Development of fatality and injury risk relationships for cyclist-vehicle impacts

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Abstract

There is very little literature addressing cyclist fatality and serious injury (FSI) risk in impacts with motor vehicles. This study built on established curves relating pedestrian FSI risk to vehicle impact speed and incorporated the effects of cyclist speed and impact angle. A technique was developed that considered a vehicle-cyclist crash as two impacts: (a) the first impact between the cyclist and the vehicle and; (b) the second impact between the cyclist and road/roadside infrastructure. Combining the FSI risk of each yielded an estimate of cyclist FSI risk. This pilot method will need to be validated using real-world data.

Background

There have been several curves developed to quantify the relationship between pedestrian fatality and serious injury risk and vehicle impact speed. Unlike pedestrians, cyclist travel speed is often of similar order of magnitude to that of the motor-vehicle and therefore this variable and impact angle also plays a role in crash severity. As part of assisting a state road authority (VicRoads) with the development of a tool to evaluate intersection safety for pedestrians and cyclists, this project sought to develop prototype relationships to quantify cyclist FSI risk as a function of vehicle and cyclist impact speed and angle.

Method

A review of the literature identified several curves quantifying pedestrian FSI risk with vehicle impact speed (e.g. Davis, 2001; Rosén and Sander, 2009). However, there is limited literature establishing a corresponding relationship for cyclists. Kröyer (2015) treated cyclists in the same way as pedestrians, creating aggregate curves without accounting for crash configuration or cyclist travel speed. Kröyer also used sample spot speeds rather than actual impact speeds.

In this study, the outcome for a cyclist was considered as a combination of two impacts to the cyclist: the first with the vehicle and the second with the road/road infrastructure. The severity of the first impact is related to the velocity change of the cyclist during the initial interaction with the car. Assuming that the mass of the cyclist is small compared with the vehicle and the cyclist engages fully with the vehicle when struck (i.e. post-impact they are travelling at the speed of the motor vehicle), their velocity change is given by:

$$\overrightarrow{V_{rel}} = \overrightarrow{V_c} - \overrightarrow{V_b} \qquad (1)$$

where

$\overrightarrow{V_c}$: car velocity;

$\overrightarrow{V_b}$: cyclist velocity;

$\overrightarrow{V_{rel}}$: cyclist velocity change during the impact.

The magnitude of this velocity change represents the speed change, ΔV_1, of the cyclist during impact 1. The cyclist is then assumed to be travelling at the speed of the impacting vehicle, colliding with the road/roadside infrastructure at speed V_2 (assuming no vehicle braking).

The individual FSI risk of each impact was determined using a suitable pedestrian impact risk curve (this study used Davis, 2001) and the two values weighted and summed. Neal-Sturgess, Carter, Hardy, Cuerden, Guerra & Yang (2007), in a study of 70 European real-world pedestrian and cyclist crashes, attributed the source of individual injuries to each impact. They found that 53% of cyclist injuries were caused by the vehicle impact and 47% with the ground. The following relationship was used to combine the individual impact risk values:

$$Pr(FSI) = wPr(FSI \mid \Delta V_1) + (1 - w)Pr(FSI \mid V_2) \quad (2)$$

where

$Pr(FSI \mid \Delta V_1)$ is the probability of a fatal/serious outcome given impact #1 speed change

$Pr(FSI \mid V_2)$ is the probability of a fatal/serious outcome given impact speed #2

w is the proportion of injuries sustained in impact #1 = 0.53

Results

Figure 1 shows a sample cyclist risk curve for a hypothetical cyclist crash involving a right-turn-against crash between a turning vehicle and a through cyclist (25 km/h) at an impact angle of 75 degrees.

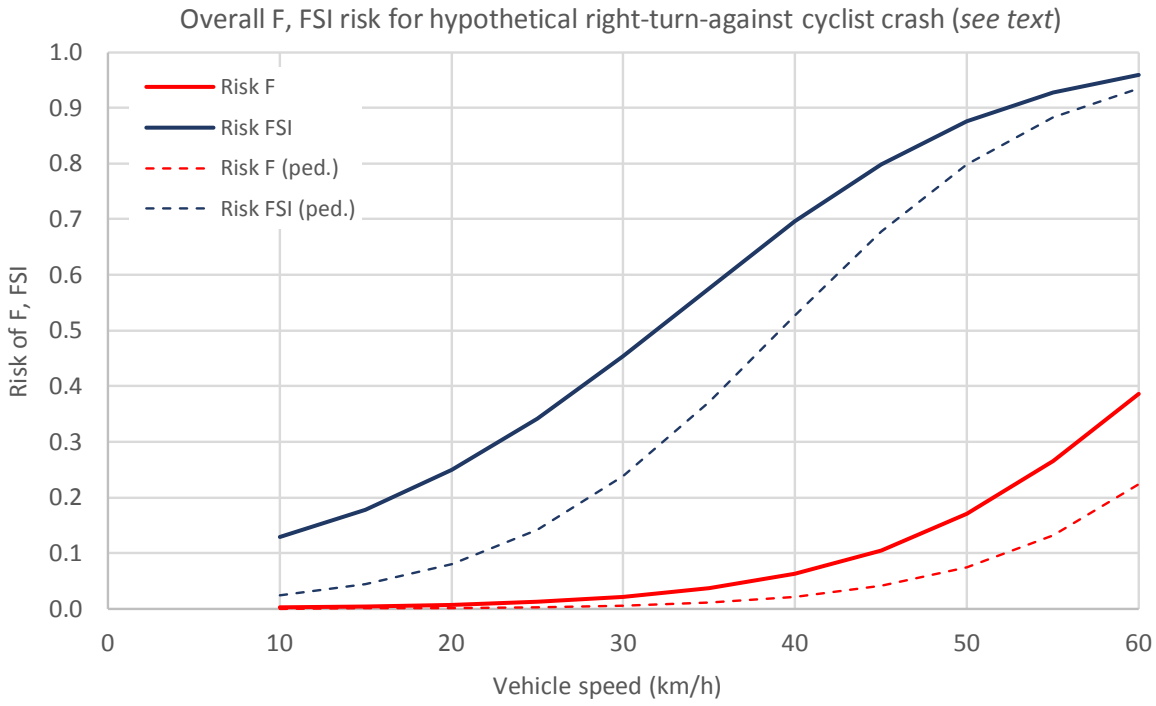

Figure 1. Sample cyclist FSI risk curve.

Conclusion

This study proposed a new method for estimating cyclist fatality and serious injury risk based on previously-established pedestrian FSI risk curves and impact speed and angles. Further work is required to validate the model.

References

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