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Considering Speeding Behavior when Designing a Workable Road Pavement at Downgrade Un-signalized Intersection

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Abstract

Result of field observation shown that the tendency of riders to exceed speed limit also occurred at downgrade road segments, whereas previous study had reported that even on a flat road only riders with braking ability of 6 m/s^2 can be avoided from crash due to the presence of unexpected object suddenly appears at 20 m ahead when traveling at around 60 km/h. This might be triggered by lack of information about pavement, geometrical and traffic condition surrounding. The aim of this study is to identify the accident risk at downgrade road segments due to inappropriate speed choice and/or pavement condition. Accident probability was assessed using the safety factor model, i.e., the ratio of available to minimum stopping sight distances. The minimum stopping sight distance was modified from the AASHTO stopping sight distance model, whilst the available stopping sight distance was determined using the average critical gap acceptance of 35 m obtained from field measurement. From the result of simulation, it was found that only riders with a braking ability of greater than 6.57 m/s^2 could avoid crash and/or fatal accident safely. Besides, if the difference in braking ability was around 2 m/s^2 then it is required a minimum safety distance of 15.1 m between the following motorcyclists. This strongly indicate that a workable road pavement design should be developed based on appropriate speed limit and/or geometrical condition.

Keywords: *Accident probability, Downgrade road segment, Motorcyclist, Speeding, Safety factor, Workable pavement*

Abstrak

Hasil observasi lapangan menunjukkan adanya kecenderungan pengendara untuk melampuai batas kecepatan maksimum pada area jalan bergradien menurun, padahal sejumlah penelitian terdahulu melaporkan bahwa bahkan pada hanya pengendara berkemampuan pengereman 6 m/det^2 yang dapat menghindari obyek penghalang pada jarak 20 meter di depannya pada kecepatan 60 km/jam. Hal tersebut mungkin dipicu oleh kurangnya pemahaman pengendara tentang pengaruh kondisi permukaan jalan, geometri dan/atau kondisi lalu lintas disekitarnya.tujuan penelitian ini adalah untuk mengidentifikasi risiko kecelakaan di jalan bergradien menurun akibat pengaruh pilihan kecepatan dan kondisi jalan. peluang kecelakaan dinilai dengan model factor keselamatan yaitu rasio jarakpandang henti lapangan terhadap jarak pandang henti minimum. Model jarak pandang henti ini dimodifikasi dari AASHTO, sedangkan jarak pandang henti lapangan ditentukan berdasarkan hasil observasi lapangan tentang rerata celah penyeberangan kritis di lapangan yaitu 35 m. dari hasil simulasi diketahui bahwa hanya pengendara berkemampuan pengereman 6,57 m/det2 yang dapat terhindar dari tabrakan atau kecelakaan fatal. Selain itu, jika perbedaan kemampuan pengereman sekitar 2 m/det2 maka diperlukan jarak aman antar kendaraan yang berjalan beriringan sejauh 15,1 m. hal ini sangat mengindikasikan bahwa perencaan perkerasan jalan yang sesuai dengan krakteristik arus lalu lintas dan geometri jalan merupakan suatu kemutlakan.

Kata kunci: *factor keselamatan, jalan menurun , peluang kecelakaan, perkerasan jalan mantap, sepeda mootr, speeding.*

Introduction

Although there is not enough information about the number of fatal accident victims on gradient roads, the relative constantly number of motorcyclists who died [1], which is seen through a fatality index and/or fatality ratio values [2], indicates that the inadequacy of current pattern of accident risk management. The fact that the achievement of the target output of accident risk management activities is lower than those stipulated in the National General Plan of Safety 2011-2035 and the Decade of Road Safety Action 2011-2020 is one of the proofs. This may be caused by the unintegrated of accident risk management patterns, or due to lack of commitment on controlling the road safety condition. This study was conducted with the assumption that the disintegration and institutional problems were triggered by the lack of accuracy and measurable technical information so that movement control products are often ambiguous. Driving in inappropriate speed on a downward observed road strongly indicates that perceptions of the risks and impacts of violating traffic rules need to be improved.

On the other hand, it is commonly known that the stages of road safety management are usually related to aspects of institutional management functions or performance, the form and strategy of interventions, and the results of the intervention / management itself (results). The scope of management activities is almost always based on or associated with aspects of education, regulation and enforcement and evaluation [3]. Unfortunately, although changes in risky behavior on the road can only be done through education, the most frequent form of intervention is in the engineering or technical field [4]. At the same time, a large number of motorists continue speeding only for the purpose of saving time [5], [6] and, even, only for a sensational seeking [1], [5], [7]..

Speeding behavior is also indicated by the driver's perception of his ability to avoid collisions, especially related to his braking ability [8]–[10], but it turns out that only a small portion of riders have succeeded in proving that their braking abilities can prevent them from collisions [11]–[13]. Thus, it can be concluded that the wrong perception affects the choice of speed that is too high (inappropriate speed) so that drivers easily lose control and / or having involve in an accident.

The results of these previous studies indicate that efforts are needed to improve the substance of the procedure for determining the maximum speed limit [14], for example by taking into account the effect of standardized braking capability on various road geometric conditions. That is why the aim of the study is focused on the characteristic of MSSD on a declining road, and types of technical interventions that can be carried out based on consideration of the influence of road functions (road pavement surface conditions, road geometric), traffic (speed), vehicles (vehicle deceleration ability), driving experience (braking ability), road user behavior (speed choices and factors that influence it) and activities around the road (side friction); without neglecting the function of road mobility (destination and / or reasons for travel). An in-depth understanding of the cumulative effect is used as a reason for strategic recommendations about determining the appropriate workable road pavement required.

Another fundamental reason is that although the Ministry of Transportation Regulation No. 111 of 2015 regulates speed restrictions due to the influence of the type and scale of activity, energy savings and geometric conditions of the road, in reality violations of the speed limit still occur; even some parts of the road are not equipped with signs and / or other speed limiting facilities. This might be occurred because the specified speed limits are considered not fully able to represent the mobility needs of the trip (such as saving travel time, relaxation etc.) and / or road, geometric and/or road environment conditions. Therefore, the feasibility indicators used to determine the requirement of a workable road pavement are speed characteristic, skid resistance value/SRV and the minimum stopping sight distance value.

Method

In this study, the calculation of minimum stopping sight distance (MSSD) on the descending road was carried out using the basic model of the MSSD version of AASHTO 2011 Edition [15] as seen in equation 1.

MSSD = reaction distance + braking distance
$= V.t + V^2 / 254\ [(a/9.81)]-G]$ (1)

Where is:

V = design speed (km/h)
a = comfortable braking deceleration rate (for this type of light vehicle = 3.4 m/s²)
t = minimum reaction time (1.68 s)
G = slope effect (gradient/100)

In this paper, the basic model was modified by using the appropriate value of reaction time, deceleration, vehicle speed, and speed changes due to downshifting which is different from the AASHTO 2011 Edition recommendations because the results of previous related studies report that in an emergency situation, reaction time and average braking ability of motorcyclists much faster and larger, i.e. 0.53 s (min 0.48, max 3.01, SD 0.2), and 6.75 m / s2 (min 3.09, max 12.49, SD 2.12), respectively [16]. Therefore, the proposed MSSD was determined based on such average minimum reaction time and maximum braking capability of motorcyclists on non-gradient roads and the condition of the pavement surface in dry conditions with a range of road roughness of 50-65 SRV because there was no adequate information about braking deceleration rate at downgrade road segment. It was limited to adjusting the values of reaction time and braking ability. In addition, modifications were also made to the speed parameters, where the value used was not the design speed but the speed of the vehicle just before the driver began to brake the amount also taken from the results of the study [16], [17], as can be seen in Eq.3.

$MSSD = 0.278\ V_0.t - 1/2 a_1.t^2 + V^2 / 254\ [(a_2/9.81)]-G]$ (2)

Where is:

V_0 = initial speed (operational speed, km/h)
V = vehicle speed before braking (approaching speed, km/h)
a_1 = engine braking deceleration rate (1 m/s², assumption)
a_2 = hard braking deceleration rate (m/s²)
t = minimum reaction and downshifting time (0.53 s)
G = effect of downgrade (measured gradient/100)

The operational speed at study location is obtained from the results of motorcycle rider speed measurements. For each sample vehicle, the speed measurement is carried out twice, i.e., when the position of the sample vehicle is around 50 m (V_0) and 25 m (V_1) before the nearest access road intersection. Speed measurements are carried out with the help of a speed gun, and carried out for 6 hours / day (@ 2 hours per morning, afternoon and evening period).

In addition, the same research results prove that the reduction in vehicle speed due to the application of engine resistance has a significant result on reducing the impact speed. The application of the MSSD model at the priority intersection has also been reported [11], but as previously mentioned, since there has not been any reference to the minimum reaction time and maximum braking ability on the downgrade road segment, the average value of reaction time, minimum and maximum braking ability on flat gradient roads from the results of previous related studies (in dry road conditions and roughness values > 55 SRV) is used in this study.

Further, the part of the road that was observed was the road segment around the Widya Mandira University Campus, located on Herman Yohanes Street, Kupang. Network characteristics, geometry and road environment which are expected to trigger an impact on increasing the risk of accidents are as follows:

a. The function of the road segment is the secondary arterial road so that the design speed is 60 km / h. However, because there are no speed limit signs, the choice of speed in the field is higher than 60 km / h.
b. Pavement type is hot rolled sheet (HRS) with visual condition of road surface with no holes and / or bumps. Thus, it is assumed that the MSSD that will be generated is the normal value for certain gradient of road conditions.
c.

The length of the slope (gradient, G) of the road body is 7-8% with an estimated length of slope ± 100 m. Because the braking distance on the road is determined by the speed, mass of the vehicle and its deceleration capability, the MSSD production capability is the key to the success of the major current rider to avoid a collision due to right-turning maneuver when entering-exiting the local intersection observed.

Result and Discussion

Speed Characteristics

From the results of measurements of the speed, it is known that most of the drivers slow down when crossing a decreasing gradient of the road area. The average slowdown is around 4 km / h. This is expected to occur because the driver only reduces the speed of the vehicle by using machine resistance (downshifting), where the combination of using engine and braking deceleration is only done when there are obstacles such as travel due to vehicle maneuvers in and out of collector road nearby. However, the average choice of speed when entering the declining road area is relatively high, i.e.:

1. Motorcyclist
   The dominant speed ranges from 40-50 km / h, but there are a number of riders (13.72%) who are driving in a relatively high speed of around 60-70 km / h (72 km/h).
2. Light vehicle driver
   Similar to the motorcycle group, the choice of dominant speed ranges from 30-50 km/h (lowest 31 km/h), but there are a number of riders (10.89%) who drive at relatively high speeds of 60-70 km/h (highest 74 km/h).

As the speeds are greater than the regulated speed limit, then it is thought that the accident risk due to exceeding speed limit at the entering-exiting gates of local road should be further investigated. In Indonesia, the determination of the maximum speed limit is based on the classification of the function of the road network system (arterial, collector and local), the characteristics of land use (center of activity, industry, housing / settlements and schools), and the geometric of the road (availability of medians, slow lanes or lanes specifically motorcycles and the number of lanes) [14], as shown in Table 1. In addition, at the global level, the determination is also based on the composition of traffic flow [9].

From this table it is clear that the regulations, guidelines and / or procedures for determining the maximum speed limit on the existing road do not accommodate the influence of the decreased gradient of the road, even though the braking distance model developed by AASHTO explicitly shows that the length of the braking distance is strongly influenced by gravity. In addition, the results of other studies indicate that the minimum braking distance needed to be able to avoid a collision is greatly influenced by the braking ability [12], [13], [17]. This means that the determination procedure of speed limit at downgrade should be improved.

Table 1. Maximum Speed Limits on Indonesia Arterial Roads

No	Road Class / Function	Types of modes: 2-wheeled vehicles	Types of modes: 4-wheeled vehicles	Road Environment Condition
A	Primary Artery			
1	Primary Artery (fast and slow path separated by median)			
	Slow lane	30		Traffic jam
		50		Quiet traffic
	Fast track	80	60	
2	Primary Artery (fast and slow path not separated median)			
	Central Business District area	40		Hub
	Industrial area	40		Working hours, industry
		80	60	After hours
	Residential area	40		All types of vehicles
	School district	30		School entrance / return hours
		80	60	Outside school hours
3	Primary Artery (If there is a special lane for motorcycle)			
	If there is no median	60		All types of vehicles
	The fast track is split by a median	80	60	
	The fast track is not separated by a median	80	60	≥ 2 lanes
		60		1 lane
4	Primary Artery (If there is no motorcycle lane available)			
	Without median	60		All types of vehicles
	The fast lane is separated by a median	80	60	≥ 2 lanes
	The fast track is not separated by a median	60		1 lane
B	Secondary Artery			
1	Secondary arteries (fast and slow paths separated median)			
	Fast track	50	40	
	Slow lane	30		Dense area
		50		Quiet traffic
2	Secondary arteries (fast and slow lane without median)			
	Central Business District area	40		Central area
	Industrial area	40		Employee shift hours, industry
		50		Outside shift hours
	Residential area	40		Solid housing
	School district	30		School in / out hours
		50	40	Outside school hours
3	Secondary arteries with special lanes on motorbikes			
	Without median	60		All types of vehicles
	The fast track is separated by the median	50	40	
	Fast lane without median	50	40	≥ 2 lanes
		60		1 lane
4	Secondary arteries without motorcycle lanes			
	Without median	60		All types of vehicles
	Traffic lane with number of lanes of ≥ 2	50	40	
	Traffic lane with number of lanes of 1	60		All types of vehicles

Skid Resistance Characteristic

The SRV standard set for roads with risky geometry characteristics is 65. In this particular case, the risky segment is located around the decreasing gradient approach area of the local road intersection. In addition, the quality or condition of the roughness of the road is visually determined based on pavement surface condition. Since the visual condition is good (the SRV is around 55-60, no potholes or waves), it can be miss interpreted when compared to the production of the braking distance on a flat gradient road. It was found that there is no significance difference of speed at downhill and flat road segments, i.e., around 60-70 km/h. This might be occurring due to rider's miss-perception about the accident probability. Good functional condition of road surface has been associated with safe riding and/or braking.

This unintended situation should be improved because previous related study reported that downward road segment usually requires premature overlay. It might be caused by the friction between road pavement surface and vehicle's wheel when braking. The absence of speed limit sign makes it worst. This strongly indicates that road surface performance at such risky road segment should be designed and/or constructed differently from other road segments types.

Determination of the Minimum Stopping Sight Distance

Based on the Eq.2, varying min SSDs then was simulated and the result as can be seen in Table 2 and Fig.1.

It can be seen that the minimum SSD length is very much determined by the choice of speed, braking ability and may also by the slope extending the body of the road so that the mass of the vehicle is a determining variable that needs special attention because, as mentioned earlier, thus far the determination of the maximum speed limit other than not taking into account the effect of slope lengthening the road body also ignores the influence of the type (mass) of the vehicle.

Table 2. Minimum SSDs at downgrade for varying speed choices and braking ability of motorcyclists

V_0, km/h	V, km/h	ASSD, m	MSSD due to varying braking ability, m		
			Below Average, 4.5 m/s^2	Average, 6.75 m/s^2	Above Average, 10.9 m/s^2
40	38	35	20.08366	15.23256	11.2137
45	43	35	24.9223	18.62796	13.48193
50	48	35	30.26735	22.3516	15.93923
55	53	35	36.11882	26.40347	18.58561
60	58	35	42.4767	30.78357	21.42107
65	63	35	49.34099	35.49191	24.4456
70	68	35	56.71169	40.52848	27.65921

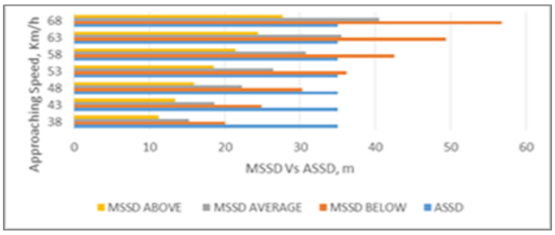

Figure 1. MSSDs for Varying Speed Choices & Braking Abilities

However, the ability of drivers to identify the presence of dangerous objects on the road is usually very good, so it is assumed that the height of the eyes of heavy vehicle drivers can enable it to detect the presence of objects and / or dangerous situations on the road more easily [15] so that braking applications can be carried out suddenly without having to do downshifting.Fig.2 strongly indicates that the impact of the mass of the vehicle and its choice of speed are the variables that most determine the chances of an accident and the consequences that can be caused.

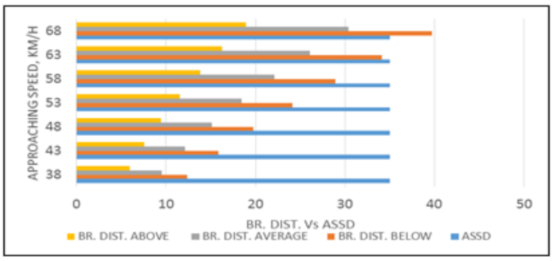

Figure 2. Braking Distance due to Varying in Speed & Deceleration Rate

It is seen that, even though the drivers have applied their maximum braking ability, if the choice of speed is higher than 60 km / h, only the driver who in the above average ability category has a great chance of avoiding a collision if the distance to the object is around 35 m. Unfortunately, this risky situation has not been sufficiently explored in various efforts to manage accident risk because the process of obtaining a driving license or determining the maximum speed limit on a part of the road, especially the downgraded gradient, does not take into account the effect of braking ability in various road gradient conditions and speed choices. Since there has not been enough data about maximum braking deceleration rate at downgrade road segment, it is thought that, in the near future, further investigation should be carried out.

On the other hand, it is estimated that the choice of speed that is too high is also caused by the lack of information about the presence of intersection, or about the impact of the choice of speed on the braking distance length for various types of vehicles and the consequences that can result. In other words, it can be stated that current road sign and/or mark has not been adequately bridging the safety and mobility issues because there was no speed limit sign and/or warning signs and/or suitable mark surrounding.

Furthermore, it is suggested that the road pavement design of risky road segment, such as downgrade, should also be improved because the job mixed design of pavement has not been considered the effect of braking to skid resistance, particularly at downgrade road segments. Even, the use of reinforced concrete roadway should be properly considered. Moreover, the aspect of consistency design of road surface at each risky road segment should also be considered so that all risky road segment should be designed and constructed based on standardized road safety directive, mostly at arterial and collector streets.

Other problem: appropriate type of recommended workable road pavement

Tabel Since the damage on declining roadway usually occur initially then it is thought that a workable road pavement design should be considered. This specific effort is intended to ensure that such risky location should always in a well-preserved condition. However, it may affect the maintenance and operational cost so that only gradient roadway which is passed through by the high number of heavy vehicles, especially located surrounding un-signalized intersection should be equipped with this workable road pavement.

Type of technology considered include use of a rigid pavement such as reinforced concrete slab pavement or concrete blocks pavement. Use of reinforced concrete may increase the durability aspect whilst use of concrete block pavement offering more cheaper and easier maintenance effort. The use of specified flexible pavement policy such as special job mixed design of HRS or a shortest period of regular overlay may also be taken into account. Although these requires further studies but the result of this study strongly indicate that the use of workable pavement to produce a well-preserved pavement at risky downgrade road segments should be properly consideredtabel.

Conclusion

The conclusion that could be drawn from the result and discussion descriptions are:

1. Since the required braking distance at downgrade was much influenced by vehicle speed, type of vehicle, road gradient, and braking deceleration rate (including road pavement condition or skid resistance value) then determination of speed limit at downgrade road segment should be conducted based on such determinant variables, proportionally and contextually. Besides, additional information about risky condition surrounds it, such as the presence of intersection or the functional condition of road, should also be informed.
2. As the quality of pavement's surface located on downgrade road segments might be much influenced by hard braking forces of heavy vehicles' volume, so that the use of rigid pavement such as reinforced concrete roadway along those segments should be properly considered. It requires further study to ensure the durability and its functional aspects.
3. In addition, accident probability and/or consequence at downgrade road segment could be predict using safety factor model, i.e., the ratio of available stopping sight distance (ASSD) to minimum SSD. Consequently, it is also requiring further study about actual ASSD at un-signalized downgrade intersection.

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