Principles for Developing Traffic Control Devices for Mixed Traffic Flow with Numerous Motor Scooters

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ABSTRACT
Motor scooters and mopeds are being aggressively marketed as low-cost alternatives to the car for commuting as the gas price are increasing. However, most of the traffic infrastructure does not accommodate the safety of moped and scooter drivers. Motor scooters (called motorcycle in Taiwan) are the most common motorized vehicles and contribute the highest traffic fatalities on Taiwanese roads. In order to enhance the traffic safety, several motor scooter management strategies and regulations were implemented in Taiwan. Nevertheless, these strategies merely focus on decreasing motorcycle usage and restricting the rights of motorcyclists. Road geometry or traffic control device designs scarcely take into account the numerous motorcycles and the motorcyclists’ points of view. This study attempts to fill those gaps in road designs and traffic control devices by considering the traveling rights of motorcyclists. Motorcycle crashes and fatalities were analyzed by objects, road types and locations, as well as crash causes to identify the major contributors of crashes due to road design issues. Based on the crashes analysis results, principles for developing guidelines for road designs and traffic control devices are proposed. At unsignalized intersections, a physical and visible traffic signing or marking should be implemented to clearly assign the passing priority for approaching vehicles. At signalized intersections, supplemental sets of signal indications for motorcycles are needed to provide a clear signal indication for vehicles traveling on the road’s side lanes. On road segments, the implementation of motorcycle exclusive and priority lanes should take into account the land use of the road side. Various speed limits by lanes and supplemental markings for motorcycles to stay on tracks or lane are also recommended.
INTRODUCTION
As gas prices go up, the usage of motor scooters or mopeds is expected to increase. It is expected that the traffic crashes will increase as the usage of motor scooters are increasing. Haworth and Nielson (1) studied the translation of increasing sales of motor scooter and mopeds into traffic crash rates. They concluded that while moped crashes comprised only a small fraction of on-road crashes of powered two-wheelers (PTWs) in 2001–2005, they are increasing at a faster rate than motorcycle crashes. Miggins et al. (2) used Florida Traffic Crash Records Database (FTCRD) from 2002 to 2008 to identify all crashes involving mopeds and scooters. The results suggest that most of the traffic infrastructure does not accommodate the safety of moped and scooter drivers.

Motor Scooters (called motorcycles in Taiwan) are the most common motorized vehicles found on Taiwanese roads. The share of registered motorcycles has consistently been more than double that of the number of automobiles for a decade in Taiwan. In 2012, there were 15 million registered motorcycles in Taiwan, representing approximately 68 percent of all 22.3 million registered automobiles (3). Motorcyclists also hold the highest traffic accident and fatality rate among total traffic accidents every year. In 2011, there were 235,775 fatal or injured traffic accidents (FITAs). Among the total FITAs, 208,408 (88 percent) of them were motorcycle-involved accidents with 264,443 motorcyclists involved (4). Those FITAs also resulted in 2,119 deaths and 262,916 injuries to motorcyclists, representing about 64 percent of the total number of deaths (3,322) and 84 percent of the total number of injuries (313,873) (4). Motorcycles are not only the most common mode of transportation among the traffic flows within the transportation network but also contribute the highest number of traffic crashes and fatalities in Taiwan. This fact indicates that motorcycle safety should be a highly important issue for transportation management in Taiwan.

To help decrease the number of motorcycle fatalities and crashes, the transportation management agents in Taiwan have implemented several control strategies and restrictions through road design and regulation measures, such as motorcycle two-stage left turns (MTLT) at Intersections, motorcycles priority lanes (MPLs) and exclusive lanes (MELs). Several studies were conducted to research motorcycle or mixed traffic flow issues (5-8), and risk factors analysis (9,10). Several studies also analyzed the effects of the MTLTs and proposed guidelines for their installation (11-13). Hsu (14-16) conducted a series of motorcycle improvement studies focusing on the geometric layout and signal timing (14), particularly on separated traffic flow concepts (14).

However, most of the motorcycle management policies in Taiwan merely focused on separating or isolating the motorcycles from the mixed traffic to decrease usage and restrict the rights of motorcyclists. Road designs scarcely took into account the high number of motorcycles as well as the motorcyclists’ points of view. Therefore, this study plans to fill those gaps in road designs and traffic control devices by considering the rights of motorcyclists. First, existing Taiwanese principles of road designs and motorcycle-specific traffic control devices or strategies will be introduced. Second, motorcycle crashes in 2011 were analyzed by objects, road types and locations, as well as crash causes to identify the major contributors of crashes due to road design issues. Motorcycle fatalities during the last decade will also be presented. The principles for establishing guidelines for road designs and traffic control devices are proposed and discussed by considering the rights of motorcyclists and the analysis results of motorcycle accidents on different road types.
MOTORCYCLE MANAGEMENT STRATEGIES

In order to help decrease the number of motorcycle fatalities and crashes, the transportation management agents in Taiwan have implemented several control strategies and restrictions through road design and regulation measures. Specific strategies and measures are introduced in the following sections. Related studies are also reviewed and discussed.

1. Motorcycle Helmet Use Law

Several epidemiologic surveys have reported that the vast majority of serious or fatal motorcycle related injuries involve the head. (17-20). In Taiwan, according to the Department of Health, 77.7 percent of fatal motorcycle-related injuries involved the head (21). Prior to 1997, more than 7,000 people died in traffic accidents each year in Taiwan. A reduction in the total number of motor vehicle-related deaths was found in 1994. From February to May 1994, enforcement of helmet use for motorcyclists was implemented in Taipei City. Helmet use increased from 21 percent in January 1994 to 79 percent in April 1994, reducing head injury hospitalizations by 33 percent and fatalities by 56 percent.(22) However, because this enforcement was not based on any law, and because some legislators criticized it on grounds of personal freedom, it was terminated by June 1994. Thereafter, the number of head injuries, along with their severity and outcome, returned to its previous levels.

After intense lobbying and discussion, a motorcycle helmet use law was eventually approved and implemented in Taiwan on June 1, 1997. Within a year of the implementation of the motorcycle helmet use law, motorcycle-related injuries decreased by 14 percent and the length of hospital stays decreased by 14.5 percent. The total number of motor vehicle-related fatalities dramatically decreased by 561, from 7,077 in 1996 to 6,516 in 1997 (23). Thereafter, the total number of motor vehicle-related fatalities decreased significantly by an average of 438 per year to 4,322 in 2002. The number of motor vehicle-related fatalities decreased again from 4,637 in 2006 to 3,470 in 2010. It should be noted that during this period the overall number of registered motorcycles increased from about 9.3 million in 1996 to 15.2 million in 2011. The total number of reported traffic crashes (excluding property damage crashes) also dramatically increased from 53,000 in 2000 to 236,000 in 2011.

As a result, the implementation of the motorcycle helmet use law was credited with a 51 percent reduction (from 7,077 in 1996 to 3,470 in 2011) in motor vehicle-related deaths in Taiwan over 15 years, despite a 63 percent increase in the number of motorcycles. However, the number of traffic accidents increased as the number of registered motorcycle increased. This indicates that the motorcycle helmet use law passively prevented deaths from traffic crashes but didn’t reduce the occurrence of traffic accidents. There are no particular road designs, control devices, management strategies, or specific changes in legislation specific to motorcycles which could actively decrease the number of traffic accidents. In fact, social, environmental and regulatory factors, as well as emergency care improvements, may have accounted for some of the reduction in motor vehicle-related fatalities. Therefore, any active safety road systems or strategies are desired not only for reducing the number of fatalities but also for decreasing the frequency of traffic accidents, particularly for the high number of motorcycle riders.

2. Motorcycle Two-stage Left Turn at Intersections

In Taiwan, the implementation of motorcycle specific traffic management policies began as far back as 1984. It began with setting up a two-stage left turn (MTLT) regulation. Motorcycle turning at intersections should follow the following regulations for two-stage turns proceeding left or right. Left-turning motorcycles need to cross straight across an intersection to the painted
motorcycle box (two-stage left-turn box) and wait there for the other traffic signal to turn green (as shown in Figure 1). If the inner lane has a No Motorcycle sign or marked line, motorcyclists should do the left turn in two-stage.

![Left-turning waiting box](image1)

Figure 1 Motorcycle two-stage left turning sign and illustration.

However, the location of the left-turning waiting box may create conflicts between left turning and straight moving motorcycles. The crosswalk and the stop line also need to be moved back to create space for the implementation of the left-turning waiting box, which will increase the crossing length of the intersection and also reduce the sight distance of the intersection. Particularly at T-intersections, due to the limitation of road side space, the implementation of a two-stage turning motorcycle waiting zone becomes difficult (as shown in Figure 2). The conflicts between left turning and straight moving motorcycles are still very common.

![A case of waiting zone for left-turning motorcycles at a T-intersection.](image2)

Figure 2 A case of waiting zone for left-turning motorcycles at a T-intersection.

3. Motorcycle Waiting/Stop Zones

Since 2000, motorcycle waiting zones (MWZs, refer to Figure 1) have officially been installed beyond the stop line at signalized intersections where the speed limits are less than 60 KPH in Taiwan. The major purpose of the MWZs is to increase the vehicle discharging rate at signalized intersections. Based on this design, motorcyclists are encouraged to overtake slow or stopped vehicles by traveling between lanes, called lane splitting, to stop and wait in the MWZs during the red light period. The implementation of MWZs was proven to decrease the total delay...
and increase the saturation flow rates of the signalized intersections. (24). The MWZs can also decrease the degree of mix traffic conditions beyond the MWZs. However, the conflicts between motorcycles and other motor vehicles were not significantly different. The crash analysis before and after the MWZs were implemented also has not yet been studied.

One of the major issues for the MWZs is the dilemma zone (or decision zone, is an area where drivers face an indecisiveness of stopping or crossing at the yellow onset) would be changed and the clearance time for the signal timing should be modified as the stop line of the vehicles moved backward from the intersections. This issue was not taken care of at most intersections where the MWZs were installed. The other issue is that there is no official regulation which allows motorcycles to travel between two driving lanes. According to the highway traffic regulation in Taiwan (No. 56) (53), lane splitting is prohibited when motor vehicles stop in the queue during the red light period. However, no specific regulation or other statement clarifies whether lane splitting is allowed or prohibited for motorcycles.

4. Motorcycle Exclusive/Priority Lanes

For segregating motorcycle traffic from the other fast vehicle traffic, there are separated motorcycles exclusive lanes (MELs) or priority lanes (MPLs) on some major roads. However, in most cases, the MELs or MPLs were implemented accompanied with MBLs and limit motorcycles to the MELs or MPLs. On most urban streets, the MELs or MPLs are likely to be occupied by parked vehicles. Consequently, the motorcycles are forced to travel on the MBLs or FVLs. Traffic accidents may occur during the lane changing process when the motorcycles are forced to stay away from the MELs or MPLs. A common scenario is shown in Figure 3, where the MPLs were occupied by parked vehicles and the other lanes are prohibit the use of motorcycles.

![Figure 3 Motorcycle Priority Lanes occupied by parking cars.](image)
MOTORCYCLE CRASH ANALYSIS

The objective of the motorcycle crash analysis is to identify causes of motorcycle accidents under various road types and traffic control scenarios, and to seek better measures to improve motorcyclists’ driving environment and safety on the basis of road geometry or traffic control design. Thus, this analysis focuses on the road types, crash types, involved objects, and the locations of accidents as well as the traffic control scenarios. The analysis data were based on the traffic accident records provided by Taiwan National Police Administration (NPA). It should be noted that the records only include the fatal or injured accidents. The accidents with only property damage were not included. The number of fatalities was counted for those who died within 30 days after the accidents occurred.

According to the traffic accident records of 2011, the total number of motorcyclist-involved accidents (MIAs) was 208,498, which is about 88 percent of the total traffic accidents (235,775) that same year. The MIAs resulted in 1,673 deaths and 263,356 injures to motorcyclists. Among those deaths and injuries, 113 deaths and 29,103 injuries were motorcycle passengers.

Table 1 shows the numbers of accidents counted by interacted-objects of the accidents, and road types where the accidents occurred. It shows that about 33 percent of MIAs were motorcycle-only accidents, 7 percent involved pedestrians and bikers, and 60 percent were with other motor vehicles. Among the MIAs, 9 percent were single motorcycle involved accidents (SMIAs) and 24 percent had multiple motorcycles involved (MMIAs). In terms of the road types where the accidents occurred, more than 60 percent of MIAs occurred at intersections.

For those accidents that occurred at intersections, more than around half (52 percent) of the MIAs occurred at unsignalized intersections. This is especially high for the MIAs with pedestrians or bicyclists involved (61 percent). Among the accidents at unsignalized/signalized intersections, about 25/27 percent were multiple motorcycles involved, 6/4 percent were pedestrian or bikes involved (MvsPB), and 0.68/0.59 percent were fatal accidents (Mdeath). The chi-square test results indicated the differences of the proportions of categories of accidents above at unsignalized and signalized intersections were significant (X^2 value shown as bold font) under the significant level of 0.05. The proportion of fatal accidents at unsignalized intersections was significantly larger than those at signalized intersections. This indicates that motorcyclists have a higher risk of traffic accidents at unsignalized intersections.

For the locations where the MIAs occurred at road segments, more than 82 percent of MIAs occurred at either “general lanes” (57 percent) or “road side lanes” (25 percent), where the motorcycles are required to ride. Road-side lanes include slow-vehicles-lanes (SVLs), motorcycle-priority-lanes (MPLs), motorcycle-exclusive-lanes (MELs) and shoulders. The general lanes include lanes at two-way two-lane roads or lanes next to the road side lanes where all vehicle types are allowed to travel. About 16 percent of MIAs occurred at motorcycles banned lanes (MBLs), where the motorcycles were not supposed to be at. In terms of the severity of MIAs, the proportion of fatal accidents occurred at road side lanes and general lanes were 1.36 and 1.17 percent, respectively. This indicates the motorcyclists have a higher risk of traffic accidents at road side lanes.
<table>
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<th>SMIAs (D/B)</th>
<th>MMIAS (E/B)</th>
<th>MvsPB (F/B)</th>
<th>MvsOthers (G/B)</th>
<th>MvsTK (H/B)</th>
<th>Mdrink (I/B)</th>
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<td>126137</td>
<td>5215</td>
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<td>82</td>
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</table>
| Note: *X²(0.05,1)=3.841;  
*The X² values in bold font indicate the differences are statistically significant at significant level of 0.05.
Intersections

The major cause of the MIAs at unsignalized intersections was “fail to yield” (47 percent), followed by “failed to look properly” (10 percent), as shown in Figure 4. In terms of SMIAs “failed to look properly” was the major crash cause (35 percent), followed by “alcohol related” (20 percent).

![Figure 4 Crash causes of MIAs at unsignalized intersections.](image)

Practically, most unsignalized intersections in Taiwan do not have physical signs, markings or other supplements to assign the passing priority for the approaching vehicles. The priority sequence at unsignalized intersection requires a self-judgment by drivers according to a series of complicated yield rules, such as left approaching vehicles should yield to right side approaching cars, as well as many others. Without physical and obvious signs or markings, drivers were not clearly warned when approaching an intersection, which is especially difficult for impaired drivers. Thus, significant and physical traffic control devices, such as “stop” signs, markings, and appropriate geometry design, such as sight distance, should be implemented at unsignalized intersections to clearly assign the right-of-way to the road users.

At signalized intersections, the main crash cause of MIAs was “against signal indications” (21 percent), followed by “failed to yield” (20 percent) and “failed to look properly” (10 percent), as shown in Figure 5. It is believed that most crashes at signalized intersections resulted from drivers breaking the law. However, by inspecting the deployment of traffic signals, it was found that the locations and indications of the traffic signals were mainly designed for main stream traffic. The motorcycles or other slow vehicles traveling on the road side or MPLs have not been considered in the traffic signal installation process. Due to the size and operational characteristics of motorcycles, the signal indications are most likely blocked by other large vehicles on the main stream. Motorcyclists could violate the signal indications when their sights to the signal indications were blocked. Thus, the installation guidelines of traffic signals need to be modified properly by taking into account the locations and operational characteristics of motorcycles.
Figure 5 Causes of MIAs at signalized intersections.

Road Segments

On the road side lanes, the major crash cause of MIAs was “failed to look properly” (23 percent), as shown in Figure 7. However, “failed to keep safe following gap” (20 percent) was the main cause of MMIAs. A high portion (9 percent) of crashes between motorcycles and other motor vehicles was due to “changing lanes improperly”. This indicates that motorcyclists changing lanes is a major traffic safety risk factor under the mixed traffic flow situation. It should be noted that “alcohol related” crashes represent 20 percent of single motorcycles accidents. Drunk driving is a very serious traffic safety issue in Taiwan.
On general lanes, in addition to “failed to look properly”, both “failed to yield” and “failed to keep safe side space” had a high portion (6 percent) among the major crash causes, as shown in Figure 8. This would be the major issue of mixed traffic lanes, with some motorcyclists traveling between lanes and other vehicles (called lane splitting).

In addition, by checking the crash types on the road segments, it was found that angle crashes and side-to-side crashes shared more than 50 percent of crashes for MMIAs (29 percent and 22 percent, respectively), as shown in Figure 8. Similarly for crashes between motorcycles and other vehicles, side angle crashes and side-to-side crashes each shared 27 percent of crash types. This would be the typical scenario in the mixed traffic, in which multiple motorcyclists are traveling on the same driving lane and change lanes frequently (as shown in Figure 8). With motorcycle lane indications (markings) on the general lanes would help motorcyclists stay on the tracks (lanes).
PRINCIPLES OF TRAFFIC CONTROL DESIGN FOR MOTORCYCLES

Even though the number of motorcycles is more than double that of other motor-vehicles, current road geometry and traffic control devices scarcely take into account the motorcyclists’ demands and traveling rights. Most road designs and control strategies focus on restricting the space of motorcyclists, such as “Motorcycle Banned Lanes” (MBLs) or “Fast Vehicle Lanes” (FVLs). On most major roadways, motorcycles are prohibited from the MBLs and FVLs. The traffic regulations also limit motorcycles to use the sides of the roads as much as possible and treat motorcycles as slow vehicles, even though some MPLs or MELs were implemented. The concept of MPLs or MELs in Taiwan today is to provide motorcycles with exclusive or priority traveling space. However, the reality is that these management strategies try to fit the numerous motorcycles into a limited space, and end up restricting the lanes or space which can be used by motorcycles. This concept did not address motorcyclists’ rights and travel demands, nor did it provide a safer environment for motorcycles. Based on these regulations, car drivers tends to become aggressive when they see motorcycles occupying the fast vehicle lanes or on their ways (lanes) and therefore try to force the motorcyclists to move to the lanes located at the side of the road. However, due to the street side parking issues, particularly on urban streets, motorcyclists must dangerously maneuver between the parked cars and cars on the MBLs or FVLs.

By considering the operational characteristics of motorcycles and the motorcyclists’ rights and travel demands, the basic principle of road design and traffic control devices should treat motorcycles as regular, although weaker, motor vehicles instead of labeling motorcycles as slow vehicles. The lane alignment and size of motorcycle waiting boxes should take into account motorcycle volumes, motorcyclists’ characteristics and road-side land use types.

Other practical principles of road alignment and traffic control designs for motorcycles are proposed by road types as following:

1. Unsignalized intersections:

   Based on the motorcycle crash analysis, the major causes of the motorcycle accidents were “failed to yield” and “failed to look properly”. It was believed that these accidents may be due to the unclear signs or markings that didn’t give motorcyclists clear indications for the priority sequence of passing the intersections. Thus, clear signs or markings, such as a “stop sign”, at every unsignalized intersection approach is needed to assign the prior sequences for the approaching vehicles. The current regulations, which regulate the passing priority sequences which are based on the sizes or functions of the roads and directions of the approaching vehicles, should be changed. Drivers can follow the rules of the obvious signs or markings for passing the unsignalized intersections and need not any self-judgment about the priority from a set of complicated regulations. The visible signs or markings can also help drivers to notice approaching vehicles at intersections and are expected to reduce the number “failed to yield” or “failed to look properly” crashes when approaching an unsignalized intersection.

2. Signalized Intersections

   According to the crash cause analysis, “against the signal indications” is a major cause of the MIA. One of the major issues is the traffic signal indications could not be clearly seen by motorcyclists from the road sides or MPLs. The other issue is that the signal timings at most intersections did not consider the operational characteristics of motorcycles. For instance, the clearance time is set based on the road width and the speed of the cars approaching the
intersection from the regular lanes, the motorcyclists’ speed and the location of the motorcycles were not considered.

The principles of the traffic control design at signalized intersections for motorcycles are discussed as below:

2.A Motorcycle signal sets or indications

At a four-way intersection, the basic signal sets include a near right set and a far left set. Due to the size and location of motorcycles, the signal indications tend to be blocked by other vehicles using the main driving lanes. Thus, supplemental sets of traffic signals or indications are needed. A vertical signal set along the road side and a supplemental little signal set in a French intersection (as shown in Figure 9.a) would be appropriate references in the design of a motorcycle signal set and supplemental indications.

2.B Signal indications by lanes

The standardized signal and indication settings in Taiwan are based on the approaches and directions at the intersections, and usually do not consider the types of vehicles or lanes. Separated signal indications by lanes (as shown in Figure 9.b) are also recommended, especially for the approaches with MPLs, MELs, or other physically separated lanes. For these separated lanes, separated signal timings may also be an option based on motorcycle volume and demand (16).

3. Road Segments

The lane alignment should take into account motorcycle volumes, motorcyclists’ operational characteristics and road-side land use types. The lane alignment should provide enough space and clearly indicate which lanes can be used by motorcycles instead of limiting motorcycles to the restricted highly mixed traffic flow lanes. Practical principles of road segment design and lane alignments are considered as following:

Figure 9 Examples of signal sets at intersections in French and USA (Source: Google Map)
3.A Principle of installing MELs or MPLs

The guidelines of installing MELs and MPLs were conducted in 2002 (27). The guidelines provide several types and options for installing MEL and MPLs under various conditions. However, only a few types of MELs/MPLs, which were usually deployed on the road sides, were in practice. The MELs/MPLs were implemented widely during these years in most major roads regardless of motorcycles volumes or the road sides land uses. Most of them were implemented in the urban streets where parking activities would result in serious conflicts with motorcycles. Thus, the principle of installing the MPLs or MELs should consider the land use types of the road side.

- It is not recommended on urban streets where a high number of parking activities occur.
- In rural areas, exclusive motorcycles lanes are recommend on major roads.
- Motorcycles and slow vehicles should be treated separately.

However, an additional study is necessary to standardize the detail criteria or guidelines for installing the MELs or MPLs.

3.B Various speed limits by lanes:

The regulation in Taiwan categorizes motorcycles as slow motor vehicles. Thus, motorcycles are restricted to slow vehicle lanes (SVLs), MPLs or MELs. However, how slow the speed should be is not regulated. In most cases, motorcycles driving at the speed limit on the slow driving lanes would create large speed differentials with other motorcycles. Particularly during periods of congestion, many vehicles other than motorcycles use the SVLs, MPLs and MELs in order to try to avoid the queue, resulting in the major cause of conflicts with motorcycles. Therefore, a clear statement or regulation to regulate the speed limits by lanes is recommended. Vehicles driving on the SVLs should drive at a slow speed regardless of the type of the vehicle driven. Similarly, vehicles driving on the FVLs should drive at a high speed, whether there are motorcycles or cars on the lane. The purpose of this strategy is to decrease the speeds differentials in the particular lanes and prevent high speed vehicles from traveling on the SVLs.

3.C Lane Splitting:

According to Taiwanese highway traffic regulations (26), lane splitting is prohibited when motor vehicles stop in the queue during the red light period. However, no specific regulation or other statement clarifies whether lane splitting is allowed or prohibited for motorcycles. Thus, a clarified regulation of lane splitting exclusively for motorcycles is needed to support the installation of motorcycle waiting boxes beyond the stop line.

3.D Supplemental motorcycle lane markings on general lanes

Due to the high motorcycle volumes in Taiwan, multiple motorcycles traveling on the same driving lane are a common scenario on most roads, especially on general lanes. To provide a clear indication for motorcycles to stay on the tracks or lanes, supplemental lane indication markings for motorcycles on the general lanes would be an option for lane alignments. As shown in Figure 10 a smaller dash line is implemented between regular lanes (general lanes), giving motorcyclists a clear indication where they can stay. This design can also warn other drivers that the general lanes can be used by motorcycles and that they should yield to motorcycles when they are using this roadway. This design could also include specific speed limits in each lane to
indicate that slow vehicles/motorcycles cannot occupy the lanes. However, a detailed and precise study or experiment is needed to evaluate the effects of this design.

CONCLUSIONS AND RECOMMENDATIONS
Motorcycles are the most common mode of transportation but also create the major safety issue in Taiwan. A long-term goal of the Taiwanese government is to reduce its usage and dependency on motorcycles. However, this long term goal must rely on a success of pedestrian and public transportation systems developed through urban planning. Restricting the space permitted for motorcycle use would not decrease the usage of motorcycles but instead deteriorate their traveling environment. Providing motorcyclists with an appropriate and suitable traveling environment would be the best solution for improving motorcycle safety. According to the motorcycle accident analysis in this study, the major principles for creating a safe motorcycle environment include considering motorcycles as regular, although weaker, giving motorcycles plenty of travel space, and providing clear signs and exclusive regulations for motorcycles. Practical strategies include: At unsignalized intersections, a physical and visible traffic signing or marking should be implemented to clearly assign the passing priority for approaching vehicles. At signalized intersections, supplemental sets of signal indications for motorcycles are needed to provide a clear signal indication for vehicles traveling on the road’s side lanes. On road segments, the implementation of motorcycle exclusive and priority lanes should take into account the land use of the road side. Various speed limits by lanes and supplemental markings for motorcycles to stay on tracks or lane are also recommended.

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