaged based on road disability level and rating as shown in Table 1 and 2 above. As mentioned earlier the observation was made within 3 km at each identified station. This 3 km road section was then segregated into each 200 m that lead into 15 segmentation of road section. It is to make sure a uniformity of understanding on the damages types was under control. Figure 1 shows the illustration on the pavement damages within 3 km length at station 1 and 2. Marks was then given based on the level of seriousness of the damage as 1 (low), 2 (moderate) and 3 (high). Hence the road rating could be classifying as very satisfying condition to less satisfying condition.

**Figure 1:** Illustration on Pavement Damages at Station 1 and Station 2

From the analysis it indicates that road rating for Station 1 as 1.73 which was in rating A indicates very satisfying condition. Meanwhile for Station 2 the road rating was 7.27 (rating C) which means less satisfying condition. It was shown that most cracking and rutting occurred at Station 2 was severe with maximum physical measurement of cracking was 200 m and rutting was 0.42 m in the 200 m road segmentation. In other words, along 200 m length of road at Station 2 the pavement surface condition was badly in damage conditions. This is in line with the study done by [10] mentioned that physical road surface condition of the main road leading to Port Klang was not satisfactory as a results

of load bearing movement of logistics operations. Moreover, [11] and [12] also mentioned that increasing in vehicular traffic especially heavier vehicles and also traffic loading was among the factors influencing pavement damage. As shown in Table 4 above, though the analysis stated that Station 1 has the highest volumes of vehicles of 5800 compared to Station 2 of 719 however the significant different in patterns of vehicles composition on both station do plays some role in the road condition and environment as in this study was focusing on pavement surface condition. Vehicles compositions in Station 1 were dominantly conquer by class 1 by 78% followed by 10% commercial vehicles of C2, C3 and C4 and remaining 12% was C5. This is in contrast with Station 2 where the existence of light and heavy vehicles was at the same par of 50%. At Station 2 the light vehicles compositions of C1 and C5 was 50% meanwhile the remaining 50% was governing by commercial vehicles of C2 and C3. Consequently, high volumes of heavy vehicles encountered at Station 2 compare to Station 1.

This finding provides some overview on the operation of heavy vehicles which perceived to have an association on pavement damage. As stated by [13], pavement damage is the process by which distress develop in pavement under the combined effect of traffic loading. 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. As trucking has become the most popular mode of freight transportation because of its efficiency and convenience it has also contributed to most of pavement deterioration [14]. Therefore the possibility of heavy vehicles damaging the road is high.

According to [15] highlighted that the using of trucks with single and tandem axles have high potential of fatigue damage compared with the use of tridem and multiples axles of trucks. This is because the load carry by the trucks will distribute evenly among the axles hence the stress imposed on the pavement is reduced. In the case of mineral logistic operations, most trucks used were single and tandem axles. If the trucks is exceed the legislated maximum axle load limit or overloading, it will worsen the pavement condition. Figure 2 below shows a historical data on the association of peak hour traffic volume, heavy vehicles composition and number of damages occurred at Station 1 from 2014 to 2016. As discussed preceded, the minerals mining industry in Kuantan was well ascertained during those years. Operated as main road that provides essential link to Kuantan Port, the expectation on heavy vehicles generated on the road will supposed increasing tremendously. However the heavy vehicles composition was observed in decreasing pattern at which the lowest compositions was in 2016 with 8.5% of heavy vehicles. Meanwhile the number of pavement damage occurred was found the highest during that year. Based on this finding, it shows that heavy vehicles compositions attributed to minerals industry in Kuantan alone not really a significant factor contributes to the pavement damages.

Figure 2 below shows a historical data on the association of peak hour traffic volume, heavy vehicles composition and number of damages occurred at Station 1 from 2014 to 2016. As discussed preceded, the minerals mining industry in Kuantan was well ascertained during those years. Operated as main road that provides essential link to Kuantan Port, the expectation on heavy vehicles generated on the road will supposed increasing tremendously. However the heavy vehicles composition was observed in decreasing pattern at which the lowest compositions was in 2016 with 8.5% of heavy vehicles. Meanwhile the number of pavement damage occurred was found the highest during that year. Based on this finding, it shows that heavy vehicles compositions attributed to minerals industry in Kuantan alone not really a significant factor contributes to the pavement damages.

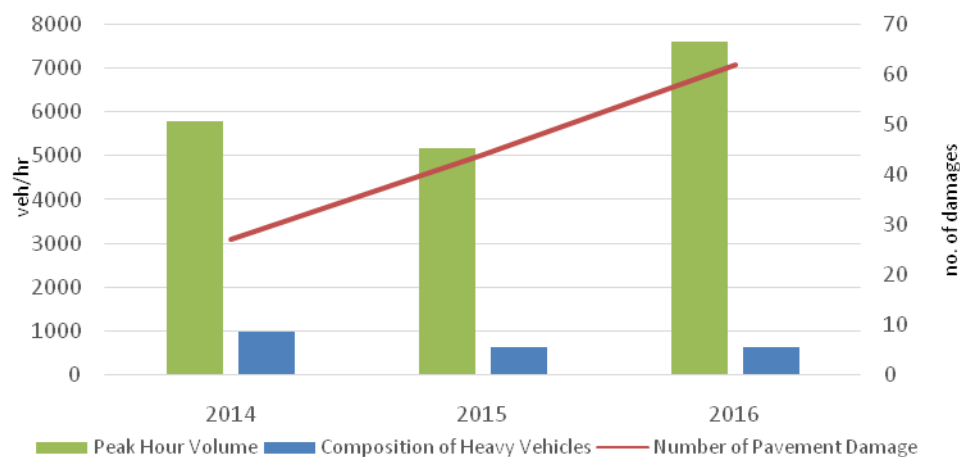


Figure 2. Association of Traffic Volume, Heavy Vehicles Composition and Pavement Damage

Nevertheless, based on the finding obtained from the field data by comparing two routes (Station 1 and Station 2) of significant different of heavy vehicles compositions with number of damage do provide insight to performance of the pavement. Looking at these scenarios, it is recommended to explore closely other factors that contribute to pavement damages.

5. Conclusion

From the analysis, it can be concluded that existence of heavy vehicles attributed to the minerals industry in Kuantan did not clearly the significance factors affect the performance of the pavement. However the compositions of heavy vehicles on the road do play a significant impact on the pavement surface condition. Based on the finding in this study, Station 1 comprises 10 % commercial vehicles with the C2 of 7%, C3 of 2% and C4 of 1%. Meanwhile for Station 2, 50 % of the vehicles class was significantly commercial vehicles with C2 of 36% and C3 of 14%. The road rating of pavement condition was very satisfying with rank A at Station 1. On the other hand, in Station 2 the road rating was less satisfying with rank C. This study gives insight on how compositions of commercial vehicles or heavy vehicles subjectively associated towards pavement condition. In order to reinforce the results, it is recommended to further analyze the pavement condition by looking at other factors such as quality of materials use, the details in design and construction process including weather and surrounding condition. With an addition of traffic generated by minerals industry in Kuantan, this study may provide an overview to the road authorities to enhance the quality of road environment and to improve Kuantan road network system thus creating sustainable land transport thereby helping to boost up the economic activities and quality of life.

6. References

- [1] Hussain NH, Hashim Z, Hashim JH, Ismail N and Zakaria J 2016 *Int. Journal of Public Health and Clinical Sciences* 3(5):174-89
- [2] Lee KY, Ho LY, Tan KH, Tham YY, Ling SP, Qureshi AM, Ponnudurai T and Nordin R 2017 *Int. Med. Journal Malaysia* 16(2)
- [3] Abdullah NH, Mohamed N, Sulaiman LH, Zakaria TA and Rahim DA 2016 *The Malaysian Journal of Medical Sciences* (3):1
- [4] Donoghue AM, Frisch N and Olney D 2014 *Journal Of Occ. and Env. Medicine* 56(5 Suppl):S12
- [5] Fares H, Shahata K, Elwakil E, Eweda A, Zayed T, Abdelrahman M and Basha I. 2012 *Str. and Inf. Engineering* 8(11):1067-79
- [6] Croney D and Croney P 1991 *The design and performance of road pavements* McGraw-Hill, Incorporated

- [7] Adlinge SS and Gupta AK 2013 *Int. Journal of Innovative Research and Development*. 2(4):437-50
- [8] Karim MR, Ibrahim NI, Saifizul AA and Yamanaka H 2014 *IATSS research* **37**(2014):124-9
- [9] Kordi NE, Endut IR, Wahab MY and Baharom B 2012 *IEEE Business, Engineering & Industrial Applications Colloquium* (pp. 430-434)
- [10] Anor N and Ahmad Z 2010 *Malaysian Universities Transportation Research Forum and Conference*.
- [11] Abdullah AS, Karim MR and Yamanaka H 2010 *17th ITS World Congress ITS Japan ITS America ERTICO*
- [12] Judin AK 2011 *Road infrastructure development in Malaysia* Public Work Department Malaysia Kuala Lumpur
- [13] Zumrawi MM 2016 *Journal of Civil Engineering and Technology* **7**(2), PP 203 – 214
- [14] Bai Y, Schrock SD, Mulinazzi TE, Hou W, Liu C and Firman U 2010 *Estimating highway pavement damage costs attributed to truck traffic* Mid America Transportation Centre
- [15] Chatti K, Salama H and El Mohtar C 2004 *Proceedings 8th International Symposium on Heavy Vehicle Weights and Dimensions* Document Transformation Technologies

Acknowledgments

The authors would like to express their gratitude to Universiti Malaysia Pahang (UMP) for providing financial assistance to this research through grant number RDU172205.