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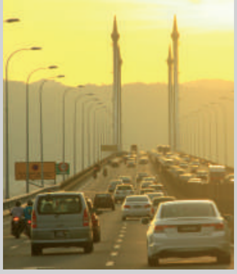
Evaluation of Roadside Safety on Malaysian Inter-Urban Expressway



Nora Sheda Mohd Zulkiffli
Nusayba Megat Johari
Akmalia Shabadin
Alvin Poi Wai Hoong
Siti Zaharah Ishak
Rizati Hamidun
Khairil Anwar Abu Kassim

MIROS
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Alvin Poi Wai Hoong, Siti Zaharah Ishak, Rizati Hamidun,
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Abstract

This study aimed to evaluate the roadside safety on Malaysian expressway on crash severity in vehicles running off the roadway and providing a wholesome view on the associated crash risks. The study was based on crashes data for PLUS expressway recorded from 2013 to 2015. In run-off from the main lane onto the roadside and hitting objects, vehicles tend to hit safety metal barrier, drainage, non-frangible sign/post/pole and temporary object increase the propensity towards serious injuries, minor injuries and vehicle damage. Result of relative risk indicated, in the case of motorcyclist, a roadside with a rigid structure/bridge or building would be 5.7 times more likely to result in a fatal crash compared to a safety barrier, whilst tree was found to be severe for vehicle occupants with 5.6 times. Downwards slope contributed to the higher risk for heavy vehicle with 5.9 times to be killed in road crashes compared to impact with safety metal barrier. The results from this study also reveal that the provision of a form of barrier against the various roadside objects is an important feature to providing a forgiving infrastructure in the event of a vehicle going off the road.

1. Introduction

In just a decade from 2007 until 2016, an average of 442, 408 crashes occurred on Malaysian roadways (Royal Malaysian Police, 2016). Both crash and fatality rates within the 10 years show an increasing trend where in 2016, 6,767 people had died while 6,462 sustained serious injury from road crashes. Additionally, based on road crash by road category, where the crash occurred is found to be highest on Federal Roads (34%) whilst only 9% of crashes occurred on expressways. However, the extent of availability of crash data on roadside objects by highway concessionaires, this study focuses on the road category expressway.

Furthermore, many factors influenced the occurrence of road crashes, one (1) of the factors contributing to the road fatality and injury statistics in Malaysia is vehicle crashing into an object on and off-road as in Figure 1. Through a study by Turner, 2004 showed that roadside hazard is a major factor in many fatal and serious crashes, particularly in rural areas at New Zealand with rural (50%) and urban (27%) crashes involve at least one roadside hazard. Additionally, a high proportion of crashes involving roadside hazards (85% plus) are single-vehicle loss-of-control crashes.

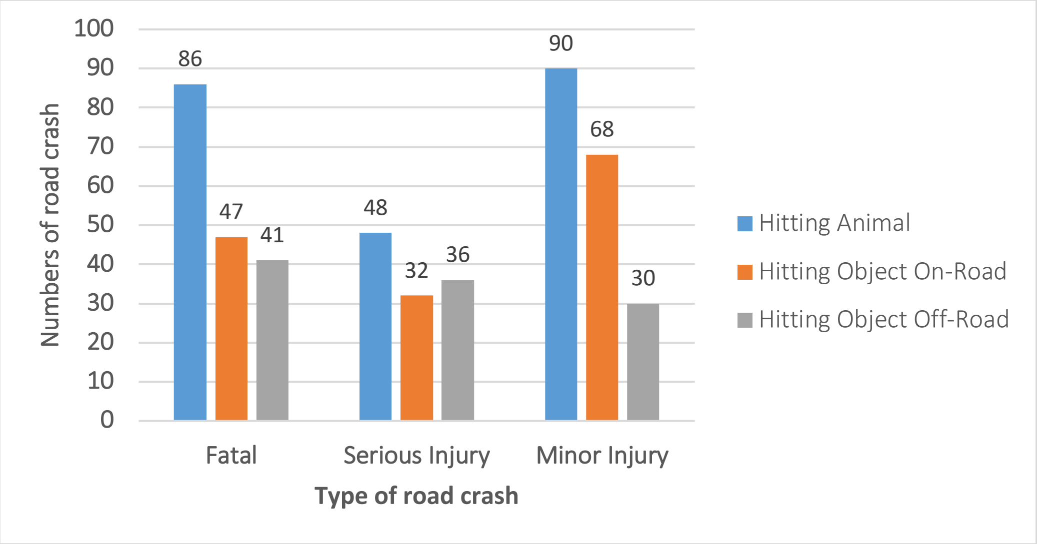


Figure 1 Road crash by hitting object 2016 (*Source:* Royal Malaysian Police, 2016)

Since 2007, the International Road Assessment Program (iRAP) has been adopted in Malaysia as part of the road assessment programme. iRAP is a proactive program to enable the risk of fatal and serious injury to be predicted and rank the cost-benefit ratio should a potential countermeasures program be applied (Alvin, 2017). In viewing the benefits to adapt to the country's environment and traffic conditions, there exists a need to look into a Malaysian centric model for road assessment. In 2016, as part of the National Blue Ocean Strategy by Government of Malaysia, the development of the iRAP Malaysia Programme was announced. The evaluation on roadside safety is part of a contribution to the development of iRAP Malaysia Programme, a tool to assess the safety performance of Malaysia's road; addressing Malaysia's road environment and traffic conditions.

The roadside safety attribute included in the current iRAP model is based on international road condition and may not accurately reflect the Malaysian context. Thus, this study is initiated to examine the risk factor based on Malaysia's road condition. The risk factors for different roadside object were determined by using the relative risk ratio. The risk prediction model is useful in providing the likelihood of a crash to occur thus allowing decision-makers to implement specific strategies or intervention countermeasures to reduce the risk of road crashes related to roadside hazards. Therefore, this study is conducted to answer the following research questions:

i. How many types of hazards are there on the road network?
ii. What is the risk factor for every different type of roadside objects?

1.1 Aim and Objectives of the Study

This research aims to determine risk factors for different roadside objects within the local environment.

The objectives of this research are:

i. To obtain roadside object inventory data and crash data for expressways;
ii. To identify the crash severity pattern involved with roadside objects on the expressway;
iii. To compute the relative risk of roadside objects based on the severity of crashes.

The outcome of this study will give light on the current situation revolving around crashes related to roadside objects on Malaysian expressways, providing a wholesome view on the associated crash risks.

1.2 Scope and Limitation of the Study

The limitation of this study is that it used only crash data on the North-South Expressway (PLUS) because the data obtained from the concessionaire contained adequate information for this study.

This study used secondary data that is only focused on roadside objects along PLUS Expressway. The secondary data consists of, crash data related to roadside objects on PLUS expressway, iRAP Malaysia survey data from Road Attribute Data-logger and Inspection System (RADIS) and data verification from street view in google maps. The three (3) years of crash data provided by PLUS used in the analysis were from the year

2013 to the year 2015. Whereas, the iRAP Malaysia survey data from RADIS was used to extract information such as location coordinate, road name and other related information. RADIS is a data collection system consisting of a video recording system and a data processing system owned by MIROS and is developed for road assessment work. Whilst, data verification using google maps based on crash data year.

2. Literature Review

The review of relevant literature begins with a discussion on iRAP, review on guidelines and previous studies regarding roadside objects.

2.1 International Road Assessment Programme (iRAP)

According to Waibl, Tate, and Brodie (2012), a Road Assessment Programme’s (RAPs) goal is to significantly reduce road casualties. The goal can be achieved by improving the safety of road infrastructure. RAP was started in Europe in the early 2000s when the Automobile Associations piloted a process for assessing the relative safety performance of different European roads (EuroRAP). It was then picked up in Australia (AusRAP) and some US states (usRAP). In 2006, an umbrella organisation iRAP (International Road Assessment Programme) was formed to oversee the global RAP programmes, to ensure a level of consistency promote them in developing countries.

iRAP in Malaysia is part of this international set of road assessment programmes. Malaysia incorporates iRAP protocols of star rating. The ratings of between one and five stars are awarded based on an assessment of how well the road is engineered for safety. The bases for the road inspection data consisting of more than 70 road attributes collected through video inspections, the predicted numbers of killed and seriously injured (KSIs) and the risk factors developed based on research findings. The raw data are uploaded to and processed in the iRAP web-based toolkit, which has been incorporated with statistical models developed by the iRAP international team (iRAP, 2010).

In 2016, four (4) inter-urban expressways were surveyed and given star ratings by using the iRAP Star Rating Protocol Version 3. As far as the safety of the road users is concerned, the assessment was carried out. The assessment covered 2,370 km of road length for both directions. Acknowledging the fact that physical improvement to the road infrastructure in addition to speed management could reduce the risk of road users, this assessment focused on improvements that can bring significance to the star ratings. The result shows that 52.4% of the assessed length were rated 3-star or better. Considering both the effects of ‘quick-fix’ (improved sections) and compliance with the speed limit, the percentage increased to 95.5%. Several types of ‘quick-fix’ treatment were treating the terminal end of crash barrier and installing a crash barrier to prevent vehicles from hitting roadside objects. Based on results, a significant milestone in road safety initiatives in the country as increased star ratings is associated with decreased crash rates. These studies indicated that on average, the crash risk is reducing by half for every increase in the star rating (iRAP, 2017).

2.2 Study of Roadside Safety – Malaysia

A study from Malaysia by Tung, Wong and Raden (2008) found that roadside object is one of the main contributing factors to motorcyclist fatalities. Their study was conducted on exclusive motorcycle lanes. The roadside objects installed along the Federal Highway F0002 and the exclusive motorcycle lane along Shah Alam Expressway is a guardrail. The data collection was collected over a 4½-year period were from the accident database of the road authorities. A total of 107 crash cases were recorded as motorcycle crashes relating roadside objects. The result shows that guardrails have been identified as the most struck object, representing approximately 33% of all roadside object-related motorcycle crashes along exclusive motorcycle lanes. However, result from an odds ratio analysis found that narrow surface objects contribute to a higher fatality rate than guardrails. However, guardrails still contribute 23.5% of all fatal roadside object-related crashes and were found to be 1.7 times more likely to cause serious injury to motorcyclists as compared to non-object-related motorcycle crashes. From their findings, it was concluded that guardrails were suitable to be used as a protection agent for the motorcyclists using the exclusive motorcycle lanes. However, further research and enhancements on the guardrail design system and material type are needed to ensure safe exclusive motorcycle lanes.

2.3 Review on Malaysia Guideline

Involvement in a road traffic crash is the leading cause of death and hospital admission for the Malaysian citizens and the plans to reduce the number of road death have come to better enforcement of safer road infrastructure. The use of passive systems such as road restraint systems undoubtedly contributes to higher safety. Longitudinal traffic safety barrier is one of road restraint systems that widely used in Malaysia practice (REAM, 2006).

According to the Arahan Teknik Jalan (1985), longitudinal traffic safety barriers are highway features designed primarily to prevent out-of-control vehicles from crossing the median, decrease the severity of run-off-road crashed, and decelerate errant vehicles. These traffic safety barrier features include W-beam guardrail, concrete barrier and wire rope fence.

Furthermore, based on REAM (2006), a safety barrier will reduce crash severity only for those conditions where striking the safety barrier is less severe than going down an embankment or striking a fixed object. However, the safety barrier should only be installed where it is clear that crash severity will be reduced, or there is a history of run-off-road crashes within the area. The safety barrier is installed to reduce the severity of run-off-road crashed. This is accomplished by redirecting a vehicle away from embankment slopes or fixed objects and dissipating the energy of the errant vehicle. Consideration should first be given to minimizing conditions requiring a safety barrier. This can be done by flattening embankment slopes and by determining alternative locations and designs of roadside appurtenances. It is worth to mention that the safety barrier is not intended to and should not be used as a barricade or to prevent indiscriminate use of otherwise clear portions of the roadside.

2.4 Study of Roadside Safety – Other Countries

In the United States, crashes with fixed objects account for 19% of all reported crashes; yet they result in 44% of all fatal crashes (National Highway Traffic Safety Administration, 2003). Studies that have investigated fixed-object crashes by the type of the object struck include study by several researchers such as Newcomb and Negri (1971); Rinde (1979); Foody and Long (1974), and Hall, Burton, and Dickinson (1976). In their findings, utility poles are among the fixed object most frequently involved in roadside crashes. Other frequently struck roadside objects include tree, sign post, guardrail, ditch embankments and bridge structures.

Graf, Boos, and Wentworth (1976) found that 47% of utility pole crashes resulted in a fatality or injury whilst also stating that ditch embankments were also amongst hazardous obstacles in terms of crash severity. According to Jones and Baum (1980), the types of fixed objects associated with the most severe accidents include narrow cylindrical objects; utility poles with 50% injury and trees with 42% injury.

Other studies also show that the number of fixed objects and their offset influences roadside crash occurrence. For example, Zegeer and Parker (1983) found that utility pole crash increased significantly with a decrease in pole offset, an increase in annual daily traffic (ADT), or an increase in pole density. Whereas a study by Jones and Baum (1980) indicate that the number of poles and pole spacing was highly related to the probability of a utility pole crash. Hall et al. reported that most of the utility pole crashes involved installation within 11.5 feet (3.5 m) of the roadway or on the outside of horizontal curves.

Referring to the AASTHO (2011), trees were the most common object struck with 48%, accounting for approximately half of all fixed-object fatal crashes. Whereas, utility poles were the second most common objects struck, denoted for 12% of all fixed object crashes followed by traffic barriers with 8%. Percentage distribution of fixed-object fatalities by object struck as in the pie chart, Figure 2.

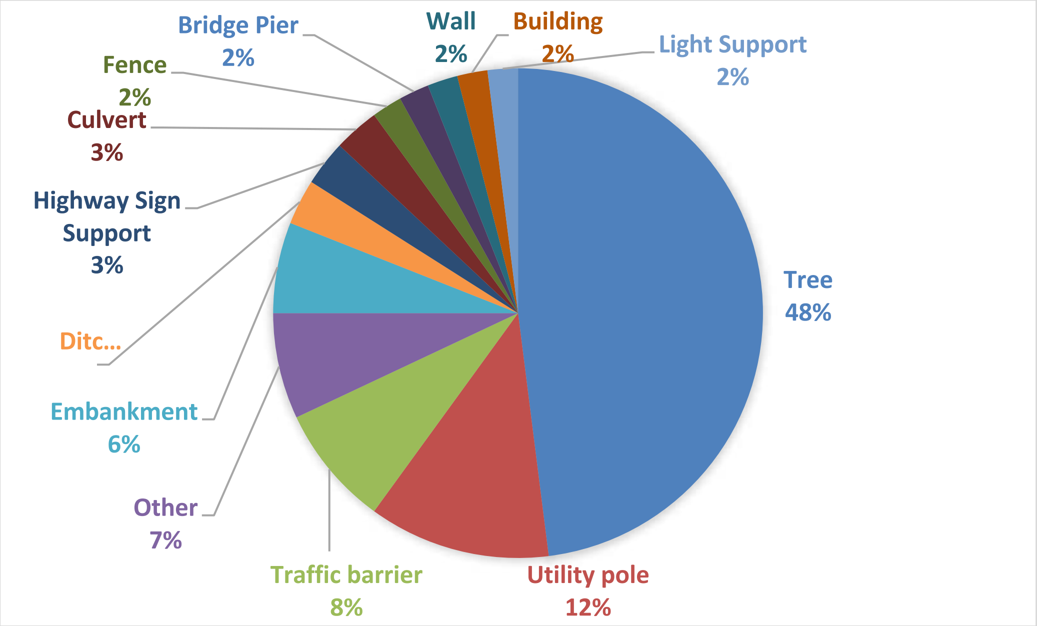


Figure 2 Percentage distribution of fixed-object fatalities by object struck (*Source*: AASHTO, 2011)

2.5 Study Design to Develop Crash Modification Factor

This section intends to identify possible study designs to develop crash modification factors (CMFs). Numerous methods can be employed to derive CMFs, which can generally divide into experimental and observational studies. Related to road safety research, observational study designs are mostly adopted. The design of observational study designs indicated as Table 1 (Gross & Persaud, n.d.):

i. Before-after with comparison group studies
ii. Empirical Bayes before-after studies
iii. Full Bayes studies
iv. Cross-sectional studies
v. Case-control studies
vi. Cohort studies

Table 1 Study design

Study design	General applicability
Before-after with comparison group	Treatment is sufficiently similar among treatment sites. Before and after data are available for both treated and untreated sites. Untreated sites are used to account for non-treatment related crash trends.
Before-after with empirical Bayes	Treatment is sufficiently similar amongst treatment sites. Before and after data are available for both treated sites and an untreated reference group. A separate comparison group may be required where the treatment affects the reference group.
Full Bayes	Useful for before-after or cross-section studies when: Complex model forms are required. There is a need to consider spatial correlation among sites. Previous model estimates or CMF estimates are to be introduced in the modelling.
Cross-sectional	Useful when limited before-after data are available. Requires sufficient sites that are similar except for the treatment of interest.
Case-control	Assess whether exposure to a potential treatment is disproportionately distributed between sites with and without the target crash. Indicates the likelihood of an actual treatment through the odds ratio.
Cohort	Used to estimate relative risk, which indicates the expected percent change in the probability of an outcome given a unit change in the treatment.

3. Methodology

The methodology framework is depicted in Figure 3 and further explanations on data provided are detailed out in the following sub-sections.

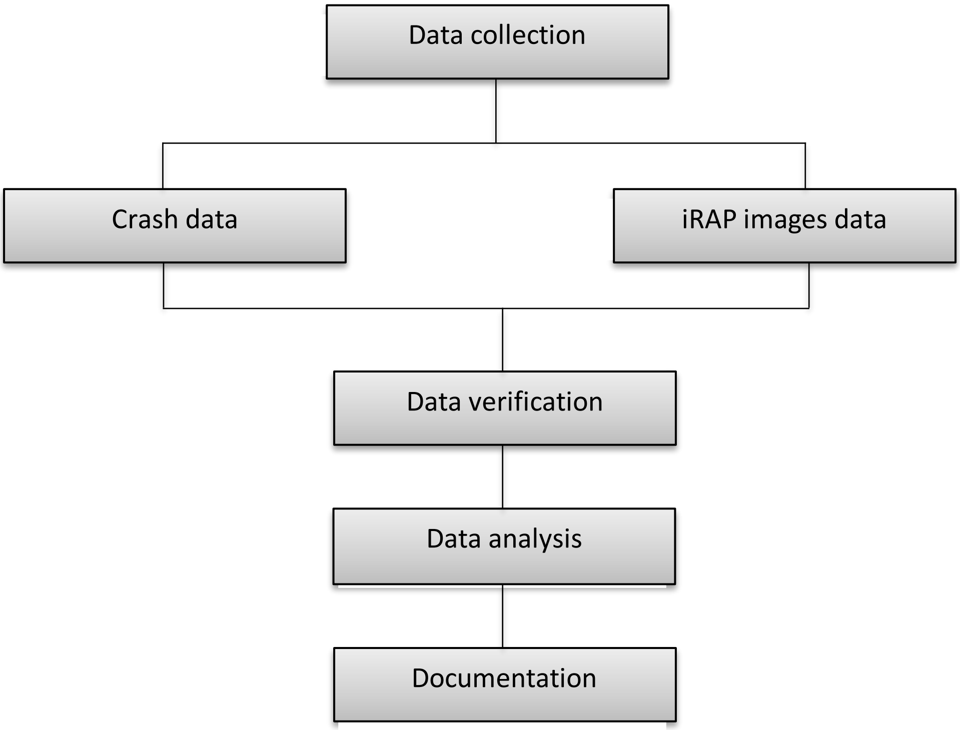


Figure 3 Methodology framework

3.1 Data Collection

Three types of secondary data were utilised in this study. The first set of data is crash data, the second set of data is road attributes from road images of the iRAP Malaysia road survey data and the third set is data verification. Crash data of incidents occurring on the North-South Expressway also known as PLUS expressway (E1 and E2) from the year 2013 to the year 2015 were provided by PLUS concessionaire through consent by the Malaysian Highway Authority (MHA). The required data is fatal and serious injury crashes involving roadside objects within the three-year. The iRAP Malaysia road survey data consist of more than 30 road attributes coded for every 100 m of road sections along expressways. However, in this study only used roadside severity attribute (roadside severity-left object), which consists of 16 variables, or type of roadside hazards without safety barrier-motorcycle friendly. The roadside severity attribute consists of safety barrier-metal, safety barrier-concrete, safety barrier-wire rope, aggressive vertical face, upwards slope-roll over, upwards slope-no rollover, deep drainage ditch, downwards slope, cliff, tree more or equal 10 cm, non-frangible sign/post/pole more or equal 10 cm, rigid structure/bridge or building, semi-rigid structure/building, unprotected safety barrier end, large boulders more or equal 20 cm high and no object. Additional roadside safety attribute based on local environment identified through the crash data records were animal, bush (small tree) and temporary objects. Temporary objects are objects found temporarily left on the road shoulder, e.g. vehicle tyre, plastic barrier, boulder, wood, iron chips, barrels, and others.

Data verification was conducted for PLUS crash data by using the iRAP Malaysia road survey coordinate. It is vital to verify whether the crash data information provided is recorded accordingly with the roadside object installed at the roadside. The verification flow for PLUS data is as Figure 4 below:

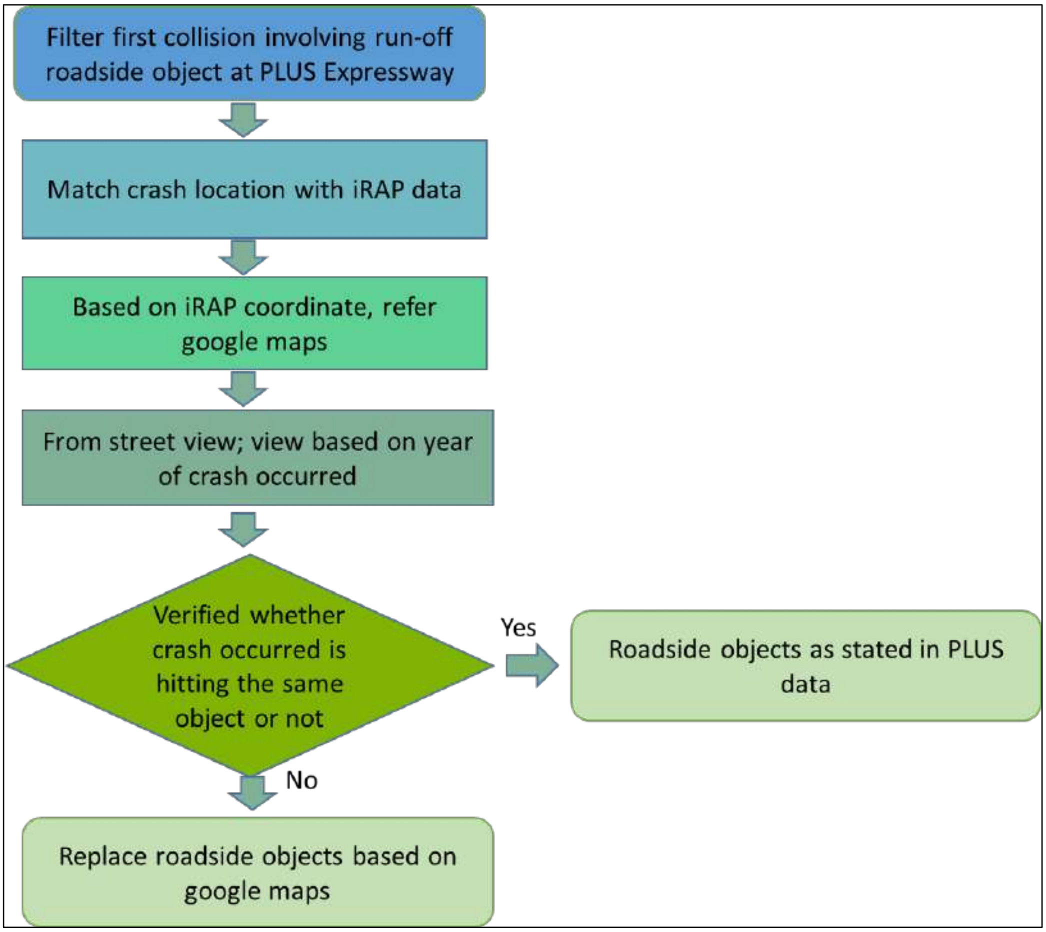
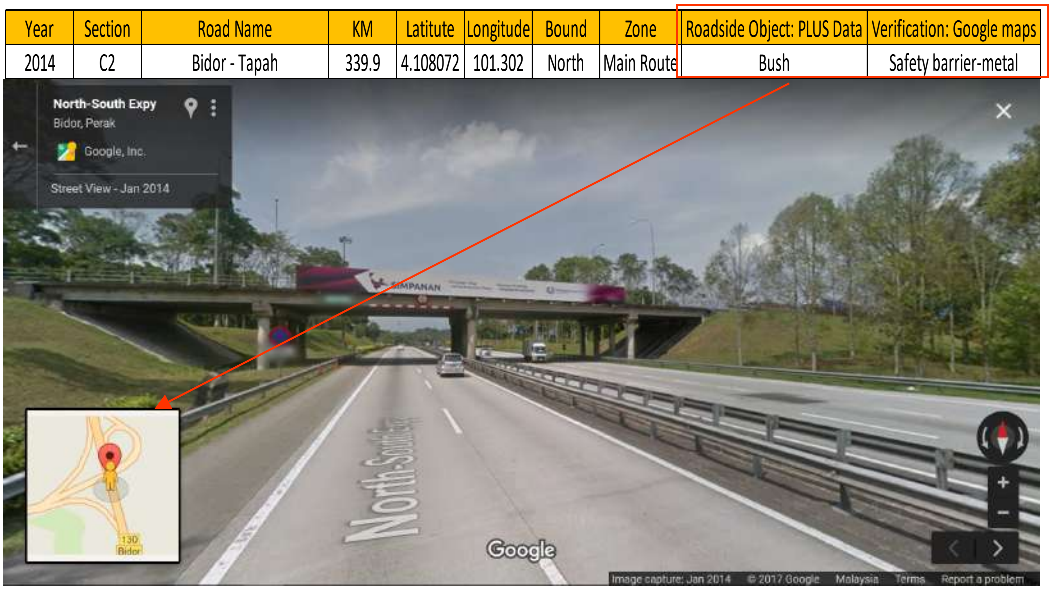


Figure 4 Verification process flow

The PLUS data were filtered based on the first collision involving run-off with the roadside object. Then, based on location or road name provided in the PLUS data necessary to match with the coordinate as provided in the iRAP data. From the coordinate, roadside objects were matched with street view image based on the year of the crash occurred. The last step is choosing whether the roadside object from PLUS data matches the street view image. If the image matches (Figure 5) then data is marked as provided in PLUS data. However, if data is different (Figure 6), roadside object replaced with objects based on street view. The significance of this verification stage is to ensure that the crash occurred is correctly due to hitting roadside objects.

Year	Section	Road Name	KM	Latitute	Longitude	Bound	Zone	Roadside Object: PLUS Data	Verification: Google maps
2014	N2	Alor Setar (S) - Sg. Petani (S)	100.5	5.662942	100.5122	South	Main Route	Deep drainage ditch	Deep drainage ditch

Figure 5 Roadside object by PLUS data matches street view image



Year	Section	Road Name	KM	Latitute	Longitude	Bound	Zone	Roadside Object: PLUS Data	Verification: Google maps
2014	C2	Bidor - Tapah	339.9	4.108072	101.302	North	Main Route	Bush	Safety barrier-metal

Figure 6 Roadside object by PLUS data does not match street view image

3.2 Data Analysis

In data analysis, the method of CMF used is cohort design. The cohort design was used to estimate relative risk (RR), which indicates the ratio of the probability of an event occurring (for example, being injured) in an exposed group to the probability of the event occurring in a comparison, non-exposed group (reference or control group). This situation is expressed in 2 × 2 tables which is the ratio of the risk of an event in the two (2) groups.

The relative risk was useful for studying rare treatments because the sample is selected based on treatment status where can demonstrate causality. The limitation of this method is only analyses the time to the first crash and large samples are often required (Gross & Persaud, n.d). Further explanations as in section 3.2.1 and 3.2.2.

3.2.1 Calculation of Relative Risk

The example of relative risk calculation as in Table 2 below:

Table 2 Example of calculation

Roadside object	**No. of crash by crash severity**		**Total crash**
	Fatal	**Non-fatal**	
Tree	a	b	a + b
Safety barrier: Metal	c	d	c + d

The related formula:

$$RR = \frac{a/(a+b)}{c/(c+d)}$$

A ratio of less than one indicates a lower risk and a ratio of more than one indicates a higher risk. An example of the working calculation from Table 2 data is as follows:

Here, a = 6, b = 2, c = 10, and d = 1. Then the relative risk of roadside object associated with crash severity would be

$$\text{RR}\,\frac{metal}{tree} = \frac{6}{6+2} / \frac{10}{10+1}$$

$$= 0.83$$

$$\text{RR}\,\frac{tree}{metal} = \frac{10}{10+1} / \frac{6}{6+2}$$

$$= 1.2$$

The explanations from the results as follows:

i. The relative risk resulting in fatality was found to be 0.83 times lower compared to the safety metal barrier.

ii. The tree would be 1.2 times more likely to result in a fatal crash compared to a safety metal barrier.

3.2.2 Calculation of Confidence Intervals for the Relative Risk

The relative risk (RR), its standard error and 95% confidence interval are calculated according to Altman, 1991.

The relative risk or risk ratio is given by:

$$RR = \frac{a/(a+b)}{c/(c+d)}$$

with the standard error of the log relative risk being:

SE {ln (RR)} = $\surd(1/a + 1\,/\,c - 1/a + b - 1\,/\,c + d)$

and 95% confidence interval:

95% CI = exp (ln(RR) – 1.96 x SE{ln(RR)} to exp (ln(RR) + 1.96 x SE{ln(RR)})

3.3 Documentation

The study work documented as a research report and academic papers. The results obtained were highlighted in the discussion. A few conclusions were made and recommendations were listed. Suggestions on how to improve 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 two (2) subsections; the first subsection discusses on the crash severity pattern involved with roadside objects on the expressway and second subsection elaborates on the relative risk of roadside objects based on the severity of crashes.

4.1 Crash Severity Related to Roadside Objects

Based on the 2013 – 2015 crash data provided by PLUS Expressways, a total of 3,740 run-off-road crashes cases related to hitting roadside objects was reported to occur on PLUS expressways. Out of this, most of the accidents involved were damage only (74%) whilst the least number of cases recorded are fatal crashes and is denoted as 2%. The distribution of crash severity involving roadside objects for all vehicle types is listed in Table 3.

Table 3 Trend of crash severity involved with roadside objects by vehicle types

Type of vehicle	Roadside objects	Crash severity				Total
		Fatal	Serious injury	Minor injury	Damage only	
Motorcyclist	**Safety barrier-metal**	**11**	**37**	**28**	**8**	**84**
	Safety barrier-concrete	0	3	1	1	5
	Safety barrier-wire rope	0	0	0	0	0
	Unprotected safety barrier end	0	1	0	0	1
	Aggressive vertical face	0	0	1	0	1
	Upwards slope-roll over	0	2	2	0	4

	Upwards slope-no roll over	0	0	0	0	0
	Downwards slope	0	0	0	1	1
	Cliff	0	0	0	0	0
	Rigid structure/bridge or building	3	1			4
	Semi-rigid structure/ building		1	1	1	3
	Deep drainage ditch	**2**	**21**	**21**	**4**	**48**
	Non-frangible sign/post/pole >=10 cm	**3**	**6**	**1**		**10**
	Tree > = 10 cm	0	2	0	0	2
	Bush	0	0	0	0	0
	No object	0	0	0	0	0
	Temporary object	**1**	**8**	**11**	**1**	**21**
	Animal	1	5	3		9
Vehicle occupant	**Safety barrier-metal**	**25**	**135**	**200**	**1316**	**1676**
	Safety barrier-concrete	1	5	13	74	93
	Safety barrier-wire rope	0	0	1	9	10
	Unprotected safety barrier end	0	7	6	20	33
	Aggressive vertical face	0	0	1	2	3
	Upwards slope-roll over	2	15	11	73	101
	Upwards slope-no roll over	0	0	1	4	5
	Downwards slope	1	0	2	20	23
	Cliff	0	0	0	3	3
	Rigid structure/bridge or building	0	3	9	19	31
	Semi-rigid structure/ building	0	12	19	88	119
	Deep drainage ditch	**7**	**30**	**66**	**341**	**444**

	Non-frangible sign/post/pole >= 10 cm	**6**	**27**	**22**	**148**	**203**
	Tree > = 10 cm	3	9	7	17	36
	Bush	0	0	2	7	9
	No object	0	1	2	5	8
	Temporary object	**1**	**14**	**22**	**111**	**148**
	Animal	0	1	2	61	64
Heavy vehicle occupant	**Safety barrier-metal**	**6**	**20**	**38**	**217**	**281**
	Safety barrier-concrete	0	0	1	9	10
	Safety barrier-wire rope	0	0	0	0	0
	Unprotected safety barrier end	0	0	0	0	0
	Aggressive vertical face	0	1	0	1	2
	Upwards slope-roll over	0	1	2	15	18
	Upwards slope-no roll over	0	0	0	1	1
	Downwards slope	1	1	2	4	8
	Cliff	0	0	0	0	0
	Rigid structure/bridge or building	1	1	1	6	9
	Semi-rigid structure/ building	0	1	1	12	14
	Deep drainage ditch	**2**	**4**	**15**	**82**	**103**
	Non-frangible sign/post/pole >= 10 cm	**1**	**3**	**5**	**32**	**41**
	Tree > = 10 cm	0	0	0	9	9
	Bush	0	0	0	1	1
	No object	0	1	0	1	2
	Temporary object	**1**	**2**	**1**	**32**	**36**
	Animal	0	0	0	3	3

The crash severity pattern of expressway involving roadside objects was identified in this report. On the PLUS expressway, the crash severity pattern dominant by non-fatal crash (serious injury, minor injury and damage only) with a roadside object was safety barrier metal, followed by drainage, non-frangible sign/post/pole and temporary object. This pattern was consistent as the top four highest non-fatal crash occurring in the period 2013 – 2015 for all types of vehicles. Vehicles consist of passenger vehicle, heavy vehicle, and motorcycles. Logically, the safety metal barrier is commonly struck on expressways due to it is extensive presence on the PLUS expressways. Besides, another fixed object should be proper protection to reduce the fatality rate. Since the temporary object listed on top four objects commonly struck, there is the need for immediate removal of temporary objects along expressways is pertinent to further improve the safety condition of the roadway.

According to a various study by (Jones & Baum, 1980; Graf, Boos, & Wentworth, 1976), it was also found that the types of fixed objects associated with the most severe accidents included utility poles, trees, bridges, culverts, ditches, and embankments which resulted in a fatality or serious injury.

4.2 Relative Risk (Effect of Roadside Objects to Crash Severity)

Table 4, 5 and 6 indicate the relative risk and 95% confidence interval for a run-off crash resulting in fatality. The findings are divided by vehicle types consisting of motorcyclist, vehicle occupant and heavy vehicle occupant for all types of roadside objects. Each roadside objects have a specific risk towards road users. In this study the reference group used to obtain relative risk is the safety metal barrier due to its extensive presence on the PLUS expressways. The safety metal barrier is an established infrastructure in providing a forgiving roadway environment in the event of a vehicle going off the road.

Table 4 Run-off onto roadside objects by motorcyclist

Type of vehicle	Roadside objects	RR	95% C.I.
Motorcyclist run-off	Safety barrier-metal	1	
	Safety barrier-concrete	0	0
	Safety barrier-wire rope	0	0
	Unprotected safety barrier end	0	0
	Aggressive vertical face	0	0
	Upwards slope-roll over	0	0
	Upwards slope-no roll over	0	0
	Downwards slope	0	0
	Cliff	0	0
	Rigid structure/bridge or building	**5.73**	**2.60 to 12.62**
	Semi-rigid structure/building	0	0
	Deep drainage ditch	**0.32**	**0.07 to 1.38**
	Non-frangible sign/post/pole >= 10 cm	**2.29**	**0.77 to 6.85**
	Tree >= 10 cm	0	0
	Bush	0	0
	No object	0	0
	Temporary object	**0.36**	**0.05 to 2.66**
	Animal	**0.85**	**0.12 to 5.84**

Each vehicle group (motorcyclist, vehicle occupant, heavy vehicle occupant) have a different form of relative risk. For motorcyclist as in Table 4, the highest relative risk obtained was for rigid structure/bridge or building where the risk of a crash resulting in fatality for roadside run-off when a rigid structure/bridge or building is present is 5.7 times higher compared to safety metal barrier. However, in the iRAP model, the highest risk factor is cliff, but due to the non-occurrence of crash involving cliff for any of the vehicles within the dataset, the same is not reflected in this study. The RR was also found to be high, 2.3 times higher when impact was with non-frangible sign/post/pole such as street lighting pole. Subsequently, when stray animal, temporary and deep drainage ditch was present, the relative risk for run-off crashes resulting in fatality was found to be 0.9, 0.4 and 0.3 times lower respectively compared to the safety metal barrier. Meaning motorcyclist is more severe when impacting with safety metal barrier as compared to stray animal, temporary and deep drainage ditch. This finding also supported based on EuroRAP (2008) reported that hitting a safety barrier had been a factor in 8 – 16% of rider deaths in Europe and that a motorcyclist was 15 times more likely to be killed than a car occupant as a result of crashing into a roadside barrier. Therefore, it is important to provide motorcycle friendly crash barrier due to usually motorcyclist falls onto the ground and may sliding into the barrier (Grzebieta et al., 2010). Through study by Anderson, C., Dua, A., and Sapkota, (2012), the example of motorcycle friendly crash barrier in Australia was used W-beam with flexible fabric barrier (see Figure 7) is shown to provide lower injury potential to motorcyclists as compared to concrete barriers. Such a system is shown to prevent serious motorcyclist injuries for most practical collision orientations and speeds.

(a) Installation (b) Complete

Figure 7 W-beam with flexible fabric barrier

Table 5 Run-off onto roadside objects by vehicle occupant

Type of vehicle	**Roadside objects**	**RR**	**95% C.I.**
Vehicle occupant run-off	Safety barrier-metal	1	
	Safety barrier-concrete	**0.72**	**0.10 to 5.26**
	Safety barrier-wire rope	0	0
	Unprotected safety barrier end	0	0
	Aggressive vertical face	0	0
	Upwards slope-roll over	**1.33**	**0.32 to 5.52**
	Upwards slope-no roll over	0	0
	Downwards slope	**2.91**	**0.41 to 20.60**
	Cliff	0	0
	Rigid structure/bridge or building	0	0
	Semi-rigid structure/building	0	0
	Deep drainage ditch	**1.06**	**0.46 to 2.43**
	Non-frangible sign/post/pole >= 10 cm	**1.98**	**0.82 to 4.77**
	Tree >= 10 cm	**5.59**	**1.77 to 17.66**
	Bush	0	0
	No object	0	0
	Temporary object	0	0
	Animal	**1.03**	**0.14 to 7.50**

Based on Table 5, taking again the safety barrier-metal as a reference, the risk of a run-off crash resulting in fatality for vehicle occupant was 5.6 times higher when a tree was impacted. This result support by a study conducted by AASHTO, 2011 shows that the tree is the most struck that contributed to the fatality risk. To a lesser degree, the relative risk of a resulting fatal crash is 2.9 for downwards slope. In comparison, a non-frangible sign/post/pole such as street lighting pole, upward slope (roll over), deep drainage ditch and stray animal has a lower relative risk (RR<2.0), indicating a less severe outcome. On the contrary, when vehicle occupant impacting with safety concrete barrier, the relative risk for run-off crashes resulting in fatality was found to be 0.7 times lower respectively compared to the safety metal barrier. According to a study by (Karim, Magnusson, &

Wiklund, 2012) was also observed that the concrete barriers collision has the lowest injury rate when compared with safety metal barrier.

Table 6 Run-off onto roadside objects by heavy vehicle occupant

Type of vehicle	Roadside objects	RR	95% C.I.
Heavy vehicle occupant run-off	Safety barrier-metal	1	
	Safety barrier-concrete	0	0
	Safety barrier-wire rope	0	0
	Unprotected safety barrier end	0	0
	Aggressive vertical face	0	0
	Upwards slope-roll over	0	0
	Upwards slope-no roll over	0	0
	Downwards slope	**5.85**	**0.79 to 43.13**
	Cliff	0	0
	Rigid structure/bridge or building	**5.20**	**0.70 to 38.85**
	Semi-rigid structure/building	0	0
	Deep drainage ditch	**0.91**	**0.19 to 4.43**
	Non-frangible sign/post/pole >= 10 cm	**1.14**	**0.14 to 9.25**
	Tree >= 10 cm	0	0
	Bush	0	0
	No object	0	0
	Temporary object	**1.30**	**0.16 to 10.50**
	Animal	0	0

In the iRAP model, effects of the heavy vehicle within the traffic stream towards different roadside hazards were not taken into consideration. However, to view whether this group of vehicle is affected differently within the Malaysian context, analysis of relative risk towards roadside objects involving heavy vehicles is included in the study. For a heavy vehicle, taking again the safety barrier-metal as a reference, the risk of run-off crash resulting in fatality was highest with a relative risk of 5.9 when there the roadside hazard was recorded as a downwards slope. Again, a rigid structure/bridge or building was recorded to have a high relative risk value of more than 5. RR was also found to be more than 1 for temporary object and non-frangible sign/post/pole. The safety metal barrier is severe for a heavy vehicle with 1.1 times the relative risk for run-off crashes resulting in fatality compared to a deep drainage ditch.

5 Conclusion and Recommendation

Road users occasionally leave the roadway unintentionally for many reasons. For example, they may have lost control, fallen asleep or being under the influence of alcohol. These mistakes of man often result in the occurrence of a road crash. Therefore, the relationship between crash severity and type of roadside objects along roadways make a vital contribution to road safety. Understanding the relative risk between different roadside objects enables the implementation of an optimally forgiving type of infrastructure to be built along roadways.

This study provides crash severity pattern involved with roadside objects on the expressways. Safety metal barrier, drainage, non-frangible sign/post/pole and temporary object increase the propensity towards serious injuries, minor injuries and vehicle damage. Logically, the safety metal barrier is commonly struck on expressways due to it is extensive presence on the PLUS expressways. Besides, other fixed objects should be proper protection to reduce the severity of run-off crashes. Since the temporary object listed on top four objects commonly struck, there is the need for immediate removal of temporary objects along expressways is pertinent to further improve the safety condition of the roadway.

Result also reveals rigid structure/bridge or building is 5.7 times likely to result in fatal crashes for motorcyclists compared to safety barrier metal, whilst tree were 5.6 times more likely to result in fatal crash compared to safety barrier metal. Thus, there is the need to protect the roadside objects by using a proper crash barrier, this is due to crash barrier can function to redirect errant vehicles and reduce the severity of run-off-road crashes. The highest relative risk is with regards to the roadside attribute of downwards slope, for heavy vehicles where its relative risk to safety barrier metal was 5.9 times higher to result in fatal crashes. For a high percentage of the heavy vehicle also vital to provide the proper restrain for roadside object with selecting an appropriate traffic barrier concerns the level of performance required (high test level). Nonetheless, it should be mentioned that findings from this study are only applicable along PLUS expressway roadways.

References

Altman, D. G. (1991). *Practical statistics for medical research.* London: Chapman and Hall.

American Association of State Highway and Transportation Officials. (2010). Highway safety manual vol 3 (1st ed.). Washington, DC.

Anderson, C., Dua, A., & Sapkota. (2012). Motorcycle safety barrier trials in South Australia: Case study – Adelaide Hills Anderson, C., Dua, A. & Sapkota, J. Department of Planning, Transport & Infrastructure, South Australia, (1982), 1 – 16.

American Association of State Highway and Transportation Officials [AASHTO]. (2011). Roadside design guide. 4th Edition 2011. Washington, DC. ISBN: 978-1-56051-509-8

Bland, J. M., & Altman, D. G. (2000). Statistics notes. The odds ratio. BMJ. 2000 May 27;320(7247):1468. Review. PubMed PMID: 10827061; PubMed Central PMCID: PMC1127651. https://lifeinthefastlane.com/ccc/odds-ratio/

EuroRAP AISBL. (2008). Barriers to change: Designing safe roads for motorcyclists. Position paper on motorcycles and crash barriers. [Online: Accessed March 2018].

FHWA. [Federal Highway Administration]. (2012). Crash modification factors clearinghouse. Retrieved from http://www.cmfclearinghouse.org/

Frank Gross, Bhagwant Persaud, & Craig Lyon. (2010). A guide to developing quality crash modification factors. FHWA Report.

Foody, T. J., & Long, M. D. (1974). The identification of relationships between safety and roadway obstructions report & executive summary (No. Ohio-Dot-06-74).

Graf, N. L., Boos, J. V., & Wentsworth, J. A. (1976). Single-vehicle accidents involving utility poles. *Transportation Research Record*, *571*, 36 – 43.

Grzebieta, P. R., Jama, H., Bambach, M., Friswell, M. R., Mcintosh, P. A., & Favand, J. (2010). Motorcycle crashes into roadside barriers stage 1: Crash characteristics and causal factors. Prepared by, (March), 1 – 29.

Gross, F., & Persaud, B., & L. C. (n.d.). A guide to developing quality crash modification factors.

Hall, J. W., Burton, C. J., Coppage, D. G., & Dickinson, L. V. (1976). Roadside hazards on nonfreeway facilities. *Transportation Research Record*, *601*, 56 – 58.

J. Dawson. (2009). iRAP Results 2009 (Malaysia). Retrieved from http://www.irap.net/en/

Star rating roads for safety: The iRAP methodology. Retrieved from http://www.irap.net/en/

Jones, I. S., & Baum, A. S. (1980). *An analysis of the urban utility pole problem.* Federal Highway Administration, Washington, D.C.

Karim, H., Magnusson, R., & Wiklund, M. (2012). Assessment of injury rates associated with road barrier collision. *Procedia – Social and Behavioral Sciences*, *48*, 52 – 63. http://doi.org/10.1016/j.sbspro.2012.06.987

Lynam, D. (2012). Development of Risk Models for the Road Assessment Programme RAP504.12 and TRL Report CPR1293. Published by iRAP and TRL and available at www.irap.org and www.trl.co.uk.

Martin, J. L., Mintsa-Eya, C., & Goubel, C. (2013). Long-term analysis of the impact of longitudinal barriers on motorway safety. *Accident Analysis and Prevention*, *59*, 443 – 451. http://doi.org/10.1016/j.aap.2013.06.024 (Martin, Mintsa-Eya, & Goubel, 2013)

National Highway Traffic Safety Administration [NHTSA]. (2003). Traffic Safety Facts 2003: A compilation of motor vehicle crash data from the fatality analysis reporting system and the general estimates system. Washington, DC. National Highway Traffic Safety Administration, U.S. Department of Transportation.

Newcomb, F. D., & Negri, D. B. (1971). Motor vehicle accidents involving collision with fixed objects.

Royal Malaysian Police [PDRM]. (2016). Statistical report of road crash Malaysia 2016. Royal Malaysia Police, Traffic Branch, Bukit Aman, Kuala Lumpur.

Rinde, E. A. (1979). Conventional road safety: A study of fixed objects, phase 1. Final report (No. FHWA-CA-79-1 Final Rpt.).

S. H. Tung, S. V. Wong, T. H. Law, & R. S. Radin Umar. (2008). Crashes with roadside objects along motorcycle lanes in Malaysia. *International Journal of Crashworthiness, 13*(2), 205 – 210. DOI: 10.1080/13588260701788534 https://www.tandfonline.com/doi/abs/10.1080/13588260701788534

Turner, S. A. (2004). Assessing the crash risk implications of roadside hazards. Unpublished Research Report prepared for the Land Transport Safety Authority, June 2004.

Waibl, G., Tate, F., & Brodie, C. (2012). The development of a proactive road safety assessment tool – KiwiRAP. *Australasian Road Safety Research …*, (October), 1 – 11. Retrieved from http://arsrpe.acrs.org.au/pdf/Waibl et al. – The Development of a Proactive Road Safety Assessment Tool KiwiRAP.pdf

Zegeer, C. V., & Parker, M. R. (1983). Cost effectiveness of countermeasures for utility pole accidents; volume 2. Final report.

Research Report

Evaluation of Roadside Safety on Malaysian Inter-Urban Expressway

Designed by: MIROS

MIROS
MALAYSIAN INSTITUTE OF ROAD SAFETY RESEARCH
ASEAN ROAD SAFETY CENTRE

Malaysian Institute of Road Safety Research
Lot 125-135, Jalan TKS 1, Taman Kajang Sentral
43000 Kajang, Selangor Darul Ehsan
Tel: +603 8924 9200 **Fax:** +603 8733 2005
Website: www.miros.gov.my **E-mail:** dg@miros.gov.my

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