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# Effect of Median Barrier Types on Crash Severity at Rural Expressway

Nora Sheda Mohd Zulkiffli
Azzuhana Roslan
Nur Zarifah Harun

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MALAYSIAN INSTITUTE OF ROAD SAFETY RESEARCH

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# Executive Summary

About 6,674 people are killed in a road crash. The total number of road crash data for 10 years (2005-2014) trend is gradually increasing. When detailed out to road crash by category, crash occurrence highest on Federal Road (33%) and the expressway denoted only by 8%. Although the lowest percentage involved in a road crash at expressways, this research need to be conducted since it seems that there has not been much research done at expressways. In addition, the median barrier has a closed relation of its existence with the head-on collision. Separation of directional flow by a median barrier, almost completely preventing the head-on collisions which very often cause crash severity. The purpose of this study was to determine the effect of median barrier types on crash severity in term of fatal and non-fatal crash occurrence at seven rural expressways. Therefore, there is a need to identify the crash severity related to median barrier types and as well as to determine the crash risk of median barrier types on crash severity. This research only covered for median safety barrier included concrete, w-beam guardrail and wire rope.

Crash severity related to median barrier types was computed using crash data provided by Royal Malaysian Police (RMP) from 2009 to 2011. A total of 120 crashes related to hitting roadside and median safety barrier were reported on seven selected rural expressways. Out of that, only 52 crashes related to hitting the median safety barrier. Findings show that the majority of the crashes resulted in fatal and non-fatal crashes for all median barrier types. A higher percentage of w-beam guardrail crashes resulted in a fatal crash than did the other barrier types. While the percentage of wire rope crashes resulted in highest involved in the non-fatal crash as compared to other barrier types.

Furthermore, the road crash risk was computed by using a formula as stated. To calculate the road crash risk, M-ROADS provided crash data for a five-year trend (2009-2013) based on the type of crash severity (fatal, serious and slight crash). Thus, total

crashes occurring between 2009 until 2013 on rural expressways for every kilometre were used for this analysis. Each expressway exits gave the different of fatal and non-fatal crash risk. Whereas, computed based on median barrier types also gave small crash risk. In addition, the road crash risk value has calculated the risk of crash severity per million vehicles involving median barrier types at expressway for the five-year period. Therefore, the data only briefly discusses the highest fatal and non-fatal crash risk value by each expressway exit and by barrier type located at the seven rural expressways.

Based on past study findings, 91% of rural expressways were installed with a w-beam guardrail. Thus, the result to determine the effect of median barrier types on crash severity can be concluded that, the odds of fatal crashes at a location located with w-beam guardrail is 1.8 times higher (95% CI: 0.3222 to 10.0552) than in the concrete barrier installation. While the odds of fatal crashes in the w-beam guardrail is 5.4 times higher (95% CI: 0.5152 to 56.5982) than in areas with installed wire rope. However, this difference also was found not to be statistically significant because a limited number of crash severity-median barrier collision data.

# 1. Introduction

As in other developing countries, the automotive industry is growing rapidly in Malaysia. The Malaysian automotive industry is growing fast forward from an assembly of manufacturing industry, focusing on passenger car over the years 1980-2009 (Wad & Govindaraju, 2011). Regarding Malaysian Investment Development Authority (MIDA), 2012, stated that Malaysia is the largest passenger car market in ASEAN due to the fast growth of the economy and the high purchasing power of its population.

Statement by MIDA, 2012 supported by the statistic by a Royal Police Malaysian (RMP) show that the numbers of registered vehicles are constantly increasing every year. The number of registered vehicles has risen from 14 million in 2005 to more than 25 million in 2014. As well, the number of the population gradually increased over the years to 30 million in 2014.

Despite the positive developments in the motor industry, as its consequences produce negative effects, particularly in humans and the environment. The negative effect relates to road crash. According to the RMP, 2014, about 6,674 people are killed in a road crash. The total number of road crash data for 10 years (2005-2014) as Figure 1. Their percent distribution of road crash by road category as in Figure 2 and in Figure 3 is percent distribution road crash by road category and first collision.

By graphical analysis presented in Figure 1, road crash on Malaysia trend is gradually increasing. When detailed out to road crash by category as in Figure 2, crash occurrence highest on Federal Roads (33%) and the expressway denoted only by 8%. Although the lowest percentage involved in a road crash at expressways, this research need to be conducted since it seems that there has not been much research done at expressways. From the current literature review, it seems that there has not been much research on the impact of traffic conditions on crash risk.

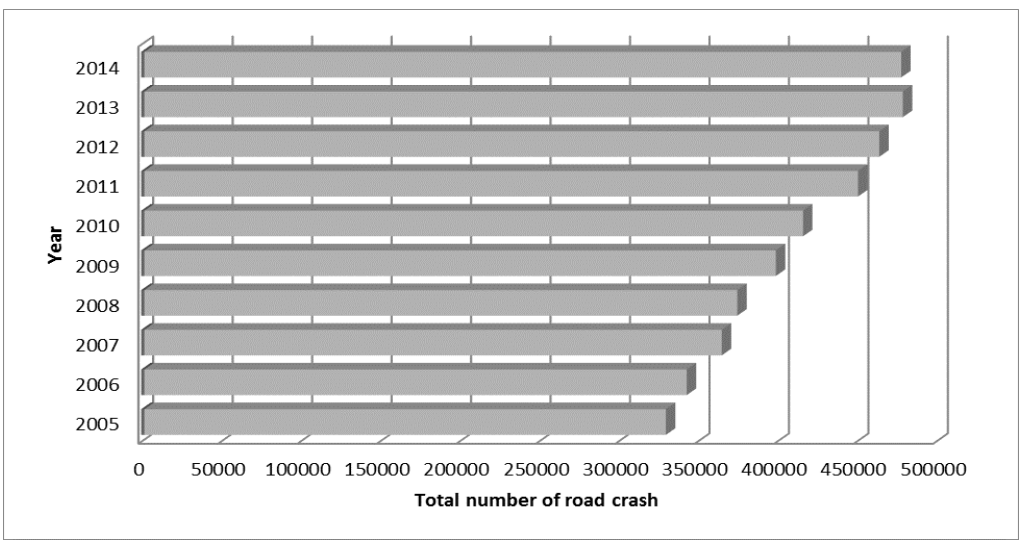


**Figure 1** The total number of road crash for ten years (2005-2014)

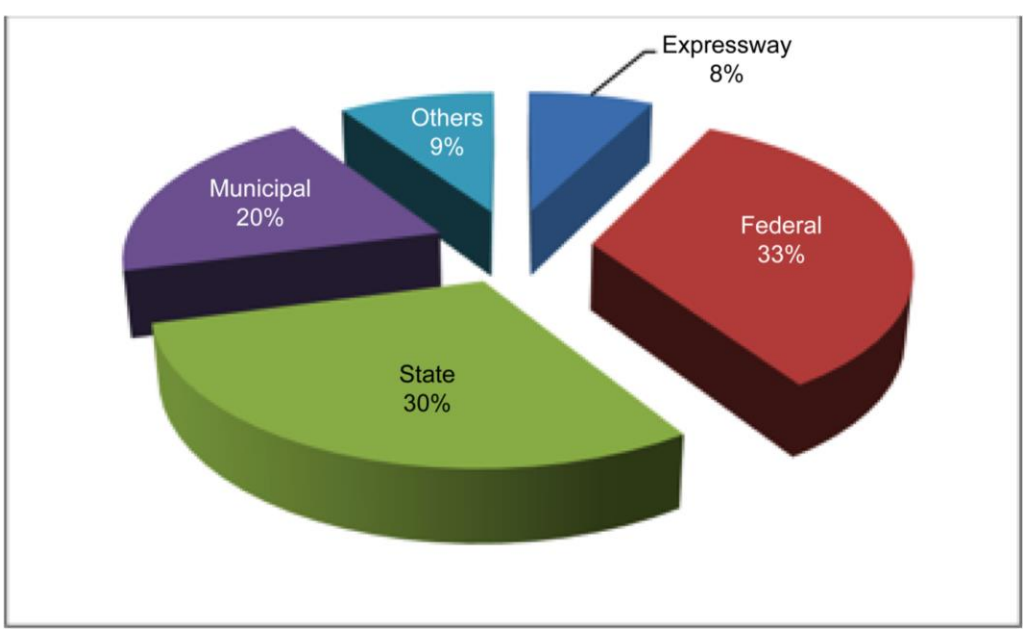


**Figure 2** Percentage of total road crash by road category in 2014

In general, road crash by type of the first collision shows that angular collision is the highest percentage contribution in a road crash in the first collision (see Figure 3). Then, the head-on collision represents the second highest percentage of crash occurrence.

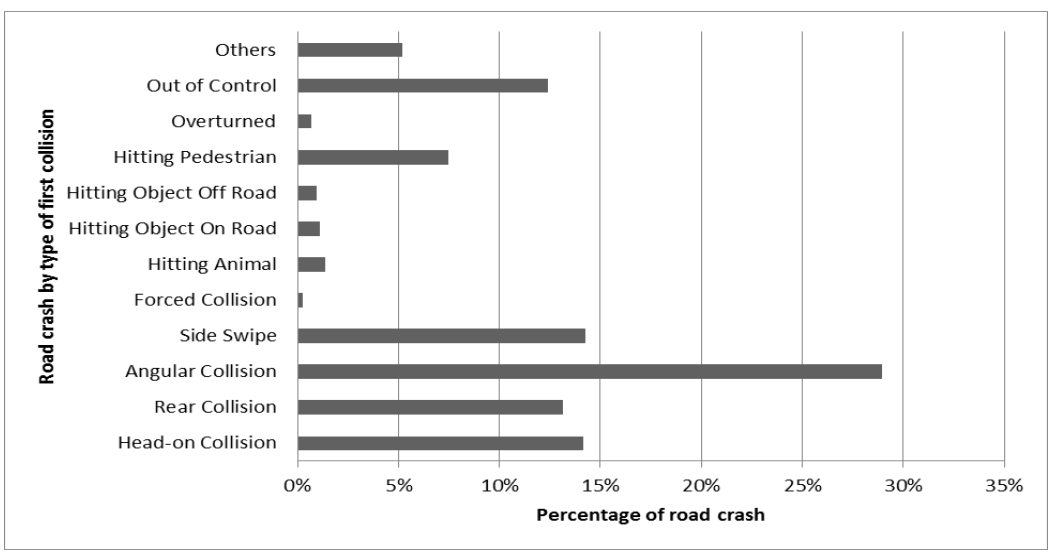


**Figure 3** Percentage of road crash by type of the first collision in 2014

A head-on collision has closed relation with existing of the median barrier. Separation of directional flow by a median barrier, almost completely preventing the head-on collisions which very often cause crash severity (Martin, Mintsa-Eya, & Goubel, 2013). According to (Prentkovskis, Beljatynskij, Prentkovskiene, Dyakov, & Dabulevičiene, 2009) stated that, for the expressway, median barriers are an effective safety solution for median-crossover crashes. The design of a median has an effect on mitigating various crashes. As an example, an errant vehicle has left the travelled way, thus; a median design should be in two benefits: one, to redirect errant vehicle without rolling over and provide a safe recovery area and two, to not have the errant vehicle cross the median and crash head-on with oncoming cars. Therefore, the installation of median safety barrier is the best way to reduce the severity of the crashes.

In addition, the factor of head-on crashes normally occurred due to three main aspects such as human errors, poor environmental conditions and poor vehicle conditions. The example is a driver misjudges the speed of oncoming vehicle before overtaking on opposite lane, a driver misjudges the curve severity and encroaches onto the opposite lane and, due vehicle brake failure causes a driver loses control.

However, there are many possible countermeasures for head-on crashes. The low cost countermeasure such as provided centreline rumble strips to alert drivers, widening the median and hatching between the centrelines. Others countermeasure includes delineation, shoulder paving, speed management, lane widening and installing a median barrier. Again, the cost and effectiveness for these countermeasures depend on the suitability of the existing environment and road (Safety Transportation, Tuominen, Sirkiä, Kallberg, Rosqvist, & Kotikunnas, n.d.).

Based on previous research regarding barrier types, about 91% the w-beam guardrails mostly installed on Malaysia's rural expressway. Regarding (Prentkovskis *et al.*, 2009) study about guardrail stated that the guardrail able to reduce the human injuries and damages caused by road crash rather than avoiding a crash particularly when hitting with the structure such as a bridge or tunnel.

Furthermore, various types of the median barrier are installed to reduce the injuries or damage caused by crashes rather than avoiding crashes. It may also be supposed that guardrails reduce not only destructive effects but their risk involved in the road crash as well. Again, the study by Prentkovskis *et al.,* 2009, they stated that by installing guardrails on a median allows reducing the fatality rate due to crashes by about 20%. While the rate of human injuries caused by traffic crash is reduced by 5% and material losses are increased by 25%. They also concluded the cable crash barrier (wire rope) is the most effective in reducing crash causing injuries to the humans. However, the cable crash barrier increases the rate of the crash causing material losses.

So that, the purpose of this study is to understand the crash severity occurrence better at seven rural expressways. As well to determine the crash risk of median

barrier types of a fatal and non-fatal crash at seven rural expressways besides to conclude the effect of median barrier types to crash severity.

## 1.1 Aim and Objectives of the Study

The aim of this study was to determine the effect of median barrier types on crash severity. Crash severity in term of fatal and non-fatal crash occurrence.

The objectives of this study are:

i. To identify the crash severity related to median barrier types
ii. To determine the risk of median barrier types on crash severity

The outcome of this study as aimed to provide understanding the relation of median barrier types installed on Malaysia's rural expressway to crash severity.

## 1.2 Scope and Limitation of the Study

This research only focused on seven rural expressways namely as North-South Expressway (Northern Route, E1), North-South Expressway (Southern Route, E2), Kuala Lumpur-Karak Expressway (KLK, E8), Guthrie Corridor Expressway (GUTHRIE, E35), North-South Expressway Central Link (ELITE, E6), Kajang-Seremban Highway (LEKAS, E21) and Seremban-Port Dickson Highway (SPDH, E29). The study only covered for median safety barrier. The median barrier types included concrete, w-beam guardrail and wire rope.

Traffic volume data for E1, E2, E6 and E8 was obtained from Malaysian Highway Authority (MHA). However, because of the limitation of secondary data provided by MHA, the data collection was conducted at only three expressways. The expressways are E21, E29 and E35. Thus, one-hour traffic volume during peak period was collected and then, by using a formula was converted to average daily traffic (ADT).

# 2. Literature Review

The review of relevant literature begins with a discussion of previous findings from a research project, past research from other countries and researchers regarding median barrier safety in term of crash severity and crash risk. Subsequently, the formula used to calculate crash risk as well as highlighted.

## 2.1 Previous Research Project Findings

Previous research on median barrier was carried out at seven rural expressways cover 936 km stretch as in Table 1. Out of 27 expressways available in Malaysia, it was found that seven (7) expressways were identified as rural expressway regarding the criteria by the Professional Engineers of Ontario report:

i. The nature of the surrounding area and development
ii. Trip length tends to be longer and
iii. Have less traffic and fewer lanes

**Table 1** Details on rural expressways

| Expressway | Length (km) | Section |
|---|---|---|
| North-South Expressway (PLUS: Northern Route, E1) | 387 | Sungai Buloh to Jitra |
| North-South Expressway (PLUS: Southern Route, E2) | 275 | Johor Bahru to Bangi |
| East Coast Expressway (LPT 1, E8) | 160 | Gombak to Gambang |
| Kajang-Seremban Highway (LEKAS, E21) | 40 | Ampangan to Semenyih |
| North-South Expressway Central Link (ELITE, E6) | 37 | Nilai to Shah Alam |
| Seremban-Port Dickson Highway (SPDH, E29) | 21 | Port Dickson to Seremban |
| Guthrie Corridor Expressway (E35) | 16 | Shah Alam to Rawang |

Due to the difficulties to secure a safe location along the expressway to conduct measurement and on-site data collection, this past research made use of data through a drive-through video recording. The drive through video recording carried out on all seven identified rural expressways for establishing much of the site characteristic and geometric data.

Types of data obtained during this process include median barrier types, road alignment, the number of lanes, median design, drainage design, and other information that deem necessary with the research objectives. Aside from that, general information, including expressway name, start and end coordinates of an expressway, date and time of video recording, and weather during the data collection was recorded.

For the purpose of data analysis, static segmentation method was used. In the static segmentation method, the length of each segment is fixed and in this study, the roads were divided into segments with 1 km interval and data were recorded for every segment. However, for this current study, only the barrier types and start and end coordinate of the expressway is needed.

Additionally, there are three general categories of median barriers: rigid, semi-rigid, and flexible. A rigid barrier, such as a concrete barrier, tends to convey most of the energy during an impact onto the vehicle's occupants. Semi-rigid barriers can accept small to moderate deflection when the collision occurred. The common example of the semi-rigid barrier is a W-beam guardrail. Wire rope is considered flexible barriers. They are designed to absorb most of the energy transmitted between a vehicle and the barrier during impact, while. Through findings in rural expressways, w-beam guardrail has installed more than concrete and wire rope. Concrete has been found installed on a hilly and curve road. Whereas, the wire rope is installed in a place with a large median width (Nora Sheda, M.Z., & Norfaizah, M.K., 2015).

## 2.2 Other Countries Findings: Crash Severity by Barrier Type

In the past years, numerous studies have examined the barrier types by the severity of crashes. Based on the study by Hunter *et al.,* 2001, reductions in the number of severe crashes have been observed with wire rope installation in North Carolina. They found that overall safety was improved after the installation of wire rope and that there were fewer serious and fatal crashes as well as head-on crashes.

A more recent study on rural divided highways in North Carolina indicated that collisions with wire rope median barriers tend to have less severe injuries (i.e., fatality) than collisions with concrete or guardrail median barriers (Hu and Donnell, 2010). They also found that increases in the median wire rope offset could lower the probability of severe crash outcomes.

A study regarding concrete barriers and guardrails by Holdridge *et al.* (2005) found that striking them could reduce the likelihood of incapacitating and non-incapacitating injuries when compared to collisions with fixed roadside objects. While Martin *et al.* (2013) concluded that concrete barriers are less effective than w-beam guardrails in reducing cross-median crashes.

Before-and-after studies conducted by Villwock *et al.* (2011) indicated that installing high-tension median wire rope can eliminate 94% of multiple-vehicle opposite-direction crashes, but can increase single-vehicle crashes on wide, depressed medians by 70%. They found that high-tension wire rope has a small effect on crash severity in terms of the proportion of injury and fatality. Studies on the cost-effectiveness of road barriers indicate that installing wire rope was more cost-effective compared to installing concrete median barriers (Cooner *et al.,* 2009) and not installing any median barriers (Hunter *et al.,* 2001).

As the summary, many types of research indicated as wire rope have many benefits rather than concrete and w-beam guardrail barrier. However, there are also disadvantages associated with wire rope. Wire rope has been found to increase the

frequency of crashes (Sposito and Johnston 1998; Sheikh *et al.*, 2008; McClanahan *et al.,* 2004; Hunter *et al.,* 2001). Although an increase in the number of crashes is undesirable, this outcome is mitigated by the fact that wire rope has been shown to reduce the severity of crashes (Sposito and Johnston 1998).

### 2.2.1 The Frequency of Crashes Related to Median Width, Speed, Volume and Number of Lanes

It should be noted that installing median barriers might increase the crash frequency, but the crashes tend to be less severe (Elvik, 1995; Miaou *et al.,* 2005; Donnell and Mason, 2006; Tarko *et al.,* 2008). In addition, the study by (Knuiman *et al.* 1993; Hadi *et al.*, 1995; Wang *et al.,* 1998) stated that when the median width is increasing, the frequency of crashes was also decreasing.

A study by Sheikh *et al.,* 2008; McClanahan *et al.,* 2004; Hunter *et al.,* 2001; Stein 2005; Marzougui *et al.,* 2007 also found that, a high level of severity typically associated with any cross-median crash. Missouri, in particular, found that expressways, with a median width less than 60 feet (18 m) had an overrepresentation of cross-median crashes (Chandler, 2007). As a result, the Missouri Department of Transportation proactively installed wire rope on all interstates with a median width less than 60 feet (18 m).

Moreover, in a book by Venkata, 2011 did mention, there is evidence that lower speeds result in fewer collisions of lesser severity. The faster the traffic speeds, the more collisions would have occurred. Venkata, 2011 also cited in a study by Andersson and Nilsson, 1997 who was developing a model based on experiments with different speed limits in Sweden found the probability of a fatal crash is related to speed. With the reduction of 10% in mean speed, there is a 40% reduction in fatalities. Research work by Finch *et al.,* (1994) reports every 1 km/h reduction in speed across the network leads to 3% drop in a crash. However, this result achieved on residential, and town centre roads and lower reductions are achieved in suburban and rural roads.

Villwock, Blond, & Tarko, 2011 study regarding wire rope on crash frequency and severity. As in their findings, the most severe crashes decrease more than 8% when adding a lane in each direction by installing a wire rope on the wide median. Meanwhile, the severe crashes are less than 6% when the width is reduced to the widening of the road by installing wire rope. Their findings further evaluate using the model. The model indicated that the frequency of crashes increases if the AADT increases. Besides, expressway segments with bridges, ramps and a high-speed limit tend to increase the number of crashes.

Innamaa, Norros, Kuusela, Rajamäki, & Pilli-sihvola, n.d. cited in Marchesini and Weijermars (2010) on the relationship between congestion and safety on expressways. They found that the likelihood of a crash seems to grow with speed variability, which is a common indicator of unstable traffic conditions. Large differences in speeds between lanes and density variations also appear to make crashes more likely. When searching for evidence to support the general perception that crash frequency increases with higher congestion levels, Marchesini and Weijermars (2010) came across conflicting results. Some studies found that high volume regarding capacity ratios led to higher crash rates; another study stated that crash rates decreased at high traffic densities. Additionally, one of the studies they examined did not find any relationship between congestion and crash frequency. None of the studies they looked at explicitly provided evidence on the influence of congested traffic conditions on crash rates.

Furthermore, Innamaa, Norros, Kuusela, Rajamäki, & Pilli-sihvola, n.d. also cited in Pajunen and Kulmala (1995) found that on two-lane roads, accident rates felt as hourly traffic volume increased. On four-lane roads, accident rates were highest at hourly traffic volumes of 3600 to 4800 vehicles. However, on highways, accident rates increased with rising hourly traffic volume and were highest at very low traffic volumes in both directions.

## 2.3 Road Crash Risk

This section discussed in other countries study regarding past study on road crash risk, then the relation between speed, volume and number of lanes with road crash risk and the last part is the formula used to compute road crash risk.

### 2.3.1 Previous Study on Road Crash Risk

The risk is a measure of the potential for a crash or casualty to take place. Risk a combination of two elements. The elements are the likelihood of a crash and the severity of that crash (Tuominen *et al.,* n.d.). The literature review revealed mostly past study related with motorcycle collision with barrier types. In addition, many other countries study regarding crash risk related to injury severity as compared to crash severity.

According to (C. Gabler, 2013) examines the issues related to fatal motorcycle collisions with a guardrail. He further investigated fatality risk for motorcycle collision with two types of the barrier, which are guardrail and concrete barriers. He analysed other studies indicated that the motorcycle impact with guardrails impacts is a much higher fatality risk rather than motorcycles crashes in general. Through his findings shows that, with guardrail collision, motorcycle riders have a higher risk of fatality than car occupants, which indicates over 80 times greater. In addition, guardrail collisions pose a significantly greater risk for motorcyclists than do collisions with either concrete barrier or cars. The fatality risk in motorcycle-guardrail collisions indicated is 12%, and the fatality risk in motorcycle-concrete barrier collisions is 8%.

Daniello & Gabler, 2011 also study about motorcycles. This is regarding motorcycle collisions with roadside objects in the United States. Roadside objects that analysed including guardrail. They also analysed fatality risk of motorcycle crashes based on crash data from 2004 to 2008. Based on their findings, motorcycle collisions with guardrail were seven times more likely to be fatal than collisions with the ground.

In addition, the study by Karim, Magnusson, & Wiklund, 2012 regarding the risk of personal injuries associated with barrier collisions using comprehensive crash data including actual barrier collisions consists of post-impact collisions by the year 2005 to 2008. The injury risk measured in the number of injuries per vehicle kilometre travelled. Findings show that the rate of injuries was higher with wire rope as compared to w-beam and concrete barriers.

Furthermore, the study by Prentkovskis *et al.,* 2009 stated that w-beam guardrails are intended for reducing the damage caused by crash rather than avoiding crashes. It may be supposed that w-beam guardrails reduce not only destructive effects but their rate as well. Actually, during a collision occurred between barriers, a driver is trying to avoid hitting that barrier. The efforts of the driver to avoid collision with a barrier help to reduce the crash rate. In addition, installing safety guardrails on a driving strip of a multilane road allows reducing casualty rates due to crash by about 20%. The rate of human injuries caused by crashes reducing by 5% and material losses caused by traffic accidents are increased by 25%. The most resilient barrier (e.g. wire rope) is most effective in reducing crashes causing injuries to the humans. However, they increase the rate of crashes causing material losses.

### 2.3.2 Relation between Speed, Volume and Number of Lanes with Road Crash Risk

In a book by Venkata, 2011 cited in Australian research found evidence regarding on increase in crash risk with an increasing travel speed. The reaction distance and the braking distance are also related to speed. Speed will increase both the reaction distance and the braking distance. A driver travelling at faster speeds will have reacted in between spotting and reacting to a hazard than a driver travelling at a slower speed, so the speeding driver is more likely to crash. Speeding also contributes to the increased risk of losing vehicle control. At higher speeds, cars become more difficult to manoeuvre, especially on curves where an evasive action is necessary (Transport Roads & Traffic Authority, 2011).

A study in Adelaide reports that travelling with 5 km/h over the speed limit doubles crash risk where the same effect of blood alcohol concentration (BAC) of 0.05. *(Karim et al.,* 2012) cited in Singelton *et al.,* 2004 and Ydenius, 2009 stated that, impact speed also affecting severity where the injury risk is proportional to impact speed. Posted speed limit also associated with higher crash severity.

A study by (Blackman and Haworth, 2013) regarding motorcyclist where they compared the crash risk and crash severity of three types of motorcycle (moped, scooter and motorcycle) in Queensland, Australia and using crash data for five years. Their findings show that motorcycle crash severity was associated with higher speed limits (more than 80 km/h) zones, horizontal curves, weekend, single vehicle and night-time crashes. Moped crashes were more severe at night and in speed zones of 90 km/h or more. Larger scooter crashes were more severe in 70 km/h zones (than 60 km/h zones) but not in higher speed zones, and less severe on weekends than on weekdays. The findings can be used to inform potential crash and injury countermeasures tailored to users of different powered two-wheelers (PTW) types.

In Sweden, wire rope is preferred as compared other barrier types mainly because of their low acquisition cost. It is worth noting that both w-beam barriers and wire rope fulfil the minimum requirements for safety performance. Hawzheen Karim, Moudud Alam, 2012 cited in studies by Carlsson and Brüde (2004, 2005, 2006) regarding performance on collision-free roads. They found that the damage risk for wire rope, expressed in the number of repairs per million vehicle kilometres, along roads with a speed limit of 110 km/h is 20% higher than on roads with a speed limit of 90 km/h.

On the other hand, Hawzheen Karim, Moudud Alam, 2012 also concluded that roads with a speed limit of 110 km/h usually have a better geometrical standard than roads with 90 km/h speed limits. This is due to smother alignment and better visibility probably contribute to a lower risk for damage roads with a 110 km/h speed limit. However, when the crash occurred, the impact forces increase the speed of the impacting vehicles cause the severe crash at the speed limit with 110

km/h. For median barriers along roads with a 90 km/h speed limit is contributed with higher crash risk because of these roads are usually located in urban regions with high traffic density, many connecting roads, and consequently, a higher crash risk.

### 2.3.3 Road Crash Risk Estimation

Road crash risk was computed by Liu, Chen, Lu, & Cao, 2010 study. They are using crash risk per million vehicles per kilometre by comparing crash risk for freeway segments with different types of lane arrangements. Therefore, in this study, the risk estimation in this study is referring to the road crash risk per million vehicles per kilometre (R) at an expressway segment. Risk was counted using the following formula:

$$R = \frac{1{,}000{,}000 \times A}{365 \times T \times V \times L}$$

Where A=number of crashes reported at the expressway segment (crashes per 5 years); T=number of years of the study period (T=5); V=Annual Daily Traffic (ADT) on the expressway mainline; and L denotes the length of the study area.

## 2.4 Effect of Median Barrier Types on Crash Severity

The effect of median barrier types on crash severity was analysed by comparing the odd ration (OR) of the fatal and non-fatal crash. OR was computed for comparisons between all barrier types.

### 2.4.1 Formula

The reported fatal and non-fatal crash related with median barrier was used to determine the different effect that each barrier type had on the severity of the road crash. For a direct comparison of the effect of barrier type of severity, the OR of fatal and non-fatal was computed for each barrier type by using formulas. The formula of odds ratio (OR), its standard error and 95% confidence interval are calculated according to Altman, 1998 as follows.
The odds ratio is given by

$$OR = \frac{a/b}{c/d} = \frac{a \times d}{b \times c}$$

with the standard error of the log odds ratio being

$$\mathrm{SE}\{\ln(OR)\} = \sqrt{\frac{1}{a} + \frac{1}{b} + \frac{1}{c} + \frac{1}{d}}$$

and 95% confidence interval

$$95\%\ \mathrm{CI} = \exp\left(\ln(OR) - 1.96 \times \mathrm{SE}\{\ln(OR)\}\right) \text{ to } \exp\left(\ln(OR) + 1.96 \times \mathrm{SE}\{\ln(OR)\}\right)$$

# 3. Methodology

The timeline of research was started from March to December 2015. Since this research an extension of the existing project in 2014, the same data available in the median barrier inventory data for seven expressways was used. Additionally, another data needed are secondary data from M-ROADS and MHA. M-ROADS provided crash data for the 2009-2013 timeframe. While MHA provided traffic volume data. Data analyses were conducted by using the road crash risk formula for risk analysis and odd-ratio analysis. Methodology framework as in Figure 4 and further detailed explanations as in part 3.1 until 3.4.

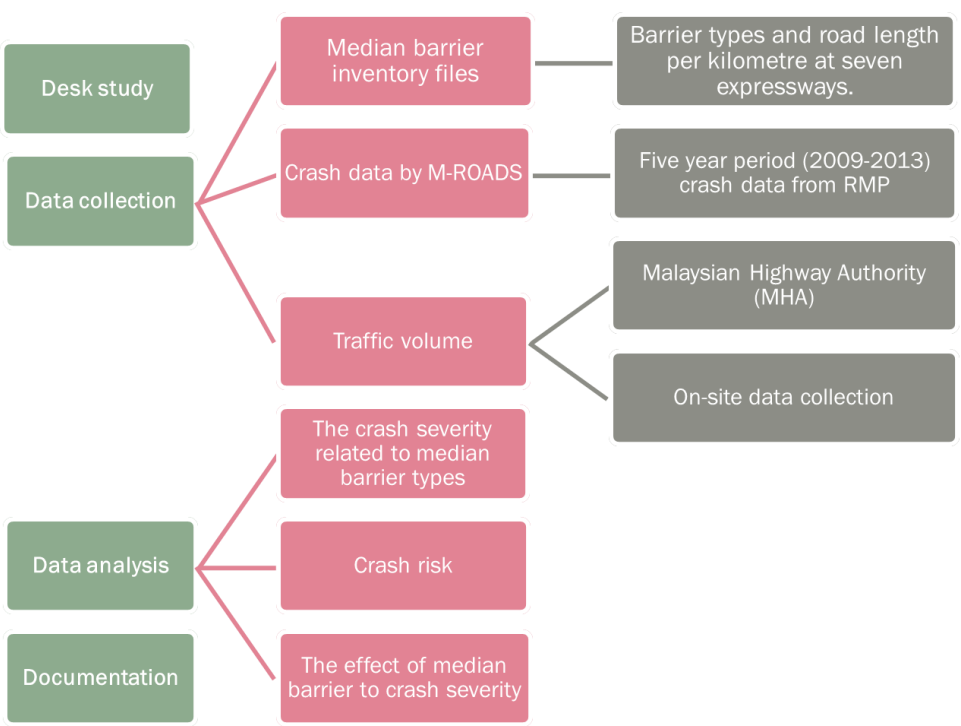


**Figure 4** Methodology framework

## 3.1 Desk Study

A desk study involved in the review of past study related to the effect of median barrier types on crash severity at expressways.

## 3.2 Data Collection

Secondary data was collected from the three main sources. The source is from median barrier inventory data (past research findings), crash data provided by M-ROADS and MHA. However, since there is a limitation in MHA provided traffic volume data at E21, E29 and E35, thus manual count on traffic volume has been conducted.

### 3.2.1 Median Barrier Inventory Data

Barrier types for every one kilometre length in seven rural expressways were acquired from median barrier inventory data. The inventory data required are kilometre post, barrier types, and road length per kilometre at seven rural expressways as in Table 2.

To date, the total available data for seven rural expressways are 936 km length. On the rural expressway included in the analysis, 859 km of expressways contained w-beam guardrail median barrier, 55 km contained concrete; and, 22 km contained wire rope median barrier.

**Table 2** Details on seven rural expressways

| Expressway | Length (km) | Section | Barrier types | Travel lane | Speed limit |
|---|---|---|---|---|---|
| North-South Expressway (Northern Route, E1) | 387 | Sungai Buloh to Jitra | Concrete, w-beam guardrail and wire rope | Two and three travel lanes per direction | 110 km/h |
| North-South Expressway (Southern Route, E2) | 275 | Johor Bahru to Bangi | Concrete, w-beam guardrail and wire rope | Two and three travel lanes per direction | 110 km/h |
| East Coast Expressway and Kuala Lumpur-Karak (LPT 1 & KLK, E8) | 160 | Gombak to Gambang | Concrete and w-beam guardrail | Two and three travel lanes per direction | 110 km/h, 90 km/h and 60 km/h |
| Guthrie Corridor Expressway (E35) | 16 | Shah Alam to Rawang | W-beam guardrail | Three travel lanes per direction | 110 km/h, 90 km/h and 80 km/h |
| North-South Expressway Central Link (ELITE, E6) | 37 | Nilai to Shah Alam | W-beam guardrail | Three travel lanes per direction | 110 km/h |
| Kajang-Seremban Highway (LEKAS, E21) | 40 | Ampangan to Semenyih | W-beam guardrail | Two and three travel lanes per direction | 110 km/h and 60 km/h |
| Seremban-Port Dickson Highway (SPDH, E29) | 21 | Port Dickson to Seremban | W-beam guardrail | Two travel lanes per direction | 110 km/h and 80 km/h |

*Source:* Nora Sheda, M.Z., & Norfaizah, M.K., 2015

### 3.2.2 Road Crash Data by M-ROADS

M-ROADS provided road crash data were acquired from the RMP for a five-year (2009 -2013) trend based on the type of crash severity (fatal, serious and slight crash). Total crashes occurring between 2009 until 2013 on rural expressways for every kilometre were used for the analysis. Thus, M-ROADS provided crash per kilometre based on kilometre post obtained from inventory. Crash severity such as the fatal, serious and slightly crash divided into two groups. Fatal crash grouped as fatal crash and serious with slightly crash grouped as a non-fatal crash. This data need to be in grouped to ease the data analysis part.

### 3.2.3 Traffic Volume Data

Classified traffic volume data collected from the Malaysian Highway Authority (MHA) and the manual count. Out of seven rural expressways, four sites obtained data from MHA and three sites based on manually count data. MHA provided an average daily traffic (ADT) of traffic volume by origin and destination for the year 2013 by all vehicle classes.

Due to unavailability of data from MHA, manual counts conducted at three expressways are LEKAS, SPDH and GUTHRIE. The classified traffic volume by vehicle types including car, motorcycle, lorry 2 axle, lorry 3 axle and bus were considered to represent the mixed traffic using rural expressways. The traffic volume was collected for a one-hour period during peak hour in the morning time. The one-hour traffic volume then converted into ADT. The ADT was estimated based on Guidebook for Traffic & Road Safety Audit, 2012 which stated that, ADT equal to one-hour traffic count during peak hours, *A* times by ten (ADT=*A*x10).

## 3.3 Data Analysis

Three types of analysis conducted in this study. The details as below:

### 3.3.1 Fatal and Non-Fatal Crash Frequency

The number of crashes related to median barrier types can be concluded by using data provided from RMP in POL27 (comment part). However, the available data that contained a comment from the police only from the year 2009 until 2011 (3 years only).

### 3.3.2 Road Crash Risk

The risk estimation in this study is referring to the crash risk per million vehicles per kilometre (R) at an expressway segment. Risk was counted using the following formula based on Liu, Chen, Lu, & Cao, 2010 study:

$$R = \frac{1{,}000{,}000 \times A}{365 \times T \times V \times L}$$

Where A=number of crashes reported at the expressway segment (crashes per 5 years); T=number of years of the study period (T=5); V=Annual Daily Traffic (ADT) on the expressway mainline; and L denotes the length of the study area.

### 3.3.3 Effect of Median Barrier Types on Crash Severity

The odds ratio analysed was conducted in this study to find the effect of median barrier types on crash severity.

## 3.4 Report Writing

The results obtained were highlighted in the discussion. A few conclusions were made and recommendations were listed. Suggestions on how to improve the further study were also included at the end of this report.

# 4. Results and Discussions

This section discusses the results and findings of the study. This section is divided into four subsections; the first findings discussed on the type of crash severity related to median barrier type, second findings is regarding crash risk, the third finding is regarding effect of median barrier types to crash severity, and last subsections discussed on the summary of findings.

## 4.1 Crash Severity Related to Median Barrier Type

From 2009 to 2011, 120 crashes related to hitting roadside and median safety barrier was reported on seven selected rural expressways. Out of that, only 52 crashes related to hitting the median safety barrier. The barrier type of these 52 crashes was identified by using inventory data based on kilometre stated in the comment part in Road Accident Police Form (POL27). Table 3 shows the distribution of crash severity by barrier type.

**Table 3** Crash severity by barrier type in seven rural expressways

| Barrier type | Crash severity | | Total |
|---|---|---|---|
| | Fatal | Non-fatal | |
| W-beam guardrail | 27 | 15 | 42 |
| Concrete barrier | 3 | 3 | 6 |
| Wire rope barrier | 1 | 3 | 4 |
| Total | 31 | 21 | 52 |

Figure 5 discussed the distribution of crash severity for each barrier type. The majority of the crashes resulted in fatal and non-fatal crashes for all median barrier types. A higher percentage of w-beam guardrail crashes resulted in a fatal crash

than did the other barrier types. Whereas, the percentage of wire rope crashes resulted from highest involved in the non-fatal crash as compared to other barrier types. However, a larger number of crashes occurred with w-beam guardrails than with wire rope and concrete median barrier.

This finding also supported the study by (Sposito and Johnston 1998; Sheikh *et al.,* 2008; McClanahan *et al.,* 2004; Hunter *et al.,* 2001) regarding their findings related to the wire rope. They indicated as wire rope has many benefits rather than concrete and w-beam guardrail barrier. However, there are also disadvantages associated with wire rope. Wire rope has been found to increase the frequency of crashes. This was also consistent with findings by (Hawzheen Karim, Moudud Alam, 2012) did mention, the number of barrier repairs and the average repair cost per vehicle kilometre for wire rope median barriers is higher than for median w-beam barriers, regardless of the road type. However, although an increase in the number of crashes is undesirable, this outcome is mitigated by the fact that wire rope has been shown to reduce the severity of crashes.

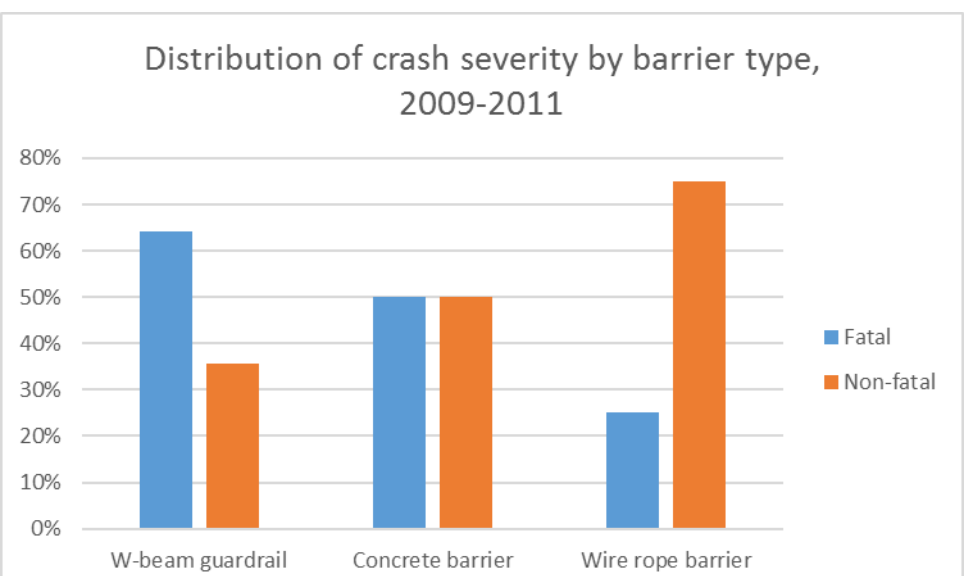


**Figure 5** Distribution of crash severity by barrier type in seven rural expressways, 2009-2011

## 4.2 Road Crash Risk

This section deliberated road crash risk by expressway exit and road crash risk by barrier type. To calculate the crash risk, M-ROADS provided crash data for a five-year period (2009-2013) based on the type of crash severity (fatal, serious and slight crash). Thus, total crashes occurring between 2009 until 2013 on rural expressways for every kilometre were used for this analysis.

### 4.2.1 Road Crash Risk by Expressway's Exit

Seven locations computed road crash risk as provided in section 4.2.1.1 until 4.2.1.7.

#### 4.2.1.1 PLUS North Bound (E1)

Road crash risk was computed by using a formula as stated in Chapter 3. As in Table 4, the five highest fatal and non-fatal crash risks by expressway exit were short-listed. A detailed fatal and non-fatal crash risk by expressway's exit along PLUS North Bound (E1) as in Appendix 1. Among the fifth, the highest fatal risk involved with the w-beam guardrail at Lembah Beringin to Bukit Tagar section. The fatal crash risk value is 0.037 indicated that, about 0.037 crashes for every million vehicles involving w-beam guardrail at that section of the E1 expressway for the five-year period. Whereas, the highest non-fatal crash risk also has related with w-beam guardrail but in a different expressway section of Sungai Petani (North Bound) to Sungai Petani (South Bound). The non-fatal crash risk value is 0.083 per million vehicles.

**Table 4** Road crash risk of expressway at selected exit per million vehicles involving median barrier types at E1

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Gurun to SP (U) | W-beam guardrail | 16 | 34504 | 28 | 0.028 | 60 | 0.060 |
| SP (U) to SP (S) | W-beam guardrail | 8 | 38658 | 20 | 0.035 | 47 | **0.083** |
| SP (S) to Bertam | W-beam guardrail | 13 | 53923 | 31 | 0.024 | 48 | 0.038 |
| Jawi to Bandar Baharu | W-beam guardrail | 12 | 40235 | 28 | 0.032 | 61 | 0.069 |
| Bandar Baharu to Bkt Merah | W-beam guardrail | 17 | 41837 | 11 | 0.008 | 71 | 0.055 |
| Kuala Kangsar to Ipoh (U) | W-beam guardrail | 1 | 50330 | 3 | 0.033 | 0 | 0.000 |
| | Concrete | 1 | 50330 | 3 | 0.033 | 3 | 0.033 |
| L. Beringin to Bukit Tagar | W-beam guardrail | 6 | 59993 | 24 | **0.037** | 13 | 0.020 |

#### 4.2.1.2 PLUS South Bound (E2)

Table 5 indicated the crash risk of fatal and non-fatal at E2 (selected exits with the five highest of crash risk fatal and non-fatal. A detailed fatal and non-fatal crash risk by expressway exit along PLUS South Bound (E2) can be referred in Appendix 1. The highest fatal risk value is 0.060 within Pagoh to Tangkak section. The median barrier located in that section is a wire rope median barrier. The fatal crash risk value is 0.060 indicated that, about 0.060 crashes for every million vehicles involving wire rope at that section of the E2 expressway for the five-year period. Whereas, the highest non-fatal crash risk at Yong Peng (North Bound) to Pagoh with risk value 0.051 per million vehicles with w-beam guardrail median barrier.

**Table 5** Road crash risk of expressway at selected exit per million vehicles involving median barrier types by expressway location at E2

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Kulai to Sedenak | W-beam guardrail | 8 | 56562 | 26 | 0.031 | 6 | 0.007 |
| S. Renggam to Machap | W-beam guardrail | 18 | 48106 | 44 | 0.028 | 16 | 0.010 |
| Y. Peng (S) to Y. Peng (U) | W-beam guardrail | 13 | 37762 | 16 | 0.018 | 32 | 0.036 |
| Y. Peng (U) to Pagoh | W-beam guardrail | 6 | 37476 | 2 | 0.005 | 21 | **0.051** |
| Pagoh to Tangkak | Wire rope | 1 | 36494 | 4 | **0.060** | 0 | 0.000 |
| | W-beam guardrail | 1 | 36494 | 3 | 0.045 | 3 | 0.045 |
| | Wire rope | 2 | 36494 | 6 | 0.045 | 5 | 0.038 |
| Tangkak to Jasin | Wire rope | 2 | 44786 | 2 | 0.012 | 8 | 0.049 |

#### 4.2.1.3 ELITE (E6)

Rural expressway at ELITE only installed with the w-beam guardrail. As in Table 6, the highest fatal risk involved with w-beam guardrail within Putrajaya to KLIA section. The fatal crash risk value is 0.009, meaning of about 0.009 crashes for every million vehicles involving w-beam guardrail at that section of the E6 expressway for the five-year period. Whereas the highest non-fatal crash risk also has related with a w-beam guardrail, but within Putra Height to Bandar Sri Putra section. The non-fatal crash risk value is 0.004 per million vehicles.

Table 6 Road crash risk of expressway every exit per million vehicles involving median barrier types by expressway location at E6

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Seafield to USJ | W-beam guardrail | 4 | 132255 | 2 | 0.002 | 0 | 0.000 |
| USJ to P. Height | W-beam guardrail | 4 | 120730 | 4 | 0.005 | 2 | 0.002 |
| P. Height to Bdr. S. Putra | W-beam guardrail | 4 | 126276 | 5 | 0.005 | 4 | **0.004** |
| Bdr. S. Putra to Putrajaya | W-beam guardrail | 11 | 100929 | 12 | 0.006 | 4 | 0.002 |
| Putrajaya to KLIA | W-beam guardrail | 13 | 92664 | 20 | **0.009** | 3 | 0.001 |

#### 4.2.1.4 KLK (E8)

Table 7 showed the crash risk of fatal and non-fatal at Kuala Lumpur-Karak, E8. The highest fatal risk value is 0.021 from Gombak to Bentong section. The median barrier located in that section is a concrete median barrier. The fatal crash risk value is 0.021 indicating that, about 0.021 crashes for every million vehicles involving concrete median barrier at that section of the E8 expressway for the five-year period. Whereas, the highest non-fatal crash risk also from Gombak to Bentong section and the risk value is 0.010 per million vehicles.

**Table 7** Road crash risk of expressway every exit per million vehicles involving median barrier types by expressway location at E8

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Gombak to Bentong | Concrete | 27 | 59617 | 61 | **0.021** | 30 | **0.010** |
| Bentong to Karak | Concrete | 15 | 41754 | 8 | 0.007 | 1 | 0.001 |
| | W-beam guardrail | 3 | 41754 | 3 | 0.013 | 0 | 0.000 |

#### 4.2.1.5 LEKAS (E21)

LEKAS Expressway consists of three types of median barrier. The median barrier types are concrete, w-beam guardrail and concrete. However, in this study, the location within study area only located with w-beam guardrail. There is 0.055 fatal crash risk value involved from Pajam to Mantin. This is indicated that, about 0.055 crashes for every million vehicles involving w-beam guardrail median barrier at that section of the E21 expressway for the five-year period. Whereas the highest non-fatal crash risk is from Setul to Temiang/Seremban section, and the risk value is 0.095 per million vehicles.

**Table 8** Road crash risk of expressway every exit per million vehicles involving median barrier types by expressway location at E21

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Kajang (S) to Semenyih | W-beam guardrail | 2 | 33010 | 0 | 0.000 | 1 | 0.008 |
| Semenyih to Pajam | W-beam guardrail | 12 | 15750 | 6 | 0.017 | 3 | 0.009 |
| Pajam to Mantin | W-beam guardrail | 7 | 8530 | 6 | **0.055** | 8 | 0.073 |
| Mantin to Setul | W-beam guardrail | 6 | 7980 | 2 | 0.023 | 4 | 0.046 |
| Setul to Temiang/ Seremban | W-beam guardrail | 1 | 17320 | 1 | 0.032 | 3 | **0.095** |
| Temiang/ Seremban to Ampangan | W-beam guardrail | 6 | 7750 | 0 | 0.000 | 1 | 0.012 |

#### 4.2.1.6 SPDH (E29)

SPDH expressways only installed w-beam guardrail along their rural expressway as in Table 9. The fatal and non-fatal crash risk value only slightly different. The highest fatal crash value is 0.063 from Lukut to Port Dickson. So that, 0.063 crashes for every million vehicles involving w-beam guardrail median barrier at that section of the E29 expressway for the five-year period. While the highest non-fatal crash risk is 0.137 crash risk value per million vehicles.

Table 9 Road crash risk of expressway every exit per million vehicles involving median barrier types by expressway location at E29

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total Non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Seremban to Lukut | W-beam guardrail | 11 | 11280 | 14 | 0.062 | 24 | 0.106 |
| Lukut to Port Dickson | W-beam guardrail | 10 | 9600 | 11 | **0.063** | 24 | **0.137** |

#### 4.2.1.7 GUTHRIE (E35)

Table 10 showed the crash risk of fatal and non-fatal at GUTHRIE, E35. This expressway also only installed with the w-beam guardrail. The highest fatal risk value is 0.026 from Puncak Alam to Bukit Subang section. The fatal crash risk value indicated that, about 0.026 crashes for every million vehicles involving w-beam guardrail median barrier at that section of the E35 expressway for the five-year period. Whereas, the highest non-fatal crash risk from Bukit Subang to Tol Elmina section and the risk value is 0.027 per million vehicles.

**Table 10** Road crash risk of expressway every exit per million vehicles involving median barrier types by expressway location at E35

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Puncak Alam to Bukit Subang | W-beam guardrail | 1 | 21440 | 1 | **0.026** | 1 | 0.026 |
| Bukit Subang to Tol Elmina | W-beam guardrail | 1 | 20160 | 0 | 0.000 | 1 | **0.027** |
| Tol Elmina to Paya Jaras | W-beam guardrail | 7 | 17520 | 0 | 0.000 | 1 | 0.004 |
| Paya Jaras to Lagong | W-beam guardrail | 6 | 16400 | 1 | 0.006 | 1 | 0.006 |

### 4.2.2 Road Crash Risk by Barrier Type

This section discusses on road crash risk at seven rural expressways according to each barrier type. Findings as below:

#### 4.2.2.1 PLUS North Bound (E1)

As in Table 11, the crash risk value is small for all median types. The w-beam guardrail median barrier gives the risk value (0.001) for fatal and non-fatal crash risk. This risk value indicated that 0.001 crashes for every million vehicles involving w-beam guardrail median barrier at the E1 expressway for the five-year period. For concrete, the risk value is 0.009 fatal crashes for every million vehicles involving concrete median barrier at the E1 expressway for the five-year period, and the non-fatal risk value is 0.006 crashes for every million vehicles involving concrete median barrier at the E1 expressway for the five-year period. Calculating for wire rope fatal crash risk indicated 0.010 crashes for every million vehicles involving wire rope median barrier at the E1 expressway for the five-year period and indicated 0.015 crashes for every million vehicles involving wire rope median barrier at the E1 expressway for the five-year period.

**Table 11** Road crash risk of expressway per million vehicles involving median barrier types by barrier types at E1

| Barrier type | Road length | ADT | Fatal | Crash risk (Fatal) | Non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|
| W-beam guardrail | 344 | 1397675 | 504 | 0.001 | 662 | 0.001 |
| Concrete | 22 | 92385 | 32 | 0.009 | 21 | 0.006 |
| Wire rope | 7 | 63144 | 8 | 0.010 | 12 | 0.015 |

#### 4.2.2.2 PLUS South Bound (E2)

Same results indicated at fatal and non-fatal crash risk by barrier type of PLUS South Bound (see Table 12) for the w-beam guardrail. The w-beam guardrail median barrier gives the fatal and non-fatal risk value of 0.001, indicated that 0.001 crashes for every million vehicles involving w-beam guardrail median barrier at the E2 expressway for the five-year period. The fatal risk value of concrete median barrier is 0.014 crashes, and non-fatal risk is 0.023 for every million vehicles involving concrete median barrier at the E1 expressway for the five-year period. Whereas, for wire rope fatal crash risk indicated 0.004 and non-fatal with 0.005 crashes for every million vehicles involving wire rope median barrier at the E1 expressway for the five-year period.

**Table 12** Road crash risk of expressway per million vehicles involving median barrier types by barrier types at E2

| Barrier type | Road length | ADT | Fatal | Crash risk (Fatal) | Non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|
| W-beam guardrail | 257 | 1361813 | 514 | 0.001 | 549 | 0.001 |
| Concrete | 2 | 215383 | 11 | 0.014 | 18 | 0.023 |
| Wire rope | 17 | 162560 | 21 | 0.004 | 25 | 0.005 |

#### 4.2.2.3 ELITE (E6)

ELITE Expressway as mention earlier only consists of the w-beam guardrail. Results indicated only with fatal crash risk (Table 13). The w-beam guardrail median barrier gives the risk value 0.001 indicated that 0.001 crashes for every million vehicles involving w-beam guardrail median barrier at the E6 expressway for the five-year period.

**Table 13** Road crash risk of expressway per million vehicles involving median barrier types by barrier types at E6

| Barrier type | Road length | ADT | Fatal | Crash risk (Fatal) | Non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|
| W-beam guardrail | 36 | 572855 | 43 | 0.001 | 13 | 0.000 |
| Concrete | - | - | - | - | - | - |
| Wire rope | - | - | - | - | - | - |

#### 4.2.2.4 KLK (E8)

Kuala Lumpur-Karak Expressway consists of w-beam guardrail and concrete median barrier as in Table 14. The w-beam guardrail median barrier gives the fatal risk value 0.013 crashes for every million vehicles involving w-beam guardrail median barrier at the E8 expressway for the five-year period. No non-fatal crash risk at E8 with this type of median barrier. Whereas, the risk value of concrete median barrier is 0.009 crashes for every million vehicles involving concrete median barrier at the E8 expressway for the five-year period and non-fatal crash risk shown 0.004 crashes for every million vehicles involving concrete median barrier at the E8 expressway for the five-year period.

**Table 14** Road crash risk of expressway per million vehicles involving median barrier types by barrier types at E8

| Barrier type | Road length | ADT | Fatal | Crash risk (Fatal) | Non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|
| W-beam guardrail | 3 | 41754 | 3 | 0.013 | 0 | 0.000 |
| Concrete | 42 | 101371 | 69 | 0.009 | 33 | 0.004 |
| Wire rope | - | - | - | - | - | - |

#### 4.2.2.5 LEKAS (E21)

Study location only covered with the w-beam guardrail at LEKAS (Table 15). The fatal crash risk w-beam guardrail median barrier gives the risk value 0.003 indicated that crashes for every million vehicles involving w-beam guardrail median barrier at the E21 expressway for the five-year period and 0.004 non-fatal crashes for every million vehicles involving w-beam guardrail median barrier at the E21 expressway for the five-year period.

**Table 15** Road crash risk of expressway per million vehicles involving median barrier types by barrier types at E21

| Barrier type | Road length | ADT | Fatal | Crash risk (Fatal) | Non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|
| W-beam guardrail | 34 | 90340 | 15 | 0.003 | 20 | 0.004 |
| Concrete | - | - | - | - | - | - |
| Wire rope | - | - | - | - | - | - |

#### 4.2.2.6 SPDH (E29)

Seremban-Port Dickson Highway comprises of the w-beam guardrail (Table 16). The w-beam guardrail median barrier gives the fatal risk value 0.031 and 0.060 non-fatal crash risk. This is indicated that 0.031 and 0.060 crashes for every million vehicles involving w-beam guardrail median barrier at the E29 expressway for the five-year period respectively.

Table 16 Road crash risk of expressway per million vehicles involving median barrier types by barrier types at E29

| Barrier type | Road length | ADT | Fatal | Crash risk (Fatal) | Non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|
| W-beam guardrail | 21 | 20880 | 25 | 0.031 | 48 | 0.060 |
| Concrete | - | - | - | - | - | - |
| Wire rope | - | - | - | - | - | - |

### 4.2.2.7 GUTHRIE (E35)

GUTHRIE also encompasses of w-beam guardrail (Table 17). The w-beam guardrail median barrier gives the fatal risk value 0.001 indicated that 0.001 crashes for every million vehicles involving w-beam guardrail median barrier at the E17 expressway for the five-year period. Whereas, the non-fatal risk value 0.002 indicated that 0.002 crashes for every million vehicles involving w-beam guardrail median barrier at the E17 expressway for the five-year period.

Table 17 Road crash risk of expressway per million vehicles involving median barrier types by barrier types at E35

| Barrier type | Road length | ADT | Fatal | Crash risk (Fatal) | Non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|
| W-beam guardrail | 15 | 75520 | 2 | 0.001 | 4 | 0.002 |
| Concrete | - | - | - | - | - | - |
| Wire rope | - | - | - | - | - | - |

## 4.3 Effect of Median Barrier Types to Crash Severity

The entire data set was analysed to determine whether median barrier had an effect on crash severity. However, to compute the effect of median barrier types to crash severity need to used hitting median barrier type data that obtained from POL27 (comment part). The effect of median barrier types on crash severity was analysed by comparing the odds ratio (OR) of a fatal and non-fatal crash by using the formula as mentioned in Chapter 2. OR was computed for comparisons between all barrier types as in Table 18.

As in Table 18, the odds of fatal crashes at a location located with w-beam guardrail is 1.8 times higher (95% CI: 0.3222 to 10.0552) than in location located with the concrete barrier installation. However, this difference was found not to be statistically significant. While the odds of fatal crashes in the area of the w-beam guardrail is 5.4 times higher (95% CI: 0.5152 to 56.5982) than in areas with installed wire rope. However, this difference also was found not to be statistically significant. Then by comparing the fatal crashes located with concrete median barrier is 3 times higher (95% CI: 0.5152 to 56.5982) than in areas with installed wire rope. These results also found not statistically significant. Next is, wire rope was compared with both w-beam guardrail and concrete median barrier. The OR of fatal crash are 0.2 (95% CI: 0.0177 - 1.9410) and 0.3 (95% CI: 0.0208 - 5.3294) respectively. This result was also found not to be statistically significant.

**Table 18** Odds ratio of crash severity in barrier crashes

| Barrier type | OR of crash severity (95% CI) |
|---|---|
| W-beam – concrete | 1.8 (0.3222 - 10.0552) |
| W-beam – wire rope | 5.4 (0.5152 - 56.5982) |
| Concrete – w-beam | 0.6 (0.0995 - 3.1035) |
| Concrete – wire rope | 3.0 (0.1876 - 47.9650) |
| Wire rope – concrete | 0.3 (0.0208 - 5.3294) |
| Wire rope – w-beam | 0.2 (0.0177 - 1.9410) |

## 4.4 Summary of Findings

Crash severity related to median barrier types was computed using crash data provided by RMP from 2009 to 2011. 120 crashes related to hitting roadside and median safety barrier was reported on seven selected rural expressways. Out of that, only 52 crashes related to hitting the median safety barrier. Findings show that the majority of the crashes resulted in fatal and non-fatal crashes for all median barrier types. A higher percentage of w-beam guardrail crashes resulted in a fatal crash than did the other barrier types. Whereas the percentage of wire rope crashes resulted from highest involved in the non-fatal crash as compared to other barrier types. This finding was supported by another study; (Sposito and Johnston 1998; Sheikh *et al.,* 2008; McClanahan *et al.,* 2004; Hunter *et al.,* 2001) regarding their findings related to the wire rope. They indicated as wire rope has many benefits rather than concrete and w-beam guardrail barrier. However, there are also disadvantages associated with wire rope. Wire rope has been found to increase the frequency of crashes. This is also consistent with findings by (Hawzheen Karim, Moudud Alam, 2012) did mention, the number of barrier repairs and the average repair cost per vehicle kilometre for wire rope median barriers is higher than for median w-beam barriers, regardless of the road type. However, although an increase in the number of crashes is undesirable, this outcome is mitigated by the fact that wire rope has been shown to reduce the severity of crashes.

Furthermore, the road crash risk was computed by using a formula as stated. Each expressways location gave the different of fatal and non-fatal road crash risk. The crash risk value has calculated the risk of crash severity per million vehicles involving median barrier types at expressway for the five-year period. The data only briefly discusses the highest crash risk value by seven rural expressways. The summary of this part provided in Table 19:

**Table 19** Summary of the highest crash risk value by expressway's exit

| Expressway | Exit | Crash risk per million vehicles | Median barrier type |
|---|---|---|---|
| *E1* | Lembah Beringin to Bkt. Tagar | Fatal (0.037) | W-beam guardrail |
| | Sg. Petani (U) to Sg. Petani (S) | Non-fatal (0.083) | |
| *E2* | Pagoh to Tangkak | Fatal (0.006) | Wire rope |
| | Yong Peng (U) to Pagoh | Non-fatal (0.051) | W-beam guardrail |
| *E6* | Putrajaya to KLIA | Fatal (0.009) | W-beam guardrail |
| | Putra Height to Bdr. Seri Putra | Non-fatal (0.004) | |
| *E8* | Gombak to Bentong | Fatal (0.021) | Concrete |
| | | Non-fatal (0.010) | |
| *E21* | Pajam to Mantin | Fatal (0.055) | W-beam guardrail |
| | Setul to Temiang/Seremban | Non-fatal (0.095) | |
| *E29* | Lukut to Port Dickson | Fatal (0.063) | W-beam guardrail |
| | | Non-fatal (0.137) | |
| *E35* | Puncak Alam to Bkt. Subang | Fatal (0.026) | W-beam guardrail |
| | Bkt. Subang to Elmina Toll | Non-fatal (0.027) | |

Regarding crash risk by barrier type, the crash risk value is small for all median types. The crash risk value has also calculated the risk of crash severity per million vehicles involving three types of the median barrier at expressway for the five-year period. Out of seven expressways, Seremban-Port Dickson Expressway (E29) shows the highest fatal and non-fatal crash risk for the w-beam guardrail. Whereas for the concrete barrier, Kuala Lumpur-Karak Expressway (E8) indicated has higher fatal and non-fatal crash risk. Lastly, wire rope has shown higher fatal crash risk at PLUS (South Bound).

In addition, for the effect of median barrier types to crash severity was analysed using an odd ratio. This analysed also using hitting median barrier type data that obtained from POL27 (comment part). The findings show that w-beam guardrail has the greater effect on fatal crash since that median barrier type was 91% installed in rural expressway as compared to concrete and wire rope median barrier. The result shows that the odds of fatal crashes at the location located with w-beam guardrail is 1.8 times higher (95% CI: 0.3222 to 10.0552) than in location located with the concrete barrier installation area. While the odds of fatal crashes in the w-beam guardrail is 5.4 times higher (95% CI: 0.5152 to 56.5982) than in areas with installed wire rope. However, this difference also was found not to be statistically significant because a limited number of crash severity-median barrier collision data.

# 5. Conclusion and Recommendations

This study has two main objectives. The first objective is to identify the crash severity related to median barrier types. Thus, crash severity related to median barrier types was computed using crash data provided by RMP from 2009 to 2011. 52 crashes reported has related to hitting the median safety barrier. Findings show that the majority of the crashes resulted in fatal and non-fatal crashes for all median barrier types. Therefore, it can be concluded that a higher percentage of w-beam guardrail crashes (64.3%) resulted in a fatal crash than did the other median barrier types. Whereas, the percentage of wire rope crashes (75%) resulted from highest involved in non-fatal crashes as compared to other median barrier types.

The second objective is to identify the risk of median barrier types on crash severity. Furthermore, the crash risk was computed by using a formula as stated. Each expressways exit gave the different of fatal and non-fatal crash risk. By comparing based on barrier types also indicated that the crash risk value is small for all median types. The crash risk value has calculated the risk of crash severity per million vehicles involving median barrier types at expressway for the five-year period.

Therefore, the aim of this study was to determine the effect of median barrier types on crash severity could be concluded. Based on past study findings, 91% of rural expressways were installed with the w-beam guardrail. Thus, the result can be concluded that the odds of fatal crashes at a location located with w-beam guardrail is 1.8 times higher (95% CI: 0.3222 to 10.0552) than in the concrete barrier installation. While the odds of fatal crashes in the w-beam guardrail is 5.4 times higher (95% CI: 0.5152 to 56.5982) than in areas with installed wire rope. However, this difference also was found not to be statistically significant because a limited number of crash severity-median barrier collision data.

As a consequence of this study, the recommendation is proposed:

- The crash data provided by police or road authority should be enhanced. This is because, for road safety research, accurate crash data along with periodic updating are required. In addition, the quality of the data also affected the usability of data. Thus, overall the crash data systems in Malaysia have a need for improvement.

Recommendation for future study:

- A similar study is recommended to be conducted by another researcher in regard to motorcycle safety. The past literature review shows that motorcycle collisions with barriers have been shown to be much more severe than other vehicle collisions with barriers. Furthermore, the impact of barrier type on injury severity for motorcyclists has been greatly debated. There is growing concern about the risk associated with motorcycles colliding with a safety crash barrier.

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# APPENDIX

# APPENDIX 1: Road crash risk by expressway's exit at PLUS North Bound (E1)

Road crash risk of expressway every exit per million vehicles involving median barrier types at E1

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Toll Hutan Kg. to A. Setar (U) | Wire rope | 1 | 26467 | 1 | 0.021 | 1 | 0.021 |
| | W-beam guardrail | 1 | 26467 | 0 | 0.000 | 1 | 0.021 |
| A. Setar (U) to A. Setar (S) | W-beam guardrail | 6 | 29685 | 8 | 0.025 | 7 | 0.022 |
| A. Setar (S) to Pendang | W-beam guardrail | 13 | 36233 | 19 | 0.022 | 16 | 0.019 |
| Pendang to Gurun | W-beam guardrail | 13 | 36677 | 12 | 0.014 | 23 | 0.026 |
| | Wire rope | 6 | 36677 | 7 | 0.017 | 11 | 0.027 |
| Gurun to SP (U) | W-beam guardrail | 16 | 34504 | 28 | 0.028 | 60 | 0.060 |
| SP (U) to SP (S) | W-beam guardrail | 8 | 38658 | 20 | 0.035 | 47 | 0.083 |
| SP (S) to Bertam | W-beam guardrail | 13 | 53923 | 31 | 0.024 | 48 | 0.038 |
| Bertam to Sg. Dua | W-beam guardrail | 9 | 61348 | 21 | 0.021 | 35 | 0.035 |
| Juru to B. Tambun (U) | W-beam guardrail | 4 | 76621 | 14 | 0.025 | 4 | 0.007 |
| B. Tambun (U) to B. Tambun (S) | W-beam guardrail | 4 | 70415 | 7 | 0.014 | 6 | 0.012 |
| B. Tambun (S) to Jawi | W-beam guardrail | 8 | 59515 | 13 | 0.015 | 9 | 0.010 |
| Jawi to Bandar Baharu | W-beam guardrail | 12 | 40235 | 28 | 0.032 | 61 | 0.069 |

Road crash risk of expressway every exit per million vehicles involving median barrier types at E1

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Bandar Baharu to Bkt. Merah | W-beam guardrail | 17 | 41837 | 11 | 0.008 | 71 | 0.055 |
| Bkt. Merah to Taiping (U) | W-beam guardrail | 12 | 41573 | 13 | 0.014 | 31 | 0.034 |
| Taiping (U) to C. Jering | W-beam guardrail | 15 | 37102 | 12 | 0.012 | 14 | 0.014 |
| C. Jering to Kuala Kangsar | W-beam guardrail | 8 | 42055 | 9 | 0.015 | 8 | 0.013 |
| | Concrete | 5 | 42055 | 12 | 0.031 | 12 | 0.031 |
| | W-beam guardrail | 7 | 42055 | 3 | 0.006 | 2 | 0.004 |
| Kuala Kangsar to Ipoh (U) | W-beam guardrail | 7 | 50330 | 11 | 0.017 | 5 | 0.008 |
| | W-beam guardrail | 5 | 50330 | 3 | 0.007 | 3 | 0.007 |
| | Concrete | 6 | 50330 | 8 | 0.015 | 5 | 0.009 |
| | Concrete | 4 | 50330 | 7 | 0.019 | 1 | 0.003 |
| | W-beam guardrail | 1 | 50330 | 3 | 0.033 | 0 | 0.000 |
| | Concrete | 3 | 50330 | 3 | 0.011 | 1 | 0.004 |
| | W-beam guardrail | 1 | 50330 | 0 | 0.000 | 1 | 0.011 |
| | Concrete | 1 | 50330 | 3 | 0.033 | 3 | 0.033 |
| | W-beam guardrail | 2 | 50330 | 2 | 0.011 | 2 | 0.011 |
| | Concrete | 1 | 50330 | 0 | 0.000 | 1 | 0.011 |
| | W-beam guardrail | 3 | 50330 | 3 | 0.011 | 0 | 0.000 |
| | Concrete | 3 | 50330 | 2 | 0.007 | 1 | 0.004 |
| Ipoh (U) to Ipoh (S) | W-beam guardrail | 15 | 28081 | 13 | 0.017 | 9 | 0.012 |

Road crash risk of expressway every exit per million vehicles involving median barrier types at E1

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Ipoh (S) to Simpang Pulai | W-beam guardrail | 30 | 52941 | 51 | 0.018 | 33 | 0.011 |
| Simpang Pulai to Gopeng | W-beam guardrail | 14 | 51295 | 18 | 0.014 | 21 | 0.016 |
| Gopeng to Tapah | W-beam guardrail | 13 | 47574 | 19 | 0.017 | 13 | 0.012 |
| Tapah to Bidor | W-beam guardrail | 19 | 49476 | 21 | 0.012 | 42 | 0.024 |
| Bidor to Sungkai | W-beam guardrail | 16 | 49243 | 17 | 0.012 | 38 | 0.026 |
| Sungkai to Slim River | W-beam guardrail | 12 | 52814 | 22 | 0.019 | 15 | 0.013 |
| Slim River to Behrang | W-beam guardrail | 9 | 53501 | 11 | 0.013 | 5 | 0.006 |
| Behrang to Tg. Malim | W-beam guardrail | 10 | 54537 | 18 | 0.018 | 10 | 0.010 |
| Tg. Malim to L. Beringin | W-beam guardrail | 9 | 59789 | 10 | 0.010 | 5 | 0.005 |
| L. Beringin to Bkt. Tagar | W-beam guardrail | 6 | 59993 | 24 | 0.037 | 13 | 0.020 |
| Bkt. Tagar to Bkt. Beruntung | W-beam guardrail | 6 | 61252 | 9 | 0.013 | 4 | 0.006 |

# APPENDIX 2: Road crash risk by expressway's exit at PLUS South Bound (E2)

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Kulai to Sedenak | W-beam guardrail | 8 | 56562 | 26 | 0.031 | 6 | 0.007 |
| Sedenak to S. Renggam | W-beam guardrail | 13 | 52706 | 34 | 0.027 | 5 | 0.004 |
| S. Renggam to Machap | W-beam guardrail | 18 | 48106 | 44 | 0.028 | 16 | 0.010 |
| Machap to A. Hitam | W-beam guardrail | 14 | 48808 | 25 | 0.020 | 14 | 0.011 |
| A. Hitam to Y. Peng (S) | W-beam guardrail | 7 | 44230 | 10 | 0.018 | 7 | 0.012 |
| Y. Peng (S) to Y. Peng (U) | W-beam guardrail | 13 | 37762 | 16 | 0.018 | 32 | 0.036 |
| Y. Peng (U) to Pagoh | W-beam guardrail | 6 | 37476 | 2 | 0.005 | 21 | 0.051 |
| Pagoh to Tangkak | W-beam guardrail | 39 | 36494 | 59 | 0.023 | 69 | 0.027 |
| | Wire rope | 1 | 36494 | 4 | 0.060 | 0 | 0.000 |
| | W-beam guardrail | 1 | 36494 | 3 | 0.045 | 3 | 0.045 |
| | Wire rope | 2 | 36494 | 6 | 0.045 | 5 | 0.038 |
| Tangkak to Jasin | Wire rope | 2 | 44786 | 2 | 0.012 | 8 | 0.049 |
| | W-beam guardrail | 1 | 44786 | 1 | 0.012 | 1 | 0.012 |
| | Wire rope | 12 | 44786 | 9 | 0.009 | 12 | 0.012 |
| | W-beam guardrail | 12 | 44786 | 14 | 0.014 | 14 | 0.014 |

Road crash risk of expressway every exit per million vehicles involving median barrier types by expressway location at E2

| Expressway exit | Barrier type | Road length (KM) | ADT | Total fatal | Crash risk (Fatal) | Total non-fatal | Crash risk (Non-fatal) |
|---|---|---|---|---|---|---|---|
| Jasin to Ayer Keroh | W-beam guardrail | 12 | 46457 | 21 | 0.021 | 17 | 0.017 |
| Ayer Keroh to S. Ampat | W-beam guardrail | 15 | 58050 | 18 | 0.011 | 27 | 0.017 |
| S. Ampat to Pedas Linggi | W-beam guardrail | 22 | 72373 | 43 | 0.015 | 35 | 0.012 |
| Pedas Linggi to Senawang | W-beam guardrail | 22 | 76591 | 46 | 0.015 | 82 | 0.027 |
| Senawang to PD | W-beam guardrail | 16 | 100683 | 27 | 0.009 | 72 | 0.024 |
| PD to Seremban | W-beam guardrail | 1 | 215383 | 6 | 0.015 | 10 | 0.025 |
| | Concrete | 2 | 215383 | 11 | 0.014 | 18 | 0.023 |
| | W-beam guardrail | 1 | 215383 | 1 | 0.003 | 6 | 0.015 |
| Seremban to Nilai | W-beam guardrail | 4 | 115269 | 16 | 0.019 | 22 | 0.026 |
| Nilai to Putra Mahkota | W-beam guardrail | 20 | 127596 | 69 | 0.015 | 82 | 0.018 |
| Putra Mahkota to Bangi | W-beam guardrail | 12 | 142479 | 33 | 0.011 | 8 | 0.003 |

**Research Report**

# Effect of Median Barrier Types on Crash Severity at Rural Expressway

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