

Research on Method for Classifying Injury Severity Using Motorcycle Accident Data for ISO 26262

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ABSTRACT

ISO 26262 was established in 2011 as a functional safety standard for passenger cars. In this standard, ASILs (Automotive Safety Integrity Levels) representing safety levels for passenger cars are determined by evaluating the hazardous events associated with each item constituting an electrical and/or electronic safety-related system according to three evaluation criteria including injury severity. On the other hand, motorcycles will be included in the scope of application of ISO 26262 in the next revision. It is expected that a severity evaluation for motorcycles will be needed because motorcycles are clearly different from passenger cars in vehicle mass and structure. Therefore, this study focused on severity class evaluation for motorcycles. A method of classifying injury severity according to vehicle speed was developed on the basis of accident data. In addition, a severity table for motorcycles classifying injury severity according to vehicle speed for each accident type was produced using accident data involved with motorcycles in Japan.

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INTRODUCTION

ISO 26262, an international standard for the functional safety of passenger cars, was formulated on the basis of IEC 61508 [1] and was established in November 2011 [2]. One of the changes planned for its forthcoming revision is the inclusion of motorcycles in its scope of application, implying a need to develop motorcycles that will comply with ISO 26262.

To contain within socially acceptable levels the risks associated with the malfunction of an electrical and/or electronic safety-related system, ISO 26262 defines functional safety requirement for cars using ASILs which consists of three evaluation criteria: severity, controllability and exposure. The severity is for rating the severity of injuries sustained by drivers and other road users in hazardous events in terms of four severity classes S0 to S3. The severity in ASILs necessitates potential injury risks to be estimated logically on the basis of various parameters such as a collision configuration, a collision object and vehicle speed. Injury types differ between motorcycle occupants and car occupants because motorcycles differ from cars in vehicle mass, vehicle structure, occupant protection devices and because, unlike car occupants, motorcycle occupants are ejected from the motorcycle body in collision accidents. Accordingly a separate severity rating method needs to be developed for motorcycles.

For severity rating, various collision test methods have been established for passenger cars according to a variety of collision configurations, so that an ample amount of test data as well as accident data are available for cars. On the other hand, collision test methods for evaluating the rider protection performances of

motorcycles have yet to be developed in the world. Thus, due to a lack of test data, it is necessary to base the severity rating of motorcycles mainly on accident data.

There are two principal data on road traffic accidents in Japan: the nationwide accident statistics data (macro data) compiled by the National Police Agency and in-depth investigation accident data (micro data) taken by the Institute for Traffic Accident Research and Data Analysis. While the latter micro data cover such detailed parameters as impact speed and injury severity, its investigated samples are relatively few. Consequently this study depended largely on macro data to examine severity rating methods. Regarding the parameters such as collision configurations, collision objects and vehicle speed which are necessary for the rating of injury severity, the item "type of accident" in the police macro data was considered equivalent to the parameters of collision configuration and collision object. As for the parameter of vehicle speed, the police macro data have the item "hazard recognition speed" defined as the vehicle speed immediately before the driver operates the steering wheel or the brake pedal to avoid an accident upon recognition of a hazardous traffic situation. The accidents involving a motorcycle were extracted from the macro data, and were analyzed with regard to the relationship between hazard recognition speed and injury for each accident type. Then a technique of classifying injury severity from hazard recognition speed was examined, and a severity table for motorcycles was produced establishing boundary speeds for severity classes in each accident type. Furthermore a correlation between hazard recognition speed and impact speed was examined in the micro data, followed by the trial production of a severity table based on the impact speeds converted from hazard recognition speeds.

RELATIONS BETWEEN HAZARD RECOGNITION SPEED AND INJURY

To classify severity, it is necessary to determine boundary speeds for severity classes in each of the representative accident types. In the case of the motorcycle-to-car accidents, it will be necessary to take account of not only the motorcycle's speed but also the car's. Consequently relations between hazard recognition speed and fatality and serious injury rate [i.e., number of fatal and serious injury accidents / number of casualty accidents x 100] were analyzed for each of the representative accident types, using the macro data covering practically all the traffic accidents that occurred on general roads, not including the toll expressways, across Japan between 2003 and 2012. Only the data on the motorcycles with engine displacement of over 50 cm³ and with their occupants wearing a helmet which had not come off were analyzed.

Figures 1, 2 and 3 show relations between fatality and serious injury rates and hazard recognition speeds (divided into intervals of 10 km/h) for motorcycle-to-car accidents of head-on, rear-end and crossing collision types. In head-on and crossing collisions, fatality and serious injury rates rose with the increase of the hazard recognition speeds of the two vehicles involved. In rear-end collisions, the hazard recognition speed of the impacting vehicle contributed notably to fatality and serious injury rates while the hazard recognition speed of the impacted vehicle was considered to be independent of those rates. In the case of motorcycle-to-car accidents, therefore, it will be necessary to select speed parameters suited for accident types and collision configurations in order to set boundary speeds for severity classes.

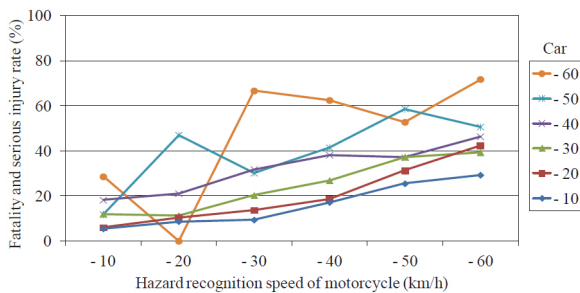
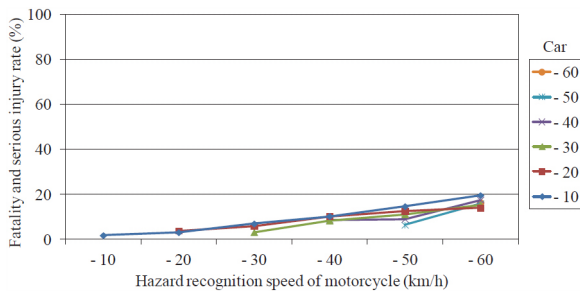
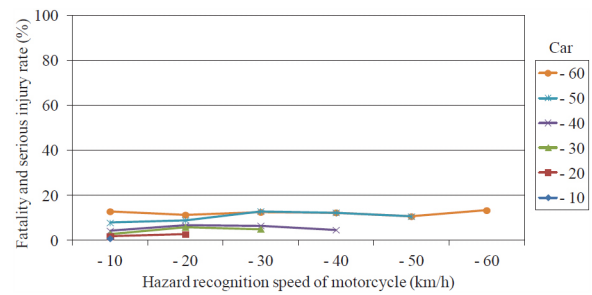


Figure 1. Fatality and serious injury rates vs. hazard recognition speeds in motorcycle(MC)-to-car head-on collisions (MC front-car front)



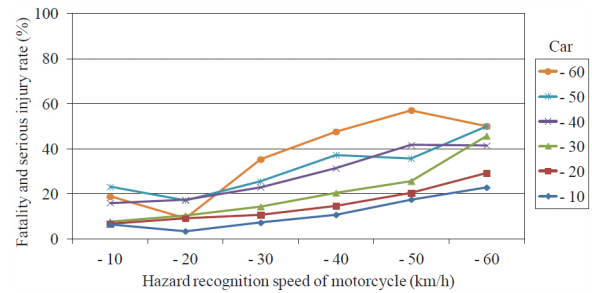
a. Collision point: MC front-car rear

Figure 2.

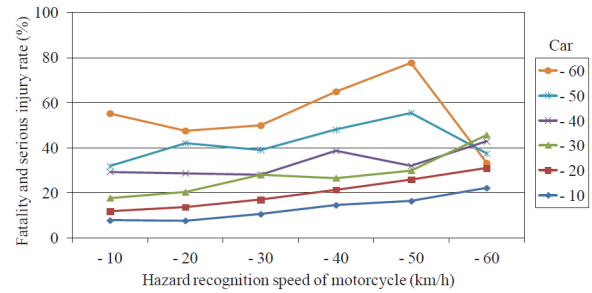


b. Collision point: MC rear-car front

Figure 2. (cont.) Fatality and serious injury rates vs. hazard recognition speeds in MC-to-car rear-end collisions



a. Collision point: MC front-car side



b. Collision point: MC side-car front

Figure 3. Fatality and serious injury rates vs. hazard recognition speeds in MC-to-car crossing collisions

METHOD FOR SETTING BOUNDARY SPEEDS FOR SEVERITY CLASSES

Table 1 shows the four severity classes S0 to S3 established in ISO 26262. To validate qualitatively described severity classes in a logical manner, it is necessary to define them in quantitative terms. Referencing the AIS-based (Abbreviated Injury Scale) severity classification given in ISO 26262 Part 3 Annex B (Table 1), this study attempted to define severity classes on the basis of the injury levels recorded in the police macro data as shown in Table 2.

Table 1. Severity classes (ISO 26262 Part 3)

	S0	S1	S2	S3
Class of severity	No injuries	Light and moderate injuries	Severe and life-threatening injuries (survival probable)	Life-threatening injuries (survival uncertain), fatal injuries
Reference for single injuries (from AIS scale)	AIS 0 and less than 10 % probability of AIS 1-6	More than 10 % probability of AIS 1-6	More than 10 % probability of AIS 3-6	More than 10 % probability of AIS 5-6

Table 2. Quantified definitions of severity classes

Class of severity	S0	S1	S2	S3
Injury level according to macro data	Slight injury rate<10 %	Slight injury rate≥10 % and fatality and serious injury rate<10 %	Fatality and serious injury rate≥10 % and fatality rate<10 %	Fatality rate≥10 %

Fatality rate: number of fatal accidents/number of fatal and injury accidents x 100

Fatality and serious injury rate: number of fatal and serious injury accidents/number of fatal and injury accidents x 100

Slight injury rate: number of slight injury accidents/number of fatal and injury accidents x 100

Fatality: Died within 24 hours as a result of accident

Serious injury: A person who needs medical treatment for a month (30 days) or more

Slight injury: A person who needs medical treatment for less than a month (30 days)

Table 3 shows scenario elements for the production of a motorcycle-related severity table on the basis of macro accident data in Japan. It was considered necessary to set boundary speeds for severity classes in each representative type of motorcycle accident.

Table 3. Scenario elements of an MC-related severity table

Type of accident	Motorcycle collision point	Car collision point	Class of severity			
			S0	S1	S2	S3
vs. pedestrian	front	-	$\leq V_{MC}$	$\leq V_{MC}$	$\leq V_{MC}$	$> V_{MC}$
vs. bicycle	front	-	$\leq V_{MC}$	$\leq V_{MC}$	$\leq V_{MC}$	$> V_{MC}$
vs. car	head-on collision	front	$\leq V_R$	$\leq V_R$	$\leq V_R$	$> V_R$
	rear-end collision	front	$\leq V_{MC}$	$\leq V_{MC}$	$\leq V_{MC}$	$> V_{MC}$
		rear	$\leq V_C$	$\leq V_C$	$\leq V_C$	$> V_C$
	crossing collision	front	$\leq V_R$	$\leq V_R$	$\leq V_R$	$> V_R$
single vehicle	roadside structure, parked vehicle	front	$\leq V_{MC}$	$\leq V_{MC}$	$\leq V_{MC}$	$> V_{MC}$
	falling	side	$\leq V_{MC}$	$\leq V_{MC}$	$\leq V_{MC}$	$> V_{MC}$

V_{MC} : Hazard recognition speed of motorcycle, V_C : Hazard recognition speed of car,

V_R : Relative hazard recognition speed

Methods of setting boundary speeds for severity classes were examined on the basis of analytical findings from the macro data. Specifically, the numbers of accidents by injury level in the macro data were used to calculate fatality and serious injury rates and slight-injury rates by speed range of hazard recognition speeds; then, severity classes were assigned to the various levels of hazard recognition speed according to the definitions given in Table 2. Table 4 shows the assignment of severity classes for each hazard recognition speed divided into intervals of 10 km/h, using the macro data on motorcycle-to-pedestrian accidents (MC collision point: front) that occurred in general roads between 2003 and 2012. The boundary speeds were estimated to be up to 20 km/h for S1, over 20 km/h up to 50 km/h for S2, and over 50 km/h for S3. Similarly, Table 5 shows the assignment of severity classes to hazard recognition speed levels, employing the macro data on motorcycle-to-bicycle accidents. Higher severity classes were assigned to higher hazardous recognition speed levels except for the decline from S3 to S2 in the highest hazardous recognition speed level over 100 km/h. This downgrading was attributed to the fact that the macro data covered only 4 accidents at this high hazardous recognition speed level.

Table 4. Hazard recognition speeds vs. severity classes in MC-pedestrian collisions (collision point: MC front)

Hazard recognition speed of motorcycle (km/h)	Number of accidents			Fatality rate (%)	Fatality and serious injury rate (%)	Class of severity
	Fatalities	Fatalities and serious injuries	Casualties			
-10	2	33	892	0.2	3.7	S1
-20	2	234	2,969	0.1	7.9	S1
-30	22	609	4,349	0.5	14	S2
-40	81	1,035	3,813	2.1	27.1	S2
-50	114	730	1,823	6.3	40	S2
-60	89	429	799	11.1	53.7	S3
-70	43	141	214	20.1	65.9	S3
-80	26	54	64	40.6	84.4	S3
-90	4	7	12	33.3	58.3	S3
-100	8	13	13	61.5	100	S3
over 100	2	5	5	40	100	S3

Table 5. Hazard recognition speeds vs. severity classes in MC-to-bicycle collisions (collision point: MC front)

Hazard recognition speed of motorcycle (km/h)	Number of accidents			Fatality rate (%)	Fatality and serious injury rate (%)	Class of severity
	Fatalities	Fatalities and serious injuries	Casualties			
-10	0	109	4,491	0	2.4	S1
-20	4	253	6,336	0.1	4	S1
-30	7	618	7,627	0.1	8.1	S1
-40	21	854	5,628	0.4	15.2	S2
-50	28	522	2,508	1.1	20.8	S2
-60	25	278	1,016	2.5	27.4	S2
-70	16	90	249	6.4	36.1	S2
-80	9	35	57	15.8	61.4	S3
-90	5	8	14	35.7	57.1	S3
-100	3	5	7	42.9	71.4	S3
over 100	0	3	4	0	75	S2

For motorcycle-to-car accidents, speed parameters corresponding to accident types and collision points were obtained from the macro data. For rear-end collisions the hazard recognition speeds of striking vehicles (collision point: front) were employed. On the other hand, for head-on and crossing collisions in which injury risks are affected equally by the hazard recognition speeds of both vehicles, the relative hazard recognition speed between the vehicles was applied. In the head-on collision configuration, relative hazard recognition speed was derived by equation (1) below, assuming that the two vehicles approach each other from exactly opposite directions. In the crossing collision configuration, relative hazard recognition speed was derived by equation (2), assuming that the two vehicles approach each other from perpendicular directions.

$$V_R = V_{MC} + V_C \quad (1)$$

V_R :Relative hazard recognition speed

V_{MC} :Hazard recognition speed of motorcycle

V_C :Hazard recognition speed of car

$$V_R = \sqrt{V_{MC}^2 + V_C^2} \quad (2)$$

V_R :Relative hazard recognition speed

V_{MC} :Hazard recognition speed of motorcycle

V_C :Hazard recognition speed of car

Table 6 shows the assignment of severity classes to the various levels of relative hazard recognition speed graduated by 10 km/h, employing the macro data on motorcycle-to-car head-on collisions (MC front-car front). The boundary speed was estimated to be up to 20 km/h for S1, over 20 km/h up to 100 km/h for S2, and over 100 km/h for S3.