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Evaluating the effect of lane width and roadside configurations on speed, lateral position and likelihood of comfortable overtaking in exclusive motorcycle lane

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ABSTRACT

Construction of exclusive motorcycle lanes is one of the measures to reduce motorcycle fatalities. Previous studies highlighted the risk of crashes with roadside objects and the tendency of motorcyclists to ride with excessive speed on exclusive motorcycle lanes. However, the risk of same-direction crashes on exclusive motorcycle lanes was not explored in much detail, especially on the impact of lane geometry and roadside configurations. This study used naturalistic riding data to determine the effects of lane width and roadside configurations on overtaking speed, lateral position and likelihood of comfortable overtaking on tangential sections of an exclusive motorcycle lane. Twenty-nine recruited motorcyclists rode the instrumented motorcycles along a 20 km stretch of an exclusive motorcycle lane along a major urban road. Results revealed that both the roadside configurations and lane width significantly affect the participants' lateral position, while the roadside configurations only affects the overtaking speed. Participants' overtaking speeds and the front motorcycles' lateral position contribute significantly to the likelihood of comfortable overtaking in exclusive motorcycle lanes. The findings highlight the importance of micro-level behavior indicators in improving the design and overall safety of the exclusive motorcycle facility.

1. Introduction

Motorcycle is one of the most vulnerable and hazardous vehicle on the road due to the little or no physical protection for the rider and yet this powered-two-wheeler is capable of moving at a rather high speed. Radin Umar et al. (1995) estimated that the relative risk of fatality in traffic crashes for motorcyclists in Malaysia is 17 times greater than that of car drivers. Motorcyclists typically ride in a mixed traffic environment, which is unsafe due to problems of space, speed differentials and high risk of collision with other automobiles. One of the effective road engineering initiatives is to segregate this vulnerable road user from the automobiles by providing an uninterrupted, one-directional exclusive motorcycle facility along the roadway. Radin Umar (2006) reported that following the opening of an exclusive motorcycle lane along the federal highway in Selangor, Malaysia, there has been a 39% reduction in motorcycle crashes, and 600% reduction in motorcyclist fatalities. Despite the reported positive impacts on the safety of motorcyclists, there are still other safety issues that yet to be understood in order to enhance the safety of the motorcycle facility.

1.1. Motorcycle lane safety issues

Motorcycle space requirement is one of the safety related concerns for one-directional exclusive motorcycle lanes (Hussain et al., 2005). Previous studies highlighted the safety issues due to the lack of a scientifically developed design guidelines for exclusive motorcycle lanes (Hussain et al., 2011, 2005, 2001). Traffic engineers have also looked into the impact of motorcycle speed-flow-density relationships and the capacity of the uninterrupted path on overall safety, especially when high motorcycle volume is expected (Hussain et al., 2011).

A study by Tung et al. (2008) found that motorcyclists travelling along the exclusive motorcycle lanes in Malaysia were at risk of involving in run-off-road crashes and crashes into fixed roadside objects. This may be due to the incompatibility in motorcycle riding speeds in the prevailing motorcycle lane and motorcycle traffic conditions. Meanwhile, Ibitoye et al. (2007) reported the risk of severe injury to motorcyclists in the event of collisions with crash barriers along the exclusive motorcycle lane. A study on riding behaviors along the exclusive motorcycle lane revealed a significant correlation between the use of exclusive motorcycle lane and speeding behaviors among

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motorcyclists along the lane (Abdul Sukor et al., 2016).

1.2. Effect of lane geometry on overtaking behavior

Overtaking is a driving maneuver that is categorized as a high demanding driving task (Vieira and Larocca, 2017) and associated with driving errors (Clarke et al., 1998; Young et al., 2013). Overtaking collisions pose a higher risk of serious injuries due to higher collision speeds, especially for vulnerable road users such as motorcyclists and bicyclists. Apart from speeds, lateral safety margin (Walker, 2007), conspicuity (Broughton et al., 2009) and risky riding behaviors (Chang and Yeh, 2007) were also reported as the risk factors of overtaking collisions involving two-wheelers.

From the perspective of riding behaviors, the decision to overtake another vehicle and to maintain certain overtaking speeds can be explained using Risk Compensation Hypothesis (Summala, 1996). Summala argues that in keeping a vehicle positon inside a lane, a driver has a margin of time before crossing the lane boundaries. This time-to-lane-crossing (TTLC) provides a control measure that explains the decision to slow down on a sharp curve or on a narrow road section. Not slowing down on these locations means a quickly diminishing time (safety) margin of boundary crossing, which could results in collision. Thus, assuming that driver have control on the safety margin and as long as it does not exceed the threshold, his or her driving behavior is not affected. On the onset of an overtaking maneuver, encountering a slower vehicle provides options for the overtaking vehicle-driver to either reduce the speed to compensate for diminishing safety margin or to increase the speed and overtake the vehicle to compensate for diminishing safety margin or to maintain a desired speed.

The decision to select higher overtaking speeds as explained using the theory of hazard perception by Groeger (2000), listed situational awareness and threat appraisal as part of process of hazard detection and responding. In an overtaking event, the slow moving vehicle is a form of driving hazards and the overtaking process is a risky maneuver that could lead to a crash. As a way to respond to the risky situation, a driver might choose a higher overtaking speed to minimize the overtaking time and reduce the risk of crash. Generally, a reduction in speed, especially by braking is less common during an overtaking maneuver, unless the perceived safety margin is compromised. In addition to speed modification, trajectory modification is also one of the ways motorcyclists commonly respond to unexpected risk of collision. Thus, overtaking speeds, braking behaviors and lateral positions are potential indicators on motorcyclist comfort during overtaking, which could influence the safety level.

1.3. Effect of road design of motorcycle or bicycle facilities on safety

Shackel and Parkin (2014) examined the effect of road markings, lane widths and driver behavior on proximity and speed of vehicles overtaking bicyclists in unseparated traffic conditions. Narrower lane, lower speed limits and the absence of centerline markings correlates with reduced overtaking speeds. The study recommends wider cross-sections and removal of centerline markings to improve the safety of cyclists in mixed traffic environment.

Milling et al. (2016) investigated the influence of road infrastructure elements on the likelihood and severity of motorcycle crashes in Australia. They found that motorcyclists have much greater risk of collision with crash barriers (e.g. guardrails) in the event of run-off-road crashes due to the design of the motorcycle and the resulted crash mechanism. In addition, motorcyclists were associated with higher risk of injuries in a collision with support pole of crash barriers (e.g. guardrail posts) due to the concentration of crash force on smaller impact surface area.

In a car drivers related study, Bella (2013) explores the effect of roadside configurations comprising trees and guardrails, cross-sections and geometric elements on speed and lateral position of driver on a two-lane rural road lined with trees. They observed higher speeds among drivers when shoulder was available on the right side of the road. In addition, the shoulder on the right side prompts drivers to move closer to the edge of the road. Based on Risk Compensation Hypothesis, the researcher postulates that drivers will increase the speed and move closer to the center of the road when guardrail is presence. This is because the presence of guardrail along a road section lined with trees gives the perception of lesser risk of collision with the trees. The study concludes that cross-sections and geometric elements affect drivers' speed and lateral position on the road. However, similar effect for the roadside configurations were not observed

In a driving simulator study, Ben-bassat and Shinar (2011) found a significant effect of shoulder width and presence of guardrail on drivers' speed, lateral position and perceived safe speed. Drivers tend to drive faster when driving on a straight section with guardrail. The researchers postulates that guardrail improves the sense of security on straight section, thus allowing the drivers to drive faster. Another study by Fitzpatrick et al. (2016) demonstrated the effect of clear zone width on speed and lateral position. The results revealed significant reduction in speed for both tangents and left curves with narrower clear zone. Interestingly, the participants would drive further away from the edge of the road (a difference of -0.25 m) when the width of clear zone decreased.

One way to improve the safety of motorcycle lane is by improving the design geometry. This is mainly because the geometries are the main operational features of highway apart from the roadside environment and traffic condition. These features are the key factors that influence motorcyclists' riding behaviors, and translated by the choice of speed, tangential and lateral acceleration rates, and lateral placement. This study seeks to understand the factors affecting speeds, lateral positions and likelihood of comfortable overtaking along the exclusive motorcycle lanes. By identifying and taking account of motorcyclists' actual reaction to the elements of the road design and interpretation of the road situations, it aims to provide a more accurate analysis and conclusion on the interaction between road design and riding behaviors of motorcyclists along the exclusive motorcycle lane.

2. Methods

A field experiment was conducted along a predetermined stretch of an exclusive motorcycle lane along the Federal Highway, Route 2 in the state of Selangor, Malaysia. The stretch has a total length of 20 km comprising both north and south bound with average riding time of 20 min. Selection was based on the roadway characteristics, availability of a long tangent section (minimum length of 100 m) to observe overtaking events and availability of suitable drop-off and pickup points. The average lane width along the selected route was 3.05 m (SD = 0.16 m) with minimum and maximum width of 2.6 m and 4.2 m respectively. This study developed an instrumented motorcycle using a Honda motorcycle with an engine capacity of 100 cc to record participants' real-time riding behaviors (Fig. 1).

2.1. Details of data logger and instrumentation

The main data logger used in this study was an off-the-shelf DR-9100 unit manufactured by Horiba Ltd. It was approximately 4.4" (W) × 3.6" (D) × 1" (H) in size, weighed around 135 g and powered by 12 v direct current. The small size made it practical and compatible to be installed inside a helmet storage box mounted at the rear of the motorcycle. The data logger recorded real-time riding speed, video output, electrical signals and outputs from acceleration sensor simultaneously and synchronously. Two high-resolution miniature cameras were mounted on the center front and at the back of the motorcycle to provide real-time video images of the forward view and the area directly behind the motorcycle. Both the front and rear view cameras were capable of recording images at 30 frames per second (fps)