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REMEDIAL SAFETY TREATMENT OF ACCIDENT-PRONE LOCATIONS

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ABSTRACT

Accident prone locations refer to locations having or susceptible to having, a greater than average number of accidents which are represented by outstanding figures of repetitive accident occurrences along the roads. Any appropriate application of remedial safety treatments will require an in-depth study to find the accident causations and the possible contributing factors. The present study adopts the combined approach of Systems Theory which proposes that accidents are the result of maladjustments in the interaction between the components of complex systems, and the Causal Accident Theory which tries to find the real causes of accidents by probing the events leading to each accident in detail. The case study was conducted at Gringsing Roundabout in Central Java and the intersecting roads, the data of which reveal a high frequency of accidents. The data were analyzed using cross tabulations to produce first-hierarchy and second-hierarchy accident causations. Results indicate that geometric features, as the predominant factors, lack compliance with the standards. The remedial safety treatment therefore focuses on geometric redesigning of the roundabout in compliance with geometric standards and traffic demand. A major change, in conjunction with other hazard reduction schemes along the roads, is also proposed to the existing roundabout. The proposed changes are expected to mitigate or remove the possible accident causes, thus reducing accident occurrences.

Keywords: Accident-prone location; Remedial safety treatment; Road geometry; Roundabout

1. INTRODUCTION

The location of study area: Gringsing, Batang, north coast of Java, is the vital national road which connects Jakarta and Surabaya and is known for its heavy traffic. (Figure 1). There are three roads which have been constructed in the study area: Jl. Beton Lingkar Selatan, Jl. Daendels, and Jl. Baru Plelen. Jl. Daendels is a winding 2.43 km central road which was built during the Dutch colonial time and it is not very much in use at present due to its sharp bends. Jl. Beton Lingkar Selatan spans a distance of 5.66 km and was built to accommodate the increasing traffic and Jalan Baru Plelen is the most recently built 4.75 km road provided with two escape ramps. Jl Baru Plelen and Jl, Beton Lingkar Selatan intersect at Gringsing Roundabout in the direction to Semarang. Traffic accident data from the Police show that the number of traffic accident occurrences along the roads at the Gringsing Roundabout and at the roundabout itself is high. Investigation and analysis were carried out focusing on the geometric features of the road, while taking into consideration the driver and vehicle performance.

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This study is aimed at finding the appropriate remedial safety treatment to improve the accident-prone sections at Gringsing Roundabout.

Figure 1 Roads in *Kecamatan* Gringsing

2. METHODOLOGY

There are several approaches to accident theories which have been applied to accident prevention schemes: accidents as Random Event Theory, which suggests that humans have no control over accidents; Accident Proneness Theory, which suggests that some people are more prone to accidents than others; Behavioral Theory, which emphasizes on human risk assessment and human risk acceptance in an accident; Systems Theory which proposes that accidents are the result of maladjustments in the interaction between the components of complex systems; and Causal Accident Theory, which states that accidents can be prevented only if real causes are known (Elvik, 2004; Elvik, 2009).

The present study adopts the combined approach of the latter theories: the Systems Theory and the Causal Accident Theory. Remedial measures of accident-prone locations need to be developed on the basis of the proposition of Systems Theory that it is not possible to pick out any part of the road transport system as more crucial than others for its successful operation and that human errors are made because the system is not adequately designed and matched to human capabilities (Elvik, 2009), as well as the Causal Accident Theory which enforces the impetus to find the real causes for accident prevention. The likelihood of an accident to occur is determined by how the technical components interact and therefore the solution to mitigate accident occurrence requires modification of these components of the road system. The improvements of the road system, traffic control and motor vehicle design will reduce the accident rates

The location under study, Gringsing, Batang, is known as an accident-prone location with a high occurrence of traffic accidents, on Kutosari (flexible pavement or asphalt road), Kutosari (rigid pavement or concrete road) and Plelen. The Gringsing Roundabout, which is the intersection of Jl Beton Lingkar Selatan and Jl. Baru Plelen was analyzed individually. A visit to the location was arranged to survey the current situation and obtain primary data as well as to update data of the survey location itself. To ascertain prominent causation, the present study utilizes the cross-tabulation process in Hierarchical Analysis and produces the structure of first-hierarchy accident causations and second-hierarchy accident causations. Cross tabulation is used to analyze categorical data, which are separated into different categories that are mutually exclusive from one another. The results were then cross-checked with road geometry data of the roads within the area under study.

3. RESULTS

Based on the preliminary survey, accidents occur along all three roads: Jl. Daendels, Jl. Beton Lingkar Selatan, and Jl. Baru Plelen, and at Gringsing Roundabout. Investigations were carried out along the roads and at the roundabout iintersection of Jl.Baru Plelen and Jl Beton Lingkar Selatan in the direction of Semarang. As geometric design consistency is not always ensured in the existing design, geometric features were investigated to check the conformity to and departure from design standards.

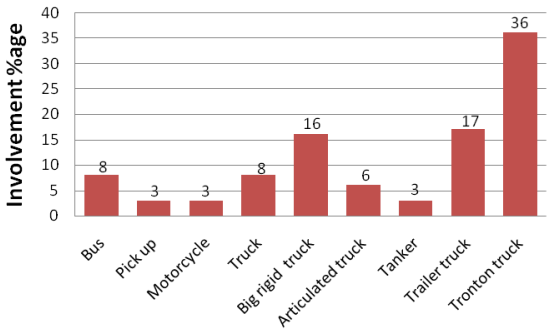


Figure 2 Percentages of vehicles' involvement in accidents

As parts of inter-city roads, the roads accommodate a significant percentage of heavy vehicles.

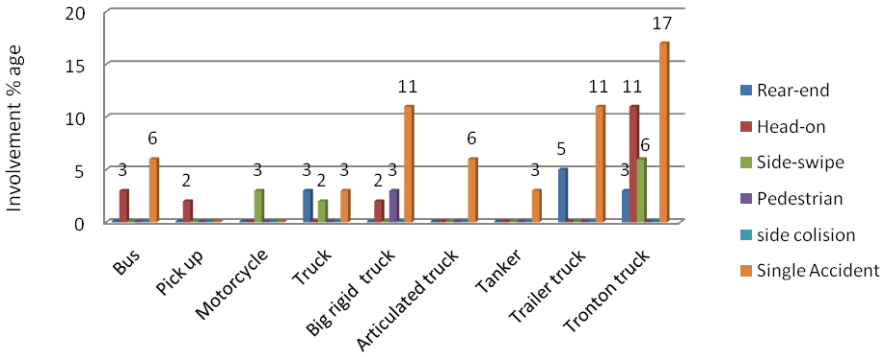


Figure 3 Accidents percentages based on types of vehicles and types of collisions

From 2005 to 2008, during the years of data collection, the total number of accidents along Jalan Kutosari (asphalt road) was 30 with total 16 fatalities; along Jalan Kutosari (concrete road) there were 39 accidents with 18 fatalities; and along Jalan Plelen there were 39 accidents causing 8 fatalities. Figure 3 shows the analysis of accident percentages based on types of vehicles and types of collisions. The high proportion of fatalities compared to the number of accidents, which is quite typical in Indonesia, may not seem to be reasonable. The fact that there are quite a significant number of unreported non-serious and serious accidents and resolved-at-site accidents (Tjahjono, 2009) may contribute to this anomaly.

3.1. First-Hierarchy Accident Causation (H1)

Hierarchy analysis process is adopted for accident causation analysis. First-Hierarchy Accident Causation (H1) results in what causes an accident to happen. It was found that single accidents due to vehicle factors dominate the types of accidents, reaching 53% of the total number of accidents. Further analysis was then carried out to find out what causes the vehicles to have accidents—which are defined by Second-Hierarchy Accident Causation (H2).

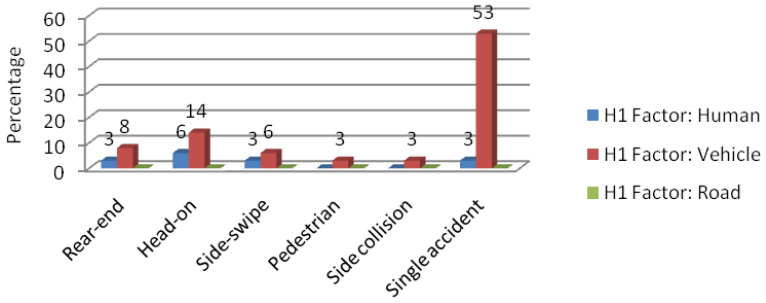


Figure 4 First-Hierarchy Accident Causation Factors (H1)

3.2. Second-Hierarchy Accident Causation (H2)

Second-Hierarchy Accident Causation (H2) is what causes the first-hierarchy accidents to occur. A figure of 47% attributed to road factors appears to be dominating in the single accident category. A preliminary conclusion can now be made that the major type of accident is single accident due to vehicle failure, which is mainly caused by road geometry standard deficiency (Figure 5).

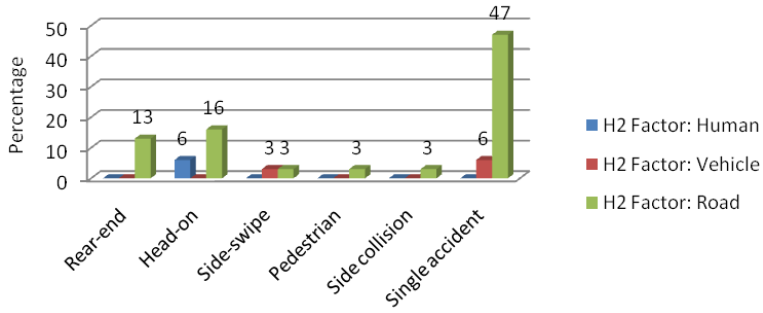


Figure 5 Second-Hierarchy Accident Causation Factors (H2)

3.3. Analysis of Road Geometry

The departure of road geometry from the standards in relation to accident causation was analyzed along the existing roads, namely Jl. Daendels, Jl. Beton Lingkar Selatan, Jl. Baru Plelen, and at Gringsing Roundabout. As the construction of Jl. Beton Lingkar Selatan was in response to the high number of accidents along the existing Jl. Baru Plelen, only Jl. Beton Lingkar Selatan and the roundabout were analyzed in terms of the design departure from geometric standards in relation to accident causation. Figure 6 shows the analysis of the geometric features of the study area and the prominent deficiencies of lighting, markings and signals as well as roadside occupancy at the roundabout.

3.3.1. Jl. Beton Lingkar Selatan

Direct measurement and on-site survey of the road conditions indicated that the vertical alignment exceeds the road geometry standard regulated by Bina Marga. Based on Figure 6 the average range of slope is between 2% to 5%, which actually does not exceed the allowable gradient of vertical alignment based on *Tata Cara Perencanaan Geometrik Antar Kota, 1997.* The road section with a 5% gradient, however, spans a length of 2,549 m which exceeds the maximum 210 m length for the gradient. This section forces drivers to press the brakes more often when they are travelling downhill, which may then cause early damage of the vehicles' braking system. This is in line with an earlier study that shows different gradients result in different levels of vehicle performance (Khan, et.al.,1990).

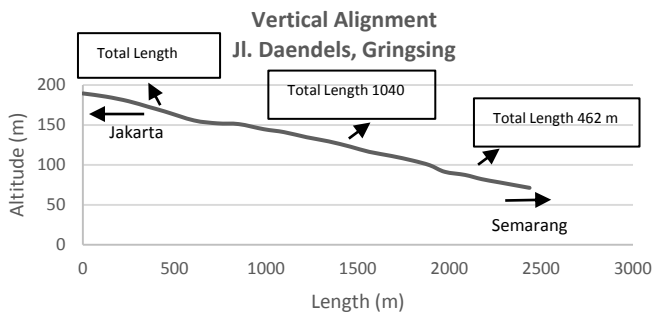
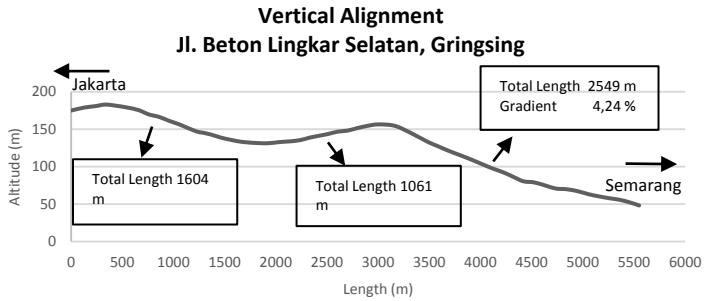
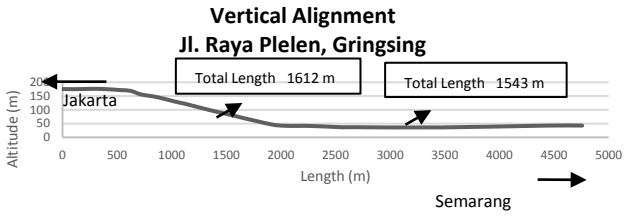
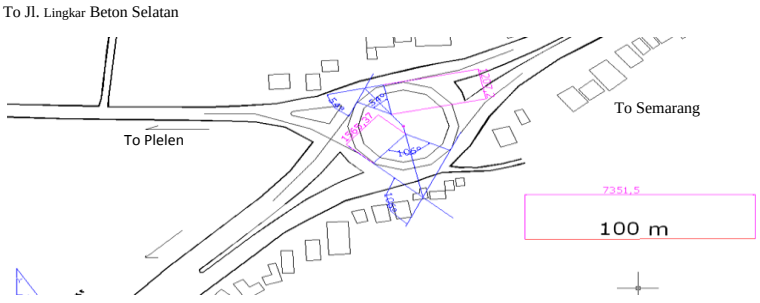
 Jl.Raya Daendels	Insufficient road lighting, lack of guard rails as the roads run adjacent to ravines on both sides. Road gradient over 4% for 2500 m
 Jl. Beton Lingkar Selatan (Desa Kutasari, concrete pavement)	Excessive sloped-length, insufficient road lighting, signals and markings. Road exceeding critical lengths for the gradients
 Jl.Baru Plelen	Steep gradient, insufficient road lighting, signals and markings, narrow and winding roads with sharp curves. Road gradient over 8% for 1,500 m.
 Gringsing Roundabout	Inappropriate application of superelevation, causing vehicles to experience centrifugal force and be forced outwards, small radius, minimum information markings, roadside occupancy by residential areas.

Figure 6 Analysis of geometric features

Long heavy vehicles are the category of vehicles which are mostly influenced by this sort of road condition as statistically confirmed by the accident data reports from the police. The plan view (horizontal alignment) of Jl. Beton Lingkar Selatan shows multiple compound short curves with relatively short tangents along a long vertical profile (2.549 m in length with 4.24% gradient). The plan and profile of the road segment are not harmoniously designed, which may

reduce drivers' anticipation capacity due to heavy driving task and may result in reduced level of alertness. Jl. Beton Lingkar Selatan leads to the 3-legged Gringsing Roundabout at the end of the section, which, based on the accident data, is one of the blackspots that needs to be analyzed.

3.3.2. Gringsing Roundabout

Gringsing roundabout is a 3-legged junction of Jl. Baru Plelen and Jl. Beton Lingkar Selatan in the direction of Semarang City. Leading to and approaching the roundabout is Jl. Beton Lingkar Selatan which runs more than 2.5 km with a continuous downhill gradient. Theoretically, roundabouts are normally the safest form of an at-grade junction over a wide range of entry flows and approach speeds. As data from the Police indicate that the roundabout is one of the accident spots, a review of design aspects of roundabout was carried out. Heavy vehicles involved in accidents lose control due to brake failure and hit the guard rail or the median. The driving complication experienced by, in particular, heavy vehicles drivers, peaks at the end of the road leading to the roundabout. The accident spots at the roundabout cluster around the roundabout curve in the direction of Semarang.

Geometric analysis shows that the approaching gradient before entry to roundabout from Jl Lingkar Selatan is 4.24%, which is relatively steep as it is higher than the 2% allowable entry roundabout approach gradient as indicated in the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (2004). This condition causes vehicles, especially heavy vehicles, to fail to maneuver well along the approach to roundabout. A roundabout is basically a safe form of junction. However, the lack of necessary markings, signs and signals may lead to induced traffic conflicts, and the substandard geometric designs will lead to drivers' incapability of carrying out required maneuvering tasks along the roundabout. Signs at the roundabout are often inappropriately located at the roundabout and not at the approach. General improvement of road alignment is expected to lead to a reduced number of accidents (Cirilio, 1992).

4. DISCUSSION

4.1. Jl. Beton Lingkar Selatan Improvement

As the length of the slope exceeds the critical length, climbing lanes need to be provided on the uphill gradient road and escape ramps need to be provided on the downhill gradient road. Based on the vertical alignment profile, a climbing lane is provided along Jl. Beton Lingkar Selatan to accommodate heavy vehicles climbing along the 4.24% uphill gradient of the 2,549 m of road section in the direction of Jakarta. The principal factor in determining the need for an emergency escape ramp should be the safety of the other vehicles on the roadway, the drivers of the out-of-control vehicles, and the residents along and at the bottom of the grade.

The relatively long downhill section of Jl. Beton Lingkar Selatan needs to be provided with an escape ramp for the vehicles facing braking system failure. The provision of an escape ramp is required in particular when vehicles lose control, machine overheating occurs or other types of mechanical problems, become a hazard to other vehicles and the need to pull out of the road traffic occurs in order to prevent accidents.

Witheford (1992) developed a synthesis of highway practice on truck escape ramps and noted that the location and siting of truck escape ramps still pose problems as no universally applicable answers have been found. An escape ramp should be located wherever grades are of a steepness and length that present a substantial risk of runaway trucks and where topographic conditions will permit construction. Figure 7 shows the proposed changes to road geometry based on the *Panduan Penempatan Fasilitas dan Perlengkapan Jalan* (2006).

4.2. Junction Improvement

As clear markings and signs are of paramount importance in roundabout operations, inadequacy of information provided by unclear or missing information due to inappropriate location of signs and/or erased markings will lead to decreased quality of safety in the intersection. (Bahar et al., 2009; Cairney, 2000). Pavement markings, signs and signals are designed to move traffic safely, rapidly and efficiently. At Gringsing Roundabout, missing signs and markings profoundly dominate the conditions, which are worsened by inadequate lighting and supporting safety facilities such as guard rails, reduced sight distance due to obstructions from trees, plants, and buildings.

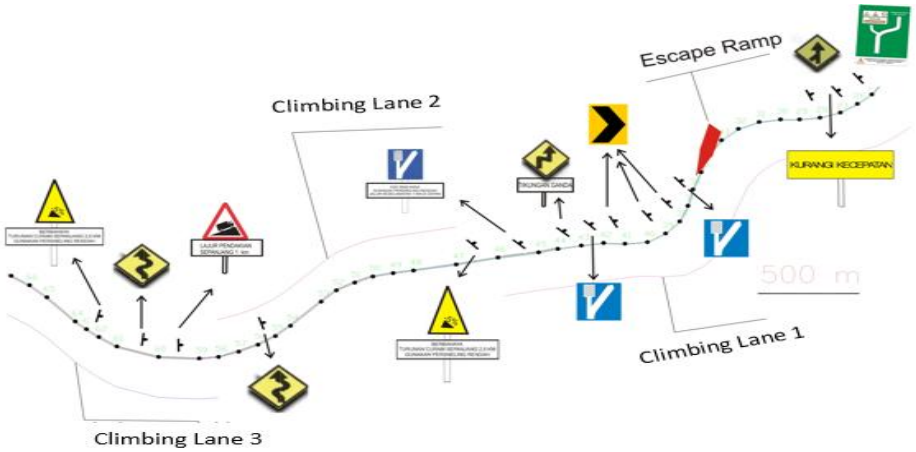


Figure 7 Proposed changes to the road geometry and signage

Regarding the dimensions, a further analysis on the roundabout geometric features was carried out and results indicated that the intersection radius is smaller than that of the minimum standard of radius. One of possible options is to recommend the minimum and followed by major physical changes to provide more turning space by widening the roundabout.

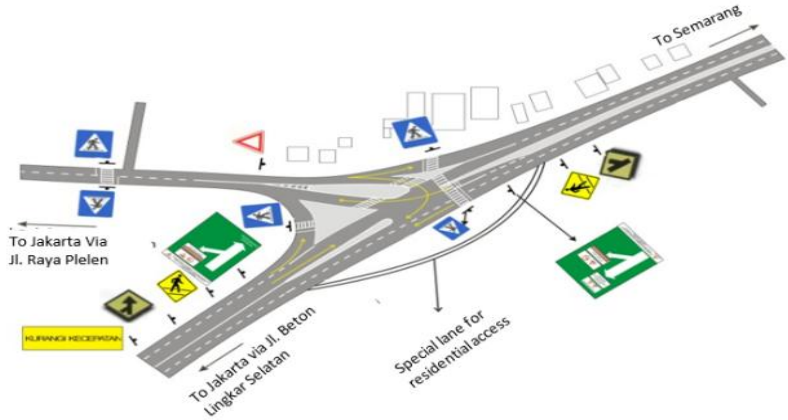


Figure 8 Proposed change of Gringsing Roundabout to a Y-junction and lay-out plan of road markings and signage

The impact however, varies with the different vehicular and pedestrian demands at the individual entries, as well as the proportion of trucks. In case of roundabouts, geometric design has a great impact: the longer the wheelbase of a heavy vehicle and the smaller the radius of the roundabout, the greater the difficulty the driver will have in negotiating the roundabout.

(Cerezo, 2010). As the roundabout under study is inconveniently located right at the end of a vertical alignment with a relatively large gradient which is suspected to be one of the main accident causations, truck drivers may have difficulties to adjust to the circulating maneuvers required along the roundabout. Ideally, steep downhill *gradients* should be avoided at maximum *roundabout approaches* or flattened to 2% before entry. The approach to the Gringsing Roundabout from Jl. Beton Lingkar Selatan (Desa Kutasari, concrete pavement) has a slope of 4.24%, much higher than the maximum 2% allowable gradient. The Highway Safety Manual (AASHTO, 2010) lists a catalog of Crash Modification Factors (CMF) for a variety of facility types, which provide guidance on the effect of grades on the expected roadway guidance safety measures (See Table 1). The base condition for grade is generally level. The Crash Modification Factor (CMF) is a measure of the safety effectiveness of a particular treatment or design element.

Table 1 Crash Modification Factor (CMF)

Approximate Grade (%)	Level Grade ($\leq$ 3%)	Moderate Terrain (3% < grade $\leq$ 6%)	Steep Terrain (> 6%)
CMF	1.00	1.10	1.16

Source: AASHTO (2010)

However, reducing the grade to a level grade is a costly alternative and therefore a possibility of changing the type of intersection is reviewed to check whether a simpler type could be adopted. Roundabouts are built so that road users cannot drive a straight path through the junction; instead, they have to drive round a traffic island located in the middle of the junction. This reduces speed (Elvik, 2004). Brake system failures experienced by drivers when approaching Gringsing Roundabout gives little possibility for drivers to reduce speed on the given length of road, thus indicating the need for a more simple type of junction to accommodate the deficiency of the road gradient. It is not always possible to improve a steep gradient by rebuilding the road. Based on AASHTO 2004 standards, it is indicated that instead of a roundabout, a minor/major priority type of junction, as a more familiar type, will still be sufficient and can be adopted. A 3-legged channelized priority junction is proposed with Jl. Beton Lingkar Selatan to serve as the major road leading in the direction of Semarang, and Jl. Plelen as the minor road. With the 3-legged type of intersection (Y-intersection) Jl. Beton Lingkar Selatan would serve as the major road leading to the direction of Semarang. It is therefore proposed that a new traffic management at the intersection is to be applied, thus allowing traffic from the major road to be prioritized with the provision of a‘Give Way’ sign at the Jl. Plelen leg, as the minor road. The proposed change of type and markings at and around Gringsing intersection would be based on the Guidance for Road Facilities and Utilities as shown in Figure 8.

5. CONCLUSION

Traffic accidents along the three roads are mainly single accidents involving trucks/heavy vehicles. The vehicle factor due to braking system failure contributes to the majority of accident causation factors. In this study, measures are proposed to improve the quality of the safety level within the case study area. Considerations on geometric design improvement along Jl Beton Lingkar Selatan result in the need for the provision of climbing lanes and an escape ramp, clear markings and signs. For Gringsing Roundabout, if the existing type and geometric design is to be maintained, a set of safety improvement schemes, such as rumble strips, provision of climbing lanes and an escape lane along Jl. Beton Lingkar Selatan need to be applied as well as

the provision of clear road markings, signs and lighting. The other possible solution is a major change in the type of intersection to a channelized 3-legged intersection which is expected to result in a higher safety level as this change could reduce the possibility of a reduction in a driver's alertness and the related-accident causation, which is more likely to occur at roundabouts, rather than in 3-legged intersections. In addition, this type of intersection minimizes geometric-related hazard potentials and allows heavy vehicles to maintain their braking system performance without significant increase in driving complications. The provision of both climbing lanes and escape ramps along Jl. Beton Lingkar Selatan also adds to the safety driving environment. These changes in road design features can be expected to change the patterns of traffic interactions, which would lead to the decrease in the probability of accident occurrences. A post-remediation case study should also be considered for further evaluation of the proposed scheme at Gringsing Roundabout**.**

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