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Use of Systematic Approach in Accident Risk Analysis for Motorcyclists: A Conceptual Idea

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Abstract. Thus far, minimum stopping sight distance (SSD) is determined based on design speed, a minimum reaction time of 1.64 s and a deceleration rate of 3.4 m/s², whereas in certain situations the latter can be shorter than 1 s and higher than 4.5 m/s². Awareness of this can trigger speculative behavior, as can be seen from the choice of speed and/or the critical crossing gap, which is often smaller than the recommended minimum SSD. This study focused on the development of an appropriate minimum SSD model that is suited to risky conditions at an un-signalized intersection and its possible usage in accident risk evaluation, particularly for motorcyclists. The data were taken from direct measurements and related studies. Variables that potentially influence minimum SSD were tested. The results strongly suggest that the speed reduction achieved by downshifting significantly influences both the braking distance and the impact speed. Moreover, the minimum SSD obtained from the proposed model significantly differs from that obtained from a similar model recommended by AASHTO. Therefore, it is worthwhile to consider the application of the proposed minimum SSD as an accident probability indicator parameter.

Keywords: *braking capability; downshifting; impact speed; minimum stopping sight distance; safety factor; speeding behavior.*

1 Introduction

Exceeding the regulated speed limit and/or inappropriate speed choices (speeding) are commonly believed to be primary factors associated with fatal accidents and are also of interest because riders have a tendency to speed for social-economic reasons [1-4]. When a hazardous object appears or an unexpected situation occurs drivers need adequate time and space to react and brake safely. These reaction time and braking distance requirements are referred to as *stopping sight distance* (SSD), while the distance between the hazardous object and the vehicle is referred to as *available SSD*. Higher accident risk due to speeding is a potential issue when the speed is compared to rider reaction time and braking performance, particularly in unexpected situations. The presence of a hazardous object or unexpected situations and the possible

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consequences related to speeding behavior are usually expressed by *deceleration rate* [5], *time to accident* (TTA) [5,6] and *ratio of sight distance to stopping distance* [7]. Unfortunately, previous studies did not discuss accident risk management. Moreover, speed management is currently determined based on the effect of infrastructure conditions and traffic composition rather than human factors.

In order to determine minimum SSD, AASHTO has recommended the use of a reaction time of 1 s and a deceleration rate of 3.4 m/s^2 [8,9], whereby when confronted with the need to suddenly stop a vehicle, most drivers can decelerate at a rate greater than 4.5 m/s^2 [10], such as 6 m/s^2 [5] or even 7.72 m/s^2 [11]. In addition, their reaction time could be less than 1 s, e.g. 0.68 s [12]. However, the use of minimum SSD in accident risk analysis is very rare. Accordingly, in the present study, accident probability was determined based on the difference between available SSD and required minimum SSD.

Reaction time and deceleration rate differ from one rider to the next, depending on riding experience [2], riding skill [13], level of familiarity with the vehicle, traffic, other road users, road and road environment conditions [14]. In unexpected situations, riders will apply hard braking instantly. Furthermore, previous studies found that motorcyclists can increase their braking capability depending on the type of brakes, the braking system, and the road condition [11,15].

In addition, SSD is calculated based on the design speed, whereas to decrease the speed of their vehicle speed riders usually also use the engine's braking force, which may reduce vehicle speed before braking. This may offer riders the opportunity to utilize their maximum braking capability. Consequently, minimum SSD may be classified based on reaction and braking capability.

Further, the current speed limit could be out of balance with riders' expectations and/or mobility needs, because when compared to the number of incidents, accident frequency is very low, which explains why so many riders who ride at excessive speed do not end up crashing. The various minimum SSDs and accident probabilities could trigger perceptions about the advantages or disadvantages of speeding and may well also influence choice of speed, distance headway and critical crossing gap. Hence, their possible consequences need to be studied.

Accordingly, the objectives of this study were to develop a calculation method for minimum SSD and its application in accident risk management. The method was developed by integrating the effects of downshifting and hard braking deceleration rate. Thus, minimum SSD was defined as a function of reaction distance, downshifting distance and braking distance. The method is based on the assumption that speed reduction due to downshifting will decrease braking distance and impact speed (accident consequences). Kerry and Bland have reported that a decrease in impact speed of 10 km/h reduces the probability of a fatal crash by up to 40% (WHO, 2008). Similarly, a change in average speed of 1 km/h reduces the risk of a serious-injury crash by 3% on a 50-km/h limit road (DaCoTA, 2013). Moreover, the deceleration rate due to downshifting is 0.8-1.6 m/s^2 [16] and during downshifting riders may have the opportunity to utilize their maximum braking capability.

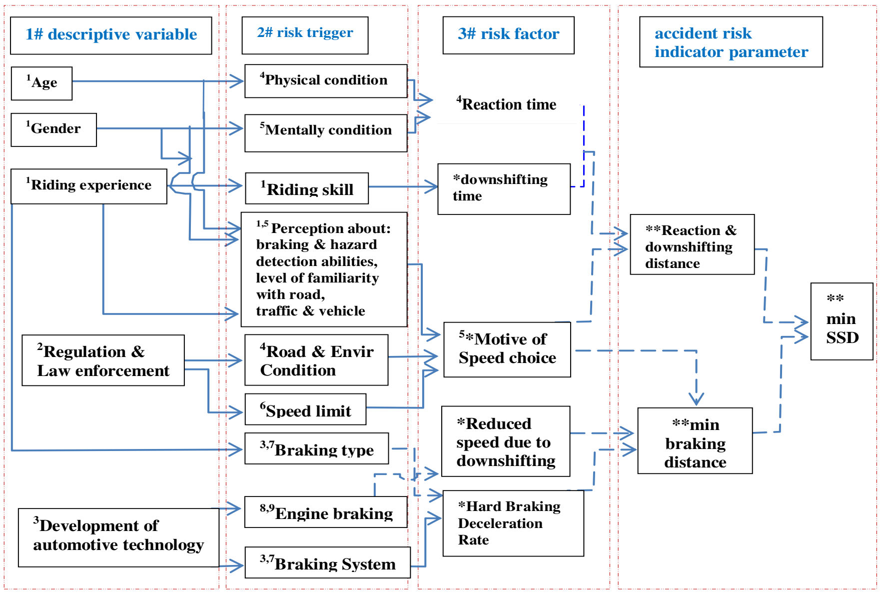
2 Method

2.1 Study Design

Risk is a function of accident probability and its possible consequences [17]. Thus far, accident risk indicators are stated in terms of deceleration rate, time to collision [5,6], ratio between sight and stopping distance [7], and impact speed [1]. This study used the safety factor (SF), i.e. the ratio of available SSD and minimum SSD, as accident probability indicator.

As previously mentioned, before braking, riders usually reduce their vehicle speed by downshifting instantly. Consequently, the speed reduction will be influenced by the duration of the downshifting. Besides, the effect of downshifting may give inexperienced motorcyclists an opportunity to utilize their maximum braking capability. It is predicted that the use of this speed reduction and a hard braking deceleration rate can decrease the braking distance as well as the impact speed. Thus, minimum SSD is considered to be the sum of the reaction distance, the downshifting distance, and the braking distance, as shown in Figure 1. This shows that minimum SSD is systematically influenced by not only technical factors but also by human behavioral (speed choice, riding ability, perception, etc.) and institutional arrangement factors. Besides, it can also be seen that each risk factor is triggered by a number of variables and the triggering of these factors can be explained by a number of descriptive variables in accordance with [14]. That is why the proposed prototypical method is referred to as a systematic approach.

Moreover, it should be noted that the effect of road pavement condition seems to apply only when the speed choice is greater than 70 km/h [18]. Hence, as the average speed choice at unsignalized intersections is usually around 40-60 km/h, the obtained minimum SSD is suitable for that particular risk condition.



[1][3]; [2][19]; [3][11]; [4][20]; [5][14]; [6][1]; [7][15]; [8][6]; [9][16]
*proposed variable; **proposed model; = assumption

Figure 1 Minimum SSD model design.

The proposed model is different from the AASHTO model, which neglects the effect of downshifting on reaction and braking distance. The proposed model assumes that although the speed reduction due to downshifting may be small, the decreased approach speed may significantly reduce the braking distance as well as the impact speed because a decrease in mean speed of 5 km/h can reduce fatal crash probability by approximately 20% [1]. This is worthwhile to investigate further.

Understandably, in emergency situations riders usually apply downshifting before braking and then apply their hard braking ability instantly so that the minimum reaction distance is the sum of the reaction distance and the downshifting distance; the harder the braking, the shorter the minimum SSD that is produced.

Hence, for accident risk analysis and/or evaluation purposes, minimum SSD may be determined using the minimum reaction time and the hard braking deceleration rate. Consequently, a number of tests are required to determine the feasibility of the proposed model, i.e. 1) the effect of engine brake force on reaction distance and downshifting distance; 2) the effect of downshifting on vehicle speed before braking; 3) the effect of a decrease in vehicle speed due to downshifting on braking distance and impact speed; 4) the combined effect of minimum reaction time, engine brake deceleration rate and hard braking deceleration rate on minimum SSD.

Accordingly, the hypotheses used were: 1) there is no significant difference in reaction distance and downshifting distance due to downshifting; 2) there is no significant difference in approaching speed due to downshifting; 3) there is no significant difference in braking distance and impact speed due to a decrease in approaching speed caused by downshifting; 4) there is no significant difference in minimum SSD due to differences in reaction time and deceleration capability. All of these hypotheses were examined using a chi-squared model.

However, the results of chi-squared tests only provide statistical evidence and cannot be used to indicate the motivation for speeding behavior and/or determine risk management strategies. Consequently, SF and MS were used as well as a questionnaire. Furthermore, the current SSD model uses the design speed, a reaction time of 2.5 s, and a deceleration rate of 3.4 m/s^2, encompassing the capabilities of most riders [20]. Conversely, this research used a minimum-margin-of-safety philosophy. Therefore, a minimum perception reaction time of 0.68 s [12] and running speed were applied. The time of 0.68 s (standard deviation 0.28) was obtained from an experiment conducted in an expected-situation scenario (participants were asked to ride at a constant speed of 60 km/h and to apply hard braking immediately when recognizing a stop sign) on a dry and level closed circuit course [12]. The experimental conditions were suited to the measured favored speed and the road condition at the study location. Moreover, the determination of braking distance was based on vehicle speed before braking and braking deceleration rate required to avoid serious injury at 6 m/s^2 [5] as opposed to the design speed and a comfortable deceleration rate of 3.4 m/s^2.

Subsequently, the obtained safety factor was used to determine the margin of safety, which describes the minimum effort required to avoid a crash and/or fatal crash. Since the minimum SSD was calculated based on various braking deceleration rates, appropriate accident risk management recommendations may be built based on these values.

However, since the proposed minimum SSD model was calculated based on a number of secondary data that have similar characteristics as the required data, the obtained minimum SSD, SF and minimum margin of safety used to describe the accident risk analysis scheme are only approximations.

2.2 Data Collection

The available SSD was taken from critical crossing gap choices at an unsignalized intersection, while the predicted minimum SSD was calculated based on the concerned minimum perception reaction time, engine and braking deceleration rates of non-ABS motorcycles obtained from an average speed of 50-60 km/h, similar to observed speed choices at the study location.

The initial speed (V_0) and approach speed (V_1) of each sample vehicle was measured twice using a speed gun. The points of measurement were at approximately 55 m and 35 m before the intersection, as can be seen in Figure 2. In this particular case, since a number of vehicles maintained their speed while passing through the intersection area, the obtained average deceleration rate was determined based on decelerating vehicles only.

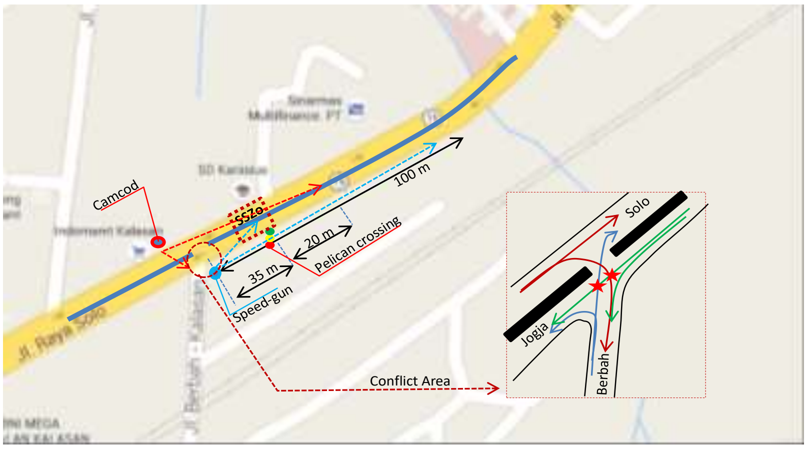


Figure 2 Characteristics of study location (not to scale).

It was shown that before entering the intersection area, riders would travel along around 100 m. As the composition of the vehicle population was dominated by motorcycles, motorcyclists had a clear overview of the intersection area so that they could freely choose to utilize the engine brake or engine braking force individually or concurrently, depending on the traffic situation. In addition, a camera recorder was placed on top of an adjacent temporary construction framework at a height of ± 2.00 m, on the outer edge of the road shoulder, to capture the monitored vehicles' maneuvers, particularly the critical crossing gap choices. However, the result was inadequate due to the mixed traffic condition. The monitored vehicles were hidden by parallel movement of larger vehicles so that the deceleration data could not be drawn using a time-space diagram.

2.3 Risk Analysis Method

Risk is a function of accident probability and its consequences, whereby accident probability arises when there is a hazardous situation and/or objects on the roadway [17]. In this study, hazardous circumstances were assumed to occur when SF was smaller than 1.0, while the consequences were determined by using a curve correlation between impact speed and fatal crash probability [1]. The available SSD is referred to as the average critical crossing gap choices as explained above.

Subsequently, SF was used to calculate the margin of safety (MS) in order to build more appropriate accident risk management strategies [22]. MS can be calculated based on different parameters using the following equation:

$$\text{Margin of Safety (MS)} = \text{Safety Factor} - 1 \quad (1)$$

The MS values were used to describe the minimum concerned mitigation effort needed to minimize accident probability and/or consequences. Meanwhile, according to the braking distance model [20], the possible consequences were measured based on predictive impact speed (V_2) for each braking capability level (a) along the braking distance path (S), simply by using the following equation:

$$V_2 = \left({V_1}^2 - 2aS \right)^{1/2} \quad (2)$$

Therefore, since SF was calculated based on the distance-based model due to varying braking capability, riders with SF less than 1.0 have to increase their braking capabilities to shorten the minimum SSD. The required shortened distance and/or braking capability may depend on a tolerable impact speed.

Subsequently, the correlation between speed choice and its explanatory variables (perception, riding skill, level of familiarity with road / road environment / traffic conditions and vehicle movement control systems), as well as between speed choice and deceleration capability was planned to be investigated using a questionnaire. Motorcyclists were taken as the object of study because they habitually exceed the speed limit, so that their serious injury probability increases by 20% [21]. However, since most of the observed motorcyclists were reluctant to participate in a road interview due to potential loss of travelling time, the respondents were randomly taken from motorcyclists encountered around the study location. Although they were not the same motorcyclists as those monitored on the road, it was assumed that their answers would be similar.

3 Result and Analysis

3.1 Data Characteristics

The result of field measurement showed that: 1) an average critical crossing gap choice of 20 m occurred when the major stream running speed (V_o) was around 50-60 km/h). Most riders tended to decrease their vehicle speed when approaching the intersection with a deceleration rate of 1.73 m/s², while the average reduced speed was around 7.8 km/h. According to WHO [1] such a decrease in speed can reduce the impact speed and may well also reduce braking distance, so this behavior had to be investigated further.

Furthermore, Winkelbauer and Vavryn [11] found that non-ABS motorcyclists' maximum braking capability in expected situationw for a running speed of 60 km/h is 8.15 m/s² (mean 5.65, minimum 2.07, standard deviation 1.12), while ABS hard braking is 9.85 m/s² (mean 7.72). Both are greater than the required deceleration rate needed to avoid serious injury, i.e. 6 m/s² [5]. Furthermore, the mean reaction time needed from the moment the rider recognizes the presence of a hazardous object until the brakes are actually applied is around 0.68 s (standard deviation 0.25) [12].

In order to avoid a crash, riders need adequate time and space to react and brake safely, referred to as SSD. However, such intention should be classified based on its purposes. For example: for road infrastructure and/or the design purposes of its complementary facilities, such as speed limit signs, SSD is determined based on a maximum-margin-of-safety philosophy so that the rider's safety can be increased. However, SSD is calculated based on design speed and comfortable braking deceleration rate, whereas riders tend to exceed the regulated speed limit due to social-economic advantages, it was thought that in order to examine their accident risk level it is needed to investigate their actual minimum reaction time and the hard braking deceleration that may allow them to produce a shorter minimum SSD. Moreover, in emergency situations, before braking, riders usually apply downshifting instantly, so that the minimum reaction distance and downshifting distance is the sum of the reaction distance and the downshifting distance, and the harder the braking, the shorter the minimum SSD that will be produced, as can be seen in Figure 3.

Hence, for accident risk analysis and/or evaluation purposes, the minimum SSD can be determined using minimum reaction time and hard braking deceleration rate. Therefore, their effects on minimum SSD were tested.

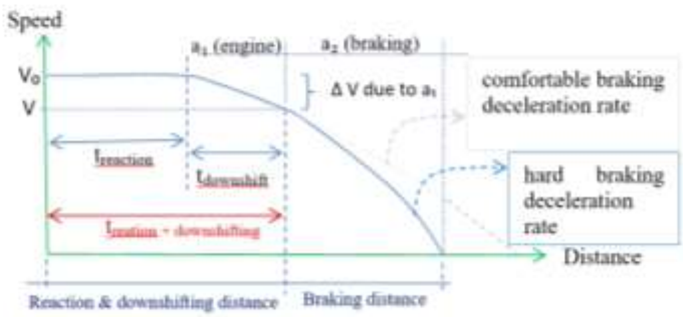


Figure 3 The proposed minimum SSD scheme.

3.2 Proposed Minimum SSD Model

First, in order to find out the effect of downshifting on the approaching speed, a chi-square test was conducted. The calculation of the approaching speed was simulated based on a downshifting time of 0.25 to 2.5 s, an engine braking deceleration rate of 1.7 m/s², and an initial speed of 60 km/h. The result showed that for level of significance 0.05, the chi-squared (χ^2) calculation was 4.169, much lower than the standardized χ^2 of 15.507 (Table 1), so that the null hypothesis (H_0), which states that there is no significant difference in approaching speed due to the use of downshifting, was accepted. However, from Table 1 it was also found that when the downshifting time was around 1 s, the decreased speed due to downshifting was 6.12 km/h lower than the design speed recommended by AASHTO. This strongly indicates that it is necessary to investigate the effect of this reduced speed on braking distance and impact speed because, as previously mentioned, such speed reduction could significantly reduce the fatal crash probability.

Table 1 Effect of downshifting on approaching speed.

Reaction & Downshift Time (s)	Approaching Speed (m/s)		Residual	Std. Residual	Chi-Squared χ^2	Deviation Speed (km/h)
	Proposed model	AASTHO				
0,25	16,26	16,68	(0,43)	0,18	0,011	1,53
0,5	15,83	16,68	(0,85)	0,72	0,043	3,06
0,75	15,41	16,68	(1,28)	1,63	0,097	4,59
1	14,98	16,68	(1,70)	2,89	0,173	6,12
1,25	14,56	16,68	(2,13)	4,52	0,271	7,64
1,5	14,13	16,68	(2,55)	6,50	0,390	9,17
1,75	13,71	16,68	(2,98)	8,85	0,531	10,70
2	13,28	16,68	(3,40)	11,56	0,693	12,23
2,25	12,86	16,68	(3,83)	14,63	0,877	13,76
2,5	12,43	16,68	(4,25)	18,06	1,083	15,26
	χ^2 calculation				4,169	
	χ^2 standardized				15,507	

Further, the calculation of braking distance was done by using a braking deceleration rate of 6 m/s² and varying the reduced speed due to duration of downshifting at 0.25-2.5 s. The differences in braking distance obtained from the proposed model and the AASHTO model were tested using chi-square. It was found that the calculated χ^2 was 18.961, i.e. greater than the standardized χ^2 of 15.507. Consequently, the null hypothesis (H_0), which states that there is no significant difference in braking distance due to differences in approaching speed, was rejected. This means, as previously predicted, that braking distance is significantly influenced by the reduced speed due to downshifting. Subsequently, Figure 4 shows that if the braking deceleration rate is 6 m/s², then the difference in impact speed, at a braking distance of 12.5 m, between the proposed model and the AASHTO is approximately 12 km/h. This can reduce the fatal crash probability by up to 40 %.

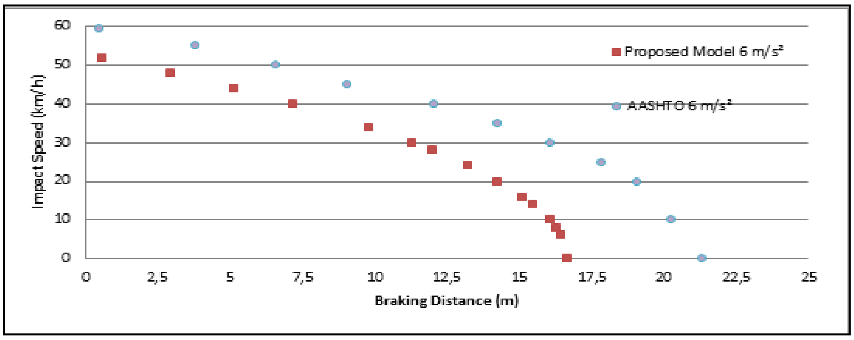


Figure 4 Effect of reduced speed due to downshifting on braking distance and impact speed (Da Costa, Malkhamah & Suparma, 2018).

The previous explanation showed that a decrease in approaching speed due to downshifting significantly influences the braking distance and impact speed. Consequently, the proposed minimum stopping sight distance should be considered as the sum of the reaction distance, downshifting distance and braking distance.

In an unexpected situation, especially when the distance between the vehicle and a hazardous object is relatively small, the reaction (t_1) and downshifting time (t_2) are very small, because [12] showed that the mean time needed from the moment the rider recognizes the presence of a hazardous object on the roadway until he/she actually applies the brakes (t_3), including downshifting, is around 0.68 s. Therefore, according to kinematic theory, the use of engine braking force will reduce vehicle speed before braking (approaching speed) linearly. Accordingly, the minimum SSD is the summation of the reaction distance, the downshifting distance and the braking distance as expressed in

Eq. (3). Such a model could also be used to determine the minimum SSD in expected situations.

$$\min SSD = V_0 . t_3 - \frac{1}{2} a_1 . t_3^2 + \frac{v_1^2}{2a_2} \quad (3)$$

V_0 = initial speed (m/s)
t_1 = mean minimum reaction time (s)
t_2 = mean downshift time (s)
t_3 = sum of t_1 and t_2 (s)
a_1 = engine braking deceleration rate (m/s^2)
V_1 = approach speed (m/s)
a_2 = maximum braking deceleration rate (m/s^2)

Subsequently, the feasibility of the proposed model was analyzed using the chi-square method. The proposed model was calculated with Eq. (3) using an initial speed of 60 km/h, a minimum reaction and downshift time of 0.68 s, an engine braking deceleration rate of 1.73 m/s^2, an approach speed of 52 km/h and a hard braking deceleration rate of 7.72 m/s^2. To determine the AASHTO minimum SSD, a design speed of 60km/h, minimum reaction time of 1 s, and a braking deceleration rate of 3.4 m/s^2 were used. The engine braking and braking deceleration rates were assumed constant because previous studies have reported that they are around 0.5-0.8 m/s^2 [16] and 0.7 ± 0.05 m/s^2 [6] respectively when the speed is 50-60 km/h. Meanwhile, [24] found that the deceleration rate is virtually constant over a certain distance in the zone where it has reached its maximum force.

By using various braking deceleration rate values (1.5 to 8.5 m/s^2), it was found that the calculated χ^2 was 35.218, greater than the standardized χ^2 for a significance level (α) of 5%, i.e. 15.507. This means that the null hypothesis (H_0), which states that there is no significant difference between the minimum SSDs obtained from the AASHTO model and the proposed model, should be rejected. This finding confirms the two previous findings and strongly suggests that it is worthwhile to consider the proposed minimum SSD as an accident probability indicator. Therefore, it is thought that for accident risk analysis and/or evaluation devices, the use of this proposed minimum SSD model could produce better accident risk management recommendations.

3.3 Accident Risk Analysis

The result of observation at the study location showed that most motorcyclists reduce their vehicle speed, but some continued to accelerate due to fear of arriving late for work. Apart from that, vehicles following uniformly distanced lines, with an average speed of 50-70 km/h, presented a drawback situation which decreased the accessibility for vehicles entering-exiting a minor road. Accordingly, since the delay time was approximately 2 minutes, some motorcyclists became impatient and insisted on crossing the intersection speculatively depending on the distance to the nearest upcoming vehicles and their predicted approaching speed. Average critical crossing gap choices of 20 m [25] occurred due to this drawback and speculative situations, but only when the average approaching speed was around 40-60 km/h. The distance to the nearest upcoming vehicles is referred to as the available SSD, which can be used to determine the safety factor (SF).

The produced minimum SSDs for various braking capabilities and speed choices can be seen in Table 2.

Table 2 Minimum SSDs, safety factor and margin of safety for various speed choices.

Speed (km/h)		**Min SSDs***			***Safety Factor****			***Margin of Safety****		
V_0	V_1	1	2	3	1	2	3	1	2	3
70	62	46,1	37,8	32,3	0,43	0,53	0,62	-0,57	-0,47	-0,38
60	52	34,4	28,5	24,6	0,58	0,70	0,81	-0,42	-0,30	-0,19
50	42	24,3	20,5	18	0,82	0,98	1,11	-0,18	-0,02	0,11
40	32	16	13,8	12,3	1,25	1,45	1,63	0,25	0,45	0,63

*1= for riders in the low braking capability category: 4.5 m/s², 2 = for riders in the moderate braking capability category: 6.0 m/s², and 3 = for riders in the high braking capability category: 7.72 m/s²

The riders' awareness of these differences was assumed to be the triggering factor of their daily favored speed choices, in accordance with [2]. It can be seen that when the minimum SSDs are applied to a hazardous situation at an unsignalized intersection, such as a critical crossing gap acceptance of 20 m, then all riders who ride at 60 km/h may be involved in a collision, particularly if the crossing vehicles cannot cross the conflict lane area normally due to traffic and concurrent geometric layout. Moreover, based on the SF and MS values, it was found that the point of crash will occur at around 3.32 m after the rider has started to brake so that, based on Figure 2, it can inferred that the predicted impact speed for riders with moderate and high braking capabilities is approximately 45 and 25 km/h, respectively.

Therefore, riders in the moderate braking capability category could be involved in a fatal crash because the predicted impact speed is greater than the tolerable head injury criteria/HIC, i.e. 43 km/h [26], which is the factor that most influences fatal crashes in Malaysia [27]. This means that riders should adjust their daily favored speed to their maximum braking capability. For example: when travelling at 50 km/h, riders in the low braking capability category should increase their braking capability by minimum 1.5 m/s². However, it is noteworthy that, based on Eq. (2), the required braking capability increases exponentially with speed.

Accordingly, although previous studies have reported that novice riders can increase their mean braking capability by 2.07 m/s^2 through braking maneuver training [11], the type of braking [15] and the vehicle's brake system [11], it seems that it will be very difficult to achieve the required braking capability increase needed to avoid collision when the speed is around 70 km/h.

These preliminary findings strongly suggest that the accident probability is largely influenced by speed choices and braking capability. Therefore, mitigation efforts should address the improvement of speed limit determination and/or the driving licensing mechanism. Thus far, the speed limit is determined based on road and traffic as well as road environmental characteristics [1,4,28] rather than driving behavior and/or driver performance. Meanwhile, in the existing driving license procedure there is a mandatory safety riding test, including normal and quick-stop braking [29]. However, [29] states that although this safety riding program has been implemented in Thailand for two decades, there is no evidence to confirm its influence in reducing both accident injuries and adverse consequences. This may be due to the following situations: 1) quick-stop braking may not be an appropriate method in relation to the critical distance to the hazardous object, as in [11] and [15], so that the obtained braking capability does not match real world conditions, 2) there is inadequate evidence that can be used to build appropriate perceptions about speeding consequences and/or the reasons of speeding behavior, 3) inadequate and discontinued traffic safety campaigns, 4) an imbalance between mobility needs and safety expectations.

Accordingly, information and/or clarification about the effect of braking capability on braking distance and impact speed should be strongly stressed during the driving licensing process, or be adopted in the formal education curriculum and become mandatory when determining speed limits and/or improving law enforcement. By doing this simultaneously, it is hoped that the information gap can be systematically bridged in order to reduce accident injuries and other adverse consequences due to speeding behavior. This conceptual idea, of course, should be investigated further.

However, appropriate future traffic accident risk management schemes cannot be recommended instantly if there is no sufficient additional information about the motivation for speeding. Therefore, this technical approach should be complemented by a social-economic approach, i.e. by using an aggregated-individual acceptance model based on data obtained from a questionnaire. The results of our interviews showed that almost every day, 56.23% of motorcyclists exceed their daily favored speed by up to 20 km/h just for saving time (41%) and sensation seeking (19%). This may be triggered by riding experience, confirmed by [30], and rider overconfidence, since 52% stated that they believed their braking capabilities to be above average. It is thought that if riders accept the social-economic advantages but neglect the possible negative consequences of speeding, then these perceptions can raise their risk tolerance, eventually leading to speeding behavior. Hence, again, effective risk perception should be explored, tested and/or proved.

Regardless of the required further studies, these initial findings strongly suggest that this pro-active and systematic accident risk analysis model can be used in traffic accident risk prevention schemes because it covers the entire accident setting characteristics, as recommended by [31].

4 Conclusion

Based on the above, using the proposed systematic and conceptual framework it can be concluded that:

1. The reduced speed due to downshifting significantly influences both the braking distance and the impact speed (fatal crash probability), so that by combining the effects of minimum reaction and downshifting time as well as hard braking deceleration, the obtained minimum SSD from this proposed model differs significantly from that of the AASHTO model. These initial finding should be experimentally validated so that the minimum perception reaction time, motorcycle engine brake deceleration rate and motorcyclist hard braking deceleration rate that are obtained reflect the contextual conditions in different study locations.
2. Since the secondary data concerned were taken from a similar research scenario (i.e. a hazardous object appearing unexpectedly), the object of study (non-ABS motorcyclists) and risky conditions (speed choice, road geometry, braking skill) then the results are just an approximation. However, this predictive minimum SSD could be used to determine accident risk analysis and/or evaluation as far as the observed risky conditions have similar characteristics as the data used.
3. The safety factor is recommended for use as an accident probability indicator because the shortened distance obtained due to differences in braking capability can be used to describe risk conditions in the real world, in accordance with (Smith, Garet, & Cicchino, 2013). However the shortened distance cannot be instantly used to determine a comprehensive accident mitigation strategy. Therefore, concerned mitigation efforts such as increasing braking capability should be determined based on the minimum margin of safety and interview results. This may be used to alter speed

management devices, as proposed by Guller and Grembek [32], such as speed limit determination and the driving licensing mechanism.

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