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RESEARCH ARTICLE

The Performance of the Exclusive Motorcycle Lane (EMCL) in Reducing Fatal Crashes Among Motorcyclists after 20 Years of Operation

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ABSTRACT - When the first exclusive motorcycle lane (EMCL) was built in the early 70s, and after it was entirely built along Kuala Lumpur to Klang in 1993, it was studied to be very effective in preventing crashes by up to 34%. However, that was more than 20 years ago. This study aimed to investigate the effectiveness of the current EMCL in terms of its potential to reduce fatal crashes among motorcyclists, its fatal risk factors, and its benefit-to-cost ratio to the government. This study uses secondary data from the Royal Police of Malaysia (PDRM) and primary data from the second Penang Bridge highway. The results show that EMCL is still an effective measure to reduce the fatalities among motorcyclists, with an effectiveness rate of 74% fatal reduction and a benefit-to-cost ratio of four times to the government. This study also finds that motorcyclists riding along EMCL who are not under substance influence, motorcyclists travelling during daytime and weekends (Saturdays and Sundays), and EMCL that are situated along Urban and EMCL with unpaved shoulders are predicted to be risky. However, when measured with traffic volume, EMCL may or may not be effective when evaluated based on the number of its utilisation or exposure. In conclusion, EMCL will save motorcyclists' lives and perform in the long term, albeit with strict enforcement of its usage and proper maintenance to accommodate safe motorcycle travel.

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1.0 INTRODUCTION

Malaysia still has the highest road fatality risk (per 100,000 population) among the ASEAN countries, and more than 60% of road crash fatalities involve motorcyclists [1]. The increasing popularity of motorcycles has brought up issues on road safety. Malaysian motorcyclists' fatality rates have increased steadily over the past ten years, from 58.7% in 2010 to 68.6% in 2021 [2-5]. Moreover, this data shows that by the end of the year 2021, the death ratio of motorcyclists has become 2:1, e.g., for every one (1) fatality involving other vehicle users, there were two fatal motorcyclists. This situation has yet to change till now.

To increase motorcycle safety, the government of Malaysia built exclusive motorcycle lanes (EMCL) at several locations on federal roads and expressways in Malaysia to segregate them from other vehicles from the early 1970s [6]. The first EMCL was constructed along Federal Route 2 (F2) in the early seventies with support from the World Bank [7]. It connects the city of Kuala Lumpur and Subang International Airport with a total length of 16 km [8]. Later, in early 1992, the extension of the EMCL was carried out by Projek Lebuhraya Utara Selatan (PLUS) from Subang International Airport to Shah Alam and Klang. The construction of significant sections of the EMCL was completed ahead of schedule, and it was opened to the public in November 1993 [6]. Other than along F2, EMCL has now been constructed at other locations, including Shah Alam Expressway (KESAS), Subang Airport Route (FT15), Putrajaya, Butterworth-Kulim Expressway (BKE), Guthrie Corridor Expressway and Port of Tanjung Pelepas Highway [8] and on the Penang second bridge in 2014 (i.e. Jambatan Sultan Abdul Halim Muadzam Shah bridge or JSAHMS) (see Figure 1). Thus, the total length of the current EMCL on all roads in Malaysia is 265km (see Table 1).

Table 1. The ten highways with EMCL

State	District	Road Name	Road Number	Length (km)	Year start of operation
Johor	Johor Bahru	Pelabuhan Tanjung Pelepas	F177	5.0 (LHS) 5.0 (RHS)	1999*
Putrajaya	Putrajaya	Lingkaran Bandar U4	F30	12.1 (LHS) 12.1 (RHS)	2003**

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Table 1. (cont.)

State	District	Road Name	Road Number	Length (km)	Year start of operation
Selangor	Petaling	Lapangan Antarabangsa Subang	F15	2.5 (LHS) 2.5 (RHS)	1974***
		Lebuhraya Persekutuan	F2	8.10 (LHS) 8.10 (RHS)	2001
	Sepang	Puchong - Putrajaya	F29	11.4 (LHS) 11.7 (RHS)	2002
		Lebohan Dagang - Nilai	F32	5.0 (LHS) 5.0 (RHS)	2009
	Shah Alam	Lebuhraya Persekutuan	F2	16.0 (LHS) 16.0 (RHS)	1974***
		Shah Alam Expressway	E5	33.0 (LHS) 33.0 (RHS)	2014
		Guthrie Corridor Expressway	E35	24.0 (LHS) 24.0 (RHS)	2005
Penang	-	Butterworth – Kulim Expressway	E15	14.0 (LHS) 14.0 (RHS)	1996
Total (both RHS and LHS)				265 km	
Note: * see [9], ** see [10], *** see [11] and [6]					

Figure 1. The exclusive motorcycle lanes (EMCL) along FR2 (left) and JSAHMS (right)

2.0 RELATED WORK

After opening the first exclusive motorcycle lane to the public, various studies were conducted to evaluate the effectiveness of the facility. Preliminary findings by [12] pointed out a significant overall reduction, excluding accidents occurring on the main carriageway by 34% [12]. Radin Umar added that introducing 30 km long (per direction) exclusive motorcycle lanes has significantly reduced motorcycle accidents by 39% per year [13]. Furthermore, [6] proved that the preliminary benefit-to-cost ratio (BCR) of providing an exclusive motorcycle lane ranges from 3.3 to 5.2 depending on assumptions used in calculating the motorcycle accident costs and the capacity of the exclusive motorcycle lane [6]. The study indicated that although the cost of providing exclusive motorcycle lanes is high, the benefit is at least three times higher than the construction cost, resulting in a cost-effective approach to tackling motorcycle safety problems in Malaysia. However, that evaluation was based on the number of reported crashes only along Federal Route 2 from Kuala Lumpur to Klang, which was done 20 years ago. Thus, the question arises: Is the EMCL still effective in terms of its potential to save motorcyclists' lives and is it still beneficial to build one?

While EMCL has demonstrated its effectiveness in decreasing motorcycle accidents, it is also plagued by additional issues, namely, under utilisation and safety concerns during entry and exit. For example, in Putrajaya and on KESAS, motorcyclists were found to be reluctant to use the facility primarily due to fears of criminal incidents, including theft [14]. As the EMCL is wholly separated from the main carriageway, motorcyclists have no escape routes if targeted by assailants, especially at bends and tunnel areas. The high usage can only be observed along F2 as reported by [15] that 89.4% of motorcyclists utilised the exclusive lane during peak hour, and 86.1% of motorcyclists complied with its use during off-peak hour [15]. On the safety of motorcyclist entry and exit of the EMCL, findings from a study by [8] revealed that only the egress section with an auxiliary lane and give way length of more than 15 m are observed to be safer than other types of egress, while for ingress sections only ingress with give way length of more than 15 m is considered low risk for motorcycles [8].

Hence, this study aimed to investigate the effectiveness of the current EMCL in terms of its potential to reduce fatal crashes among motorcyclists, its fatal risk factors and its benefit-to-cost ratio to the government.

3.0 METHODOLOGY

3.1 Binary regression with marginal effects analysis

This study uses only fatal crash data involving motorcyclists along all roads equipped with EMCL, obtained from the Malaysian Royal Police (PDRM) from 2008 to 2018. [1] These data were used to analyse EMCL's potential reduction of fatal crashes and investigate the associated risk factors behind the motorcyclist fatalities along EMCL, for which a simple

binary regression was utilised. Only fatal crash data was used because our injury crash data is still severely underreported (see [1] and [16]).

The average marginal effects were computed onto the binary regression to provide clear insight into the results. Marginal effects analysis can be seen carried by many previous studies, such as in [17], [18], [19] and [20]. The marginal effects for categorical variables show how $p(y=1)$ changes as the categorical variable changes from 0 to 1, holding all other variables at their means [21]. That is, for a categorical variable $x_{i/j/k/l}$.

$$\text{Marginal Effect } x_{i/j/k/l} = p\ (y = 1|x, x_{i/j/k/l} = 1) - p\ (y=1|x, x_{i/j/k/l} = 0) \quad (1)$$

For categorical variables with more than two possible values, e.g. *speed limit*, the marginal effects show the difference in the predicted probabilities for cases in one category relative to the reference category [21]. For example, if *the speed limit category* were coded 1 = 50km/h, 2 = 60km/h, 3 = 70km/h, and. 4 = 90km/h, the marginal effect for a road with a 50km/h speed limit would show the likelihood the particular road was to be fatal to motorcyclists compared to motorcyclists on an EMCL with a 60km/h speed limit. The marginal effect for 70km/h roads would show how much more (or less) likely to have fatalities among motorcyclists than on EMCL with a 60km/h speed limit.

To evaluate motorcycle crashes along the EMCL based on the exposure of the motorcycle, we had to collect motorcycle crash data on a specific road with complete or reliable motorcycle traffic volume data. We used the crash and traffic volume data from the Sultan Abdul Halim Muadzam Shah Bridge (JSAHMS, or Penang Second Bridge) from 2018 – 2021. The data from this location was used because the EMCL was tolled, and all motorcycle was counted.

As for the benefit-to-cost ratio analysis, we used the International Road Assessment Program (iRAP) guide in obtaining the Malaysian value of statistical lives (VOSL) (see iRAP [22]). In addition, the cost of building the EMCL per kilometre was based on the figures obtained from the Department of Road Works Malaysia (JKR) in 2013 [23].

4.0 RESULTS AND DISCUSSION

In terms of reducing road traffic fatalities, it has been successful. Based on the crash data from 2008 to 2018 on all ten highways with EMCL, there have been three times more motorcycle fatalities (n=43 fatalities) occurred along the main road (n=163 fatalities) equipped with EMCL as compared to those fatalities that occurred along the EMCL (see Table 2). Hence, the current EMCL has an effectiveness of 74% fatality reduction. This effectiveness is not based on the assumption that all motorcyclists used the EMCL instead of the main road during 2008 - 2018 (74% = (1- 4.3/16.3) x100). Moreover, motorcycle fatalities based on the total length of EMCL show that motorcycle fatalities are lower for every 10km (1.62) compared to those fatalities along the main road (6.20). It shows two interpretations. First, those motorcyclists who used EMCL have a lower fatal risk than those who did not use EMCL or ride along the main road. Secondly, despite being segregated, motorcyclists are still involved in road fatalities in the EMCL.

Table 2. Road fatalities involving motorcycles along ten highways with EMCL from the year 2008 to 2018

Motorcycle fatalities along ten highways with EMCL from the year 2008 to 2018	Number of Fatalities	Average fatalities/ year	Percentage Motorcycle fatalities	Motorcycle fatalities per 10km*
On the EMCL (n=43)	43	4.3	21%	1.62
On the main road (n=163)	163	16.3	79%	6.15
Note: * Based on the total EMCL length of 265km				

Table 3 shows the tabulation of all the variables used in the regression analysis. The total data is 206, with 18 variables considered. The variables range from the location, road geometry, the environment of EMCL, the weather, and rider characteristics riding along EMCL. Based on Table 3, it is evident that most of the fatalities occurred along the main road regardless of the categories.

Table 3. Number of motorcyclists based on each categorical variable

1	Location type	Main road	EMCL
	City centre	24	9
	Urban	65	22
	Suburban	15	3
	Rural	59	9
3	Traffic system	Main road	EMCL
	one way	87	30
	two ways	23	4
	three-lane	32	7
	dual carriageway	21	2

2	Area type	Main road	EMCL
	Residential	19	2
	Office	13	4
	Bridge/Footbridge	7	4
	Others	124	33
4	Road Type	Main road	EMCL
	Expressway	123	25
	Federal	37	17
	Other	3	1

Table 3. (cont.)

4	Road Type	Main road	EMCL
	Expressway	123	25
	Federal	37	17
	Other	3	1
6	Road condition	Main road	EMCL
	Flat	160	41
	Slope	3	2
7	Shoulder type	Main road	EMCL
	Paved	136	23
	Unpaved	27	20
8	Road geometry	Main road	EMCL
	Straight	144	32
	Bend	15	9
	Interchanges	4	2
9	Lane Marking	Main road	EMCL
	Double	4	0
	Single	78	13
	One way	49	18
	Divider	30	11
	No marking	2	1
10	Speed Limit	Main road	EMCL
	50	10	4
	70	23	11
	80	27	5
	90	48	9
	110	41	6
	Other	14	8
11	Weather	Main road	EMCL
	Clear	156	39
	Rain	7	4
12	Day of week	Main road	EMCL
	Sunday	39	6
	Monday	10	5
	Tuesday	20	8
	Wednesday	24	5
	Thursday	28	5
	Friday	28	9
	Saturday	14	5

13	Light condition	Main road	EMCL
	Day	62	27
	Dawn/Dusk	17	3
	Dark with streetlight	54	10
	Dark without streetlight	30	3
14	Gender	Main road	EMCL
	Male	158	42
	Female	5	1
15	Riders under the influence	Main road	EMCL
	Not suspected	7	4
	Positively tested	156	39
16	License Status	Main road	EMCL
	No License	5	1
	L License	30	7
	Full License < 5 years	13	1
	Full License > 5 years	50	12
	Int. License/Foreign	65	22
17	Collision type	Main road	EMCL
	Head-on	4	2
	Rear	53	7
	Right Angle side / Angular	11	1
	Sideswipe	17	7
	hitting pedestrian	2	1
	out of control	70	24
	others	6	1
18	Vehicle movement	Main road	EMCL
	Parked	4	2
	Diverging	5	
	Converging	3	2
	Out of control	12	2
	Left turn	1	1
	Forward	101	26
	Other	37	10

The binary regression shows that only variables such as *Day of the week, Location Type, Shoulder Type, Lighting Condition and Driving under the Influence* have significant risk factors (see Table 4). The model indicates that during weekends (Saturdays and Sundays), motorcyclists are more likely to be involved in a fatal crash compared to Mondays (or weekdays). The likelihood of fatality increases by 28% more when motorcyclists ride along the EMCL during weekends than on weekdays. Another risk factor is that motorcyclists riding along EMCL situated in Urban areas have an increased chance of being fatal, up to 14%, compared to those riding along EMCL in Rural areas. Moreover, EMCL with unpaved shoulders has the likelihood of fatality increase by 23% compared to EMCL with paved shoulders. As for the risk factor on the lighting condition, motorcyclists have an 18% increase in the likelihood of being involved in a fatal crash along EMCL during daytime compared to night-time or dark lighting conditions. Finally, the regression also shows that riders who are not under substance influence (drugs or alcohol) are less likely to be involved in a fatal crash along EMCL compared to a rider who is under substance influence.

Table 4. Binary regression results with marginal effects

Risk factors / Statistics	Odds Ratio	Std. Err.	95% Conf. Interval		Marginal effects dy/dx (%)	Std. Err.	95% Conf. Interval	
Constant	0.002	0.002	0.000	0.023				
Day of the week								
Tuesday	4.384	3.646	0.859	22.376	18.0%	0.113	-0.042	0.402
Wednesday	2.727	1.856	0.718	10.353	11.1%	0.078	-0.042	0.263
Thursday	1.893	1.545	0.382	9.370	6.5%	0.087	-0.105	0.234
Friday	1.292	0.954	0.304	5.491	2.4%	0.069	-0.111	0.158
Saturday	*4.674**	*3.268*	*1.187*	*18.403*	*19.0%**	*0.087*	*0.019*	*0.361*
Sunday	*8.124**	*6.589*	*1.657*	*39.829*	*28.3%**	*0.114*	*0.059*	*0.508*
Monday	1.000	(base)						
Location type								
City centre	3.524	2.323	0.968	12.828	15.0%	0.082	-0.012	0.311
Urban	*3.337**	*1.855*	*1.123*	*9.921*	*14.1%**	*0.061*	*0.022*	*0.260*
Suburban	2.947	2.606	0.521	16.672	12.3%	0.114	-0.100	0.347
Rural	1.000	(base)						
Shoulder type								
Unpaved	*4.509**	*2.053*	*1.847*	*11.004*	*23.1%**	*0.075*	*0.084*	*0.378*
Paved	1.000	(base)						
Light condition								
Day	*4.089**	*3.000*	*0.971*	*17.225*	*18.1%**	*0.078*	*0.027*	*0.334*
Dawn/Dusk	1.481	1.441	0.220	9.973	3.9%	0.099	-0.156	0.234
Dark with streetlight	1.383	1.071	0.303	6.313	3.2%	0.074	-0.112	0.176
Dark without streetlight	1.000	(base)						
Driving under influence								
Not suspected	*5.409**	*4.532*	*1.047*	*27.950*	*26.8%**	*0.146*	*-0.018*	*0.555*
Positively tested	1.000	(base)						

Notes:
Number of obs = 206
Wald chi2(17) = 31.37
Log-likelihood = -82.846
Prob > chi2 = 0.018
* > 95% level of significance based on the likelihood ratio test versus ordinary logistic regression

Measuring the effectiveness based on fatality crashes is not sufficient. One must also evaluate motorcycle crashes along the EMCL based on the exposure of the motorcycle, i.e., the motorcycle volume. Table 5 shows a small sample of data from the JSAHMS, which is equipped with EMCL extensively. The table indicates that the number of crashes per 100,000 motorcycles along the EMCL (8.25) of JSAHMS is far more than those motorcycle crashes along the main road (3.00). Thus, from this small sample, we can see that EMCL tells a different perspective when measured with traffic volume. In other words, EMCL may or may not be effective when evaluated based on the number of its utilisation.

Table 5. Road crashes involving motorcycles along JSAHMS from the year 2018-2021

Motorcycle crashes along JSAHM highways with EMCL from the year 2018-2021	% Motorcycle crashes	Num. of motorcycle crashes per 100,000 motorcycles (n = 1,200,000 motorcycle)
On the EMCL (n=99)	73%	8.25
On the main road (n=36)	27%	3.00
Note: JSAHMS: Jambatan Sultan Abdul Halim Muadzam Shah		

Fatal motorcyclists along EMCL show that EMCL is under-utilisation. However, the exact figure of the under-utilisation rate was only available along some highways equipped with EMCL. For example, in Putrajaya and on KESAS, motorcyclists were found to be reluctant to use the facility due to threats of criminal activities such as theft [8], poor maintenance and risk road deficiencies. Moreover, non-compliance cases were where other vehicles (such as passenger cars and trucks) used the EMCL, but these cases are rare. On the other hand, another study by Abdul Manan and Syed Tajul Malik [15] has shown that high usage can only be observed along FR2, with 89.4% of motorcyclists utilising the exclusive lane during peak hours and 86.1% of motorcyclists complying with its use during the off-peak hour. It clearly shows that all fatal motorcyclists may be associated with non-compliance with EMCL and that some motorcyclists are using the main road instead.

The progress of building more EMCLs in the country could be better. It is because the last road or highway built with EMCL was on the Penang second bridge, i.e., JSAHMS, which was in 2014. Since then, no other EMCL has been built for the last eight years, which shows the non-commitment from the road authorities to build more EMCLs. However, in 2017, the government allocated around RM29 million to improve the existing EMCL [24], which still needs to be higher and will only cover some of the existing EMCL in operation. So, the question arises: Why the low commitment? Does it cost too much to build one? It is estimated that 1 km of EMCL will cost around RM4 million per km (on both sides) [23]. Hence, for 10km of EMCL, the government must allocate around RM45 million to build it. Taking the fact that every 10km of EMCL could save six motorcyclists' lives (assuming they utilised the EMCL, see Table 1), multiplied by the Value of Statistical Lives (VOSL) of each Malaysian is RM3,547,058.00 million (based on GDP/capita x 70, see iRAP toolkit 2022 [12]); therefore, the government could have saved RM212,823,534.00 million for the 10km of EMCL. It shows that the building EMCL has four times the benefit of saving lives that outweighs the cost of building it (i.e., BCR = 4.73).

In conclusion, we still recommend that motorcyclists be separated from the primary traffic via an exclusive motorcycle path or lane along high-speed roads, as it is still proven to reduce motorcycle crashes successfully. If complete separation is not feasible, introducing road shoulder along rural roads can also provide a space for the motorcycle to move safely[25]. A countermeasure to eliminate multi-vehicle crashes involving motorcycles on roads with continuous double-line markings is installing a middle barrier or milling the surface along the middle lines to alert drivers passing the line on these roads [25]. Based on our findings, other countermeasures of interest are making the motorcyclists more visible by, among others, more striking clothing and the use of daytime running lights [26, 27].

6.0 CONCLUSION

This paper aims to investigate the effectiveness of the EMCL, which is still an effective measure to reduce the fatalities among motorcyclists with an effectiveness rate of 74% while having a benefit-to-cost ratio of four times to the government. Moreover, this paper also shows that the fatal risk factors of EMCL are riding not under substance influence, motorcyclists travelling during daytime and weekends, and EMCLs situated along Urban and EMCLs with unpaved shoulders.

If the government wants a quick solution to the motorcycle fatality problem, EMCL is not the solution. EMCL effectively saves motorcyclists' lives in the long run, which may or may not be in favour of the lawmakers to appease the public. Based on the evidence, EMCL is seen as effective from a particular perspective. If we solely look at the fatal data, it can save motorcyclists' lives, but evaluating it by motorcycle exposure may not be effective (more data is needed before concluding). In general, EMCL will save motorcyclists' lives, but will it perform in the long term, with strict enforcement on its usage and proper maintenance to accommodate safe motorcycle travel?

From this study, we recommend that EMCL be implemented cautiously. New EMCL should be built along new roads with a high motorcycle volume projection. Moreover, these new roads must be well maintained, e.g., tolled highways. On the other hand, we are recommending that existing roads that have a consistently high number of motorcycle crashes should be equipped with the Non-exclusive motorcycle lane (NEMCL), which is effective (see [14]) and only occupies the existing road shoulder.

7.0 AUTHOR CONTRIBUTIONS

Muhammad Marizwan Abdul Manan: Conceptualization, Methodology, Software, Data curation Writing- Original draft preparation

Nur Fazzilah Mohamed Noordin: Writing- Reviewing and Editing

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9.0 DATA AVAILABILITY STATEMENT

The data used to support the findings of this study are included within the article.

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11.0 CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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