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機車撞擊路側固定物交通事故之危險因子分析

TheRisk Factors of Motorcycles Crashes with Roadside Fixed Objects

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摘要

依據 2012 年全國交通事故資料統計，在機車交通事故中，因機車撞擊路旁固定物（設施）之致死率遠大於機車其他交通事故之致死率，且高達十倍之多。本研究以台南市近三年機車交通事故為主，調查機車撞擊路側路固定設施（物）案件中的死亡事故比率，並以 Logit 迴歸統計方法分析此類事故中致死危險因子。結果發現機車撞擊路側固定物事故中的致死風險，與駕駛人「無照駕駛」、「未戴安全帽」、騎乘「大型重型機車」、事故發生在「市區道路」、時間界於「午夜 12 點至凌晨 6 點」，行駛在「有分隔島的路段上」，以及「撞擊橋或建築物」、「路樹或電桿」有明顯的相關。更進一步分析發現，駕駛人無照駕駛的事故中，以女性且年齡界於 55 至 65 歲之間駕駛人的致死比率最高。機車撞擊橋端、路樹或電桿的致死比率，也明顯高於機車撞擊護欄的致死率。在凌晨 0-6 點的事故中，有 70%為酒醉駕車自撞事故，且致死比率高於 50%。因此，本研究建議應針對年長的女性駕駛人加強無照駕駛之取締，且立法實施特定時段(如午夜 12 點至清晨)，禁止銷售酒精類飲料等政策，並全面檢討路側設施的設置位置，加設保護裝置，以徹底降低整體機車交通事故及死亡率，全面提昇交通安全。

關鍵詞: 機車交通事故、撞擊路側固定物事故、致死危險因子

ABSTRACT

In 2012, the risk of death for motorcycle crashes with roadside fixed objectsis about ten times higher than that of total motorcycle crashes in Taiwan.This study investigated the major factors contributing to the fatality of crashes with roadside fixed objects using descriptive and logistic regressionstatistical methodsbased onthe recent

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three-year traffic crash data in Tainan City. The results found that the factors that increase the fatality risk for motorcycle crashes with roadside fixed objects are driving without driver's license, not wearing a helmet, riding a large heavy duty motorcycle, occurring in the urban areas, during the time period between midnight and 6 am, and traveling on the roads with island or barrier median, as well as colliding with a bridge end, a tree or utility pole. Further analyses also found that most motorcyclists who did not have a driver's license with the highest fatality risk were female aged between 55 and 65 years old. Compared to the crashes with guardrails, crashes with bridge ends and trees or utility poles had significantly higher fatality risk due to the lacks of crash protection cushions. A high proportion of drunken motorcyclists (70%) with a high fatality risk (0.5) of motorcycle crashes occurred at midnight (0-6 am). Based on these findings, enforcements focusing on female motorcyclists aged between 55 and 65 years old, and during the midnight for stopping the non-licensed and drunken driving are recommended. The installations of crash cushions in front of the bridge ends or trees/utility poles along the roadsides are also recommended.

Key Words: Motorcycle Crashes, Crashes with roadside fixed objects, Fatality risk factors

INTRODUCTION

Motorcycles are the common transport modes and also the major concern for the traffic safety in Taiwan. In 2012, a total of 2,119 motorcyclists died and 262,916 were injured due to traffic crashes (IOT, 2013). Among all the motorcycle fatal crashes, 400 deaths (about 19%) were of collision with road side fixed objects. The risk of death for a motorcyclist who collided with a fixed object was about 0.065, which is ten times higher than the risk of death among total motorcycle crashes (0.006). However, the road geometry design and facility deployment barely took into account the numerous motorcyclists. For example, signal, sign and utility poles, were placed on and along the roadsides without any collision protections. Motorcyclists who are normally forced to travel on the most right side lane of road might tend to collide with those roadside fixed objects.

General overviews of roadside safety havebeen introduced (Mak, 1995). Numerous run-off-the-road crash studies haveconsidered types of roadside objects (e.g.,bridge rails, guardrails, utility poles, sign supports, ditchesand fences) and their effect on accident severity; (Good et al., 1987; Gattis et al., 1993;Viner, 1993; Michie&Bronstad, 1994; Viner, 1995;Kennedy, 1997; Mauer et al.,1997; Reid et al., 1997; Ray, 1999). Particularly for motorcycles, the risk of fatal injury for motorcyclists significantly increases whenmotorcyclists collide with roadside fixed objectssuch as trees, poles, or traffic barriers (Oullet, 1982; Quddus et al.,2002; Quincy et al., 1988; Shankar and Mannering, 1996; Tung et al.,2008; Bambacha et al., 2012).

Yamamoto and Shankar (2004) modeled the driver's and the passenger's injury severities (IS) in collisions with fixed objects using the bivariate ordered-response probit model. The results reveal the effects of the driver's characteristics, vehicle attributes, types of objects, and environmental conditions on both driver's and passenger's injury severity, and that the IS have different elasticities to some of the risk factors.

More recently, Daniello and Babler (2011) compared the fatality risks in motorcycles collisions with roadside objects and with ground in the United States. The analysis concluded that collisions with fixed objects were more harmful to

motorcyclists than collisions withthe ground.Based on the most harmful event reported in the crash, motorcycle collisions with guardrail were 7 timesmore likely to be fatal than collisions with the ground, and collisions with trees were almost 15 timesmore likely to be fatal than collisions with the ground.

Jama et al. (2011) examined seventy seven (77) motorcycle fatalities involving a roadside barrier in Australia andNewZealand. They found that a majority of fatalities occurred on a weekend, during daylight hours, on clear days with dryroad surface conditions indicating predominantly recreational riding. Speeding and driving with a bloodalcohol level higher than the legal limit contributed to a significant number of these fatalities.

Holdridge et al. (2005) investigatedthe significant factors that affect crash severities involving fixed roadside objects. The results found thatthe leading ends of guardrails and bridge rails, along with large wooden poles (e.g. trees and utility poles) increase the probability of fatalinjury. The face of guardrails is associated with a reduction in the probability of evident injury, and concrete barriers are shown to be associatedwith a higher probability of lower severities. They, therefore, recommended to use welldesignedleading ends and to upgrade badly performing leading ends on guardrails and bridges. It is also important to use appropriatefacticityfor protecting vehicles from crashes with rigid poles and tree stumps.

Tung et al., (2008) investigated the severity factors of crashes with roadside objects along the exclusive motorcycle lanes in Malaysia. They found that narrow surface objects (e.g. street-lighting columns, traffic sign posts, trees and guardrails' end treatment) contributed to nearly 60% of fatal crashes along the lanes. Although guardrails still contribute 23.5% of all fatal roadside object-related crashes, however, they also suggested that a better type and design of guardrail systems is needed for safer exclusive motorcycle lanes.

In Taiwan, Huang and Lai (2011) studies the influence of alcohol on the fatality ratios of the single vehicle crashes. The results found that the traffic island separation between a car moving ata higher speed and motorcycle traffic resulted in a higher risk of death for motorcycle drivers whoconsumed alcohol. The factors attributed to a higher risk of death for motorcycle drivers were olderage, crashing into trees, night-time driving, driving on curved roads, and driving on local roads. The results also indicated that alcohol increases the death risk of motorcycle drivers when they collide withroadside objects, such as traffic islands or bridges. These results may suggest that the probability of the physicalseparations causing death upon collision by a motorcycle driver whohad consumed alcohol is a disadvantage of these barriers. The possiblereasons may include their unforgivable designs. However, other factors that affectthe severity of the crashes with roadside fixed objects were not discussed in this study.

The objective of this study is to provide deeper insight into significant factors that affect crash severities involving fixed roadside objects, through a statistical multivariate analysis. Three years (2011-2013) of traffic crash data in Tainan City in Taiwan were used as an example for the analysis.Fatality risk, which is the ratio of fatal crashes out of total crashes, was used to express the severity of traffic crashes. Characteristics related to motorcyclists (gender, age, driver's license situation, helmet usage, and alcohol consuming level as well as motorcycle engine size), the road and environment (road geometry, traffic separation facility, speed

limit, time and day, light condition, pavement condition, and location), and the crash type (type of fixed objects involved) were investigated to determine major contributors to the fatalities in the motorcycle crashes with the fixed objects.

DATA AND METHODS

Three years (2011-2013) of traffic crash data in Tainan City in Taiwan were usedfor the analysis. The traffic crash data were based on the investigation reports from the Tainan City Police Bureau following a standardized format of the national traffic accident investigation report system. The traffic crash database in Tainan City includes three severity types of traffic crashes, including fatal, injury and property damage only (PDO). The data set contains 29 variables recording environment conditions, driver characteristics, crash types and causes. All variables are categorical variable except driver age, speed limit, and time of day.

A fatality crash is defined asa crash-related death (either driver or passenger) within 30 days that required, according to policereports. The fatality risk for each crash category is the proportion of the fatal crashes of each crash category among the total crashes. Descriptive statistics were computed, including the proportionof various categories in the sample and the fatality risk across various characteristics of motorcyclists, crashes and road environments.Logistic regression analysis was used to examine theimpact of those characteristics on the fatality risks in motorcycle crashes with roadside fixed objects.

Independentvariables were selected if they were shown to havesome relationship with the outcome variable (fatality) in univariateanalyses ($p < 0.1$) or when there was some evidence in theliterature pointing to a possible relationship.Independent variablesconsidered for the analysis included individual characteristicsof the motorcyclists: gender,age, helmet use, driver's license holding, and motorcycle engine capacity as well as alcohol consuming;crash characteristics:day and time of crash, light condition at time of crash, and type of crash. Other independent variablesincluded in police reports were related to the road conditionat the time of crash, including road location (rural, urban), speedzone, road geometry (intersection), road curvature, surface condition (dry, wet, etc.), types of median, and types of motorcycle traffic separation facility.

Backward stepwise regression was used to determine thefactors that contributed to the fatality, by starting with a full model and variables were eliminated from the modelin an iterative process. The final model, which contained only independentvariables that significantly contributed to the fatality,was reached when no more variables could be eliminated. The analyses were carried out using R (R, 2010).

RESULTS AND ANALYSIS

There were 1041motorcycle crashes with roadside fixed objects were reported to the police in Tainan City between 2011 and 2013 with 109 (10.5%) resulting in fatality of motorcyclists. Tables 1–3 show the characteristics of motorcyclists, crashes and road environments along with the proportion of fatality crashes as well as fatality risks.

In the traffic crash record database, the types of roadside objects include guardrails, signal/sign poles, toll facilities, refuge islands, bridges, and trees/utility poles. Table 2 shows the frequency, percentage and fatalityrisk of each type of crash with each type of fixed object, as well as the time and day of the crash.

Table 1. Crash Types, and Time and Day Distribution of the Crashes with Fixed Objects

Variables	N	Percentage in sample (%)	No. of Death	Fatality Risk
Crash type (Object)				
Guardrail	198	19	14	0.071
Signal/Sign poles	98	9.4	1	0.010
Islands	121	11.6	13	0.107
Tree/Utility poles	561	53.9	72	0.128
Bridge ends	63	6.11	9	0.143
Day of week				
Weekday	700	67.2	69	0.099
Weekend	341	32.8	40	0.117
Time of day				
00:00-05:59	204	19.6	36	0.176
06:00-09:59	161	15.5	13	0.081
10:00-15:59	286	27.5	29	0.101
16:00-19:59	193	18.5	13	0.067
20:00-23:59	197	18.9	18	0.091
Total Observations	1041		109	0.105

It is obvious that motorcycle crashes with trees or utility poles share the majority of the crashes (53.9%). It should be noted that the original traffic accident report did not separate the crashes with trees or utility poles. Another 19% of the crashes were with guardrails and 11.6% were with islands (50 centimeter wide or above) or barriers. The remaining 9.4% and 6.1% of the crashes were with the signal or sign poles and bridge end, respectively. The crashes with bridge ends were the most harmful, with the highest fatality risk (0.143), followed by the crashes with tree/utility poles (0.128).

The majority of the motorcyclecrashes with fixed objects (67.2%) occurred duringweekdays. Day time off peak hours between 10 am to 4pm were the periods with the highest proportionof motorcycle crashes with fixed objects (27.5%), followed by the period between midnight to early morning at 6 am (19.6%) with the highest fatality risk (0.176).

Table 2 presents the characteristics of motorcycles/motorcyclists in crashes with roadside fixed objects. It was found that nearly nine in ten of motorcycle engine sizes were original heavy-duty motorcycles (88.2%). This is reasonable that the population of registered original heavy-duty motorcycle is 79.1% of total registered motorcycles (1,320,984) in Tainan (in the end of 2012), and 20.6% of them are light-duty motorcycle. Only 0.2% of them were large heavy-duty motorcycle. Although only 0.7% of motorcycles colliding with fixed objects were

large heavy-duty motorcycles, nearly half of them (three out of seven) leading to fatal crashes.

Table 2. Characteristics of Motorcyclists in Crashes with Roadside Fixed Objects

Variable	N	Percentage in sample (%)	No. of Death	Fatality Risk
Motorcycle engine capacity				
Large Heavy- Duty Motorcycle(250cc or above)	7	0.7	3	0.429
Light-Duty Motorcycle (below 50cc)	116	11.1	13	0.112
Original Heavy-Duty Motorcycle(above 50 cc and below 250cc)	918	88.2	93	0.101
Gender				
Male	737	70.8	85	0.115
Female	304	29.2	24	0.079
Age group				
<18	38	3.7	6	0.158
18-24	282	27.1	27	0.096
25-45	353	33.9	40	0.113
45-65	284	27.3	28	0.099
>65	84	8.1	8	0.095
Drivers' license situation				
with license	874	84.0	80	0.092
without license	159	15.3	26	0.164
unknown	8	0.8	3	0.375
Helmet use				
No Helmet	74	7.1	24	0.324
Unknown	106	10.2	25	0.236
Helmet	861	82.7	60	0.070
Alcohal related				
No Alcohol	577	55.4	36	0.062
Drink(0<BrAC <0.25mg/l)	21	2.0	3	0.143
Drunk(BrAC≧0.25mg/l)	396	38.0	34	0.086
Unknown	47	4.5	36	0.766
Total observations	1041		109	0.105

In terms of motorcyclist's characteristics, more than 70% of motorcyclists involved in crashes with road fixed objects were male with around 40% aged between 25 and 45 years old. It was reported that 15.3%of themotorcyclists/drivers did not hold a driver's license and 15.3% of them did not wear a helmet (7.1%) or the use of helmet situation were unknown (10.2%). The use of a helmet was reported as "unknown" when the helmet was found around the crash scene but was not on the head of motorcyclists. It could be that the motorcyclist did not wear or firmly wear (untie) the helmet at the time of crash.It is obvious that a motorcyclist without a driver's license or did not wear a helmet had a higher fatality risk (0.164 and 0.364, respectively) than those who had a driver's license and wore a helmet (0.092 and 0.07, respectively) at the time of crashes.

It was also reported that about 40% of motorcyclists were alcohol related, 38% of them with breath alcohol content (BrAC) higher than 0.25 mg/l. The alcohol consuming situation reported as "unknown" shared an extremely high fatality risk (0.766). It is because the BrAC test was impossible due to the death of

the motorcyclists. This could lead to a serious bias for analyzing the influence of the alcohol consuming on the severity of traffic crashes.

Table 3 shows the road and environment characteristics of the crashes with fixed objects. It was found that more than half of the crashes (51.6%) occurred in day light and 40% in the dark in areas with street lights were on. Although only 3.3% of crashes occurred during dusk/dawn, it had the highest fatality risk (0.206) compared to other light conditions.

Table 3. Road Characteristics of Crashes with Fixed Objects in Tainan City, 2011-2013

Variable	N	Percentage in sample (%)	No. of Death	Fatality Risk
Location				
Rural	384	36.9	31	0.081
Urban	657	63.1	78	0.119
Light condition				
Day	537	51.6	49	0.091
Dusk/dwan	34	3.3	7	0.206
Dark with street light on	425	40.8	50	0.118
Dark without street light or light off	45	4.3	3	0.067
Speed zone				
30-40 km/hr	178	17.1	15	0.084
50 km/hrr	651	62.5	65	0.100
60 km/hr	142	13.6	17	0.120
70+ km/hr	70	6.7	12	0.171
Road Geometry/curvature				
Straight segment	726	69.7	82	0.113
Cross intersection	106	10.2	7	0.066
T-intersection	52	5.0	1	0.019
Multiple intersection	11	1.1	2	0.182
Curve segement	114	11.0	15	0.132
Others(tunnel/undergrough)	32	3.1	2	0.063
Surface condition				
Dry	954	91.6	98	0.103
Wet/muddy	87	8.4	11	0.126
Median type				
Marking only	513	49.3	55	0.107
With Island	211	20.3	29	0.137
With Barrier/guardrail	49	4.7	9	0.184
Non	268	25.7	16	0.060
Motorcycle traffic separation				
Marking	294	28.2	34	0.116
Island/bariers	23	2.2	3	0.130
Non	724	69.5	72	0.099
Total Observations	1041		109	0.105

The majority of the crashes occurred in urban areas (63.1%)and morethan half (62.5%) on roads with a speed limitof 50 km/h with 17.1% occurred on roads with speed limits of 30–40 km/h. Another 13.6% occurred on roads with a speed limit of 60 km/h and 6.7% on roads with a speed limit of 70 km/h or higher.Numerically, the fatality risk increased as the speed limit increased.

Most motorcycle crashes with fixed objects occurred at the straight segments of roads (69.7%). Another 11% of crashes occurred at the curve sections of roads. About 16% of motorcycle crashes with fixed objects occurred near intersections in which 10.2% were at cross intersections, 5% were at T-intersections, and 1.1% was at multiple intersections. Morethan nine in ten motorcyclecrashes with fixed objects occurredon dry road surfaces (91.6%)with another 8.4% occurring on wet ormuddy roads with a slightly higher fatality risk.

In terms of the road median types, nearly half of the motorcycle crashes with fixed objects occurred on roads with marked medians (49.3%). Another 20.3% of the crashes occurred on roads with islanded median (more than 50 centimeter wide). About a quarter of the motorcycle crashes with fixed objects occurred on roads with no central line markings (25.7%), normally on the narrow road sections. Motorcycles traveling on the roads with barriers/guardrails and islands of medians had higher fatality risks (0.137 and 0.184, respectively) than those traveling on the roads with marking medians only (0.108). Most of the motorcycle crashes with fixed objects occurred on the roads without a motorcycletraffic separation facility (69.5%). More than 28.2% occurred on the roads with motorcycle traffic separation by markings.

The logistic regression analysis results for univariate and multivariate variables are shown in Table 4. The results present the significant characteristic categories and factors contributing to the fatality of motorcycle crashes with fixed objects. It should be noted that all factors within a category were modeled as long as one of the factors in that category was significantly associated to the fatality of crashes. The common factor was selected as a reference factor in each category for estimating the relative fatality risk of all other factors.

As a result, the univariateanalysis shows that male motorcyclists had 1.5 times higher fatality risk than female motorcyclists when they crashed with a fixed object. However, the final model does not significantly show this tendency, probably due to the interactive influences by other factors. Similar to light condition and speed zone characteristics, the univariate model shows that the crashes with roadside fixed objects occurring during the dusk/dawn light condition had 2.58 times higher fatality risk compared to those occurring during the day light condition. Regardless the influence of other factors, the crashes on the roads with a speed limit of 70 km/h had 2.3 times higher fatality risk than those occurring on the road with a speed limit between 30 and 40 km/h.

Overall, as the results of the final model, a motorcyclist who did not have a driver’s license was over twice (2.21) more likely to be fatally injured than the one who had a driver’s license at the time of the crash with a fixed object. Similarly, a motorcyclist not wearing a helmet was more than eight times (8.6) more likely to be fatally injured than a motorcyclist wearing a helmet firmly at the time of the crash.

Compared to the non-alcohol related motorcyclists, the motorcyclists with positiveBrACs did not have significant fatality risks. However, the motorcyclist with “unknown”BrACs had an extremely high fatality risk. Motorcycle crashes with fixed objects thatoccurred in urban areas were about 1.7 times more likely leading to fatal crashes. While most motorcycle crashes with fixed objects occurred during daytime, the analysis results found that motorcycle traveling at the time period between 12 am to 6 am had the fatality risk three times higher than

those riding at the time period between 4 pm to 8 pm when crashing with a fixed object.

Table 4. Logistic Regression of Factors Contributing to the Fatality of Motorcycle Crashes with Fixed Objects

Variable	Single Variable Model			Final Model		
	Adjusted OR[c]	5%	95%	Adjusted OR[c]	5%	95%
(Intercept)				0.01	0.00	0.03
Gender (Intercept)	0.09	0.06	0.12			
Female[b]	1					
Male	1.52	1.03	2.30			
Drivers' license situation(Intercept)	0.10	0.08	0.12			
With license[b]	1			1		
Without license	1.94	1.28	2.88	2.21	1.32	3.64
License unkown	5.96	1.60	19.61	1.53	0.20	8.62
Motorcycle engine capacity(Intercept)	0.13	0.08	0.20			
Light-Duty Motorcycle (below 50cc)[b]	1			1		
Large Heavy- Duty Motorcycle(250cc or above)	5.94	1.45	22.94	9.48	1.31	57.49
Original Heavy-Duty Motorcycle(above 50 cc and below 250cc)	0.89	0.55	1.54	1.41	0.74	2.89
Helmet use(Intercept)	0.07	0.06	0.09			
With helmet[b]	1			1		
Helmet Unkown	4.12	2.64	6.33	4.20	2.42	7.18
No Helmet	6.41	4.00	10.14	8.60	4.66	15.82
Alcohol Consuming(Intercept)	0.07	0.05	0.09			
No Alcohal[b]	1			1		
Drink(0<BrAC <0.25mg/l)	2.50	0.75	6.61	1.95	0.53	5.78
Drunk(BrAC≧0.25mg/l)	1.41	0.94	2.13	0.77	0.46	1.27
Unknown	49.18	26.69	95.35	46.18	22.66	99.19
Time of day(Intercept)	0.07	0.04	0.11			
16:00-19:59[b]	1			1		
06:00-09:59	1.22	0.62	2.39	0.89	0.40	1.97
20:00-23:59	1.39	0.75	2.63	1.02	0.47	2.20
10:00-15:59	1.56	0.89	2.83	1.11	0.56	2.25
00:00-05:59	2.97	1.72	5.32	3.00	1.51	6.18
Light condition (Intercept)	0.10	0.08	0.13			
Day[b]	1					
Dusk/dwan	2.58	1.17	5.23			
Dark with street light on	1.33	0.94	1.88			
Dark without street light or light off	0.71	0.22	1.76			
Speed zone(Intercept)	0.09	0.06	0.14			
30-40 km/h[b]	1					
50 km/h	1.21	0.75	2.02			
60 km/h	1.48	0.80	2.75			
70+ km/h	2.25	1.12	4.45			
Road location(Intercept)	0.09	0.06	0.12			
Rural[b]	1			1		
Urban	1.53	1.07	2.23	1.70	1.07	2.77
Median type(Intercept)	0.12	0.09	0.15			
Marking only[b]	1			1		
With Island	1.33	0.88	1.98	2.19	1.25	3.78
With Barrier/guardrail	1.87	0.94	3.49	2.83	1.19	6.26
Non	0.53	0.32	0.84	0.50	0.27	0.89
Crash object(Intercept)	0.08	0.05	0.12			
Guardrail[b]	1			1		
Island	1.58	0.81	3.08	0.53	0.22	1.25
Tree/Utility poles	1.94	1.20	3.28	1.86	1.04	3.51
Bridge end	2.19	1.02	4.58	3.03	1.22	7.31
Signal/Sign poles	0.14	0.01	0.55	0.10	0.01	0.52

a Dependent variable : fatality vs others.

b Reference category.

c Adjusted for all other factors in the model.

On the roads with islands and barriers as medians, motorcycle crashes with fixed objects had about 2.2 and 2.8 times, respectively, fatality risks than those on roads with marked median. Although an island or barrier median can reduce the probability of head-on collisions, it would increase the chance of vehicles crashing with the island and barrier, and may also increase the fatality risk.

Compared to colliding with aguardrail, a motorcyclist had 3 times higher fatality risk who collided with a bridge end when colliding with a bridge end, and 1.86 times higher fatality risk when colliding with a tree or utility pole.

DISCUSSIONS

Regarding the license situation, it was found that 10 out of 14 (71%) of fatal female motorcyclists who collided with roadside fixed objects did not have a driver's license. It was also found that about 44% of female motorcyclists who did not have a driver's license were aged between 55 and 65 years old. This tendency was not found in their male motorcyclist counterparts. Enforcement focusing on the female motorcyclists aged between 55 and 65 years old is recommended.

In terms of the crash type, most of crashes with roadside fixed objects were crashes with tree or utility (54%) with the second highest fatality risk (0.128). Although the number of crashes with bridge ends only shared 6% of the total crashes with roadside fixed objects, the fatality risk of them was the highest (0.143) and was 3 times significantly higher than the crashes with guardrails. The installations of guardrails along the roadside can decrease the severity of the crashes with fixed objects. Consequently, the lack of protection devices increased the fatality risk when colliding with roadside trees/utility poles or bridge ends. The installations of crash cushion devices, such as compressors, sand barriers, attenuators or guardrails, are recommended.

The highest fatality risk (0.176) of crashes with fixed objects occurred between midnight and 6 am. It was found that 70.1% of the crashes occurring between midnight and 6 am were alcohol related crashes with 37.3% of them had the BrAChigher than 0.85g/ml. Among the total of fatal crashes (36) occurring between midnight and 6 am, half of them were drunken motorcyclists related. Although the final model result found that the fatality risk of drunken motorcyclists was not significantly higher than that of non-alcohol related motorcyclists when they collided with the roadside fixed objects, a high proportion of drunken motorcyclists (70%) and high fatality risk (50%) of them at midnight is still a major issue for traffic safety. A time restriction code for selling alcohol drink and strengthenenforcement during midnight are recommended.

CONCLUSIONS AND RECOMMENDATIONS

This study found that the factors to increase the fatality risk for motorcycle crashes with roadside fixed objects are driving without a driver's license, not wearing a helmet, riding a large heavy duty motorcycle, occurring in the urban areas, during the time period between midnight and 6 am, and on the roads with island or barrier median, as well as collided with a bridge end and a tree or utility pole. Detail analyses also found that most motorcyclists who did not have a driver's license and had the highest fatality risk were female aged between 55 and

65 years old. Compared to the crashes with guardrails, crashes with bridge ends and trees or utility poles had significantly higher fatality risk due to the lacks of crash protection cushions. Although the fatality risk of drunken motorcyclists was not significantly higher than that of non-alcohol related motorcyclists when they collided with the roadside fixed objects, a high proportion of drunken motorcyclists (70%) and high fatality risk (50%) of them at midnight is still a major issue for traffic safety.

Based on these findings, enforcements focusing on the female motorcyclists aged between 55 and 65 years old, and during the midnight for stopping the non-licensed and drunken driving are recommended. The installations of crash cushion devices, such as compressors, sand barriers, attenuators or guardrails, in front of the bridge ends, trees as well as utility poles along the roadsides are also recommended to provide the injury protection from the collisions.

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