Proceedings of the Eastern Asia Society for Transportation Studies, Vol.7, 2009

A Comparison of Accident Characteristics in Highland and Lowland Regions: A Case Study in Malang District, Indonesia

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Abstract: An accident is defined as an incident which involves one or more vehicles on a lane of road and causing losses of properties, injuries and fatalities. Accident could be caused by several factors, such as human behavior, vehicles, road conditions, and environment. This research is intended to identify the accident characteristics, to identify accident black-spots, and to obtain the relationship between accident rate and traffic characteristics and road geometry in two different topographies, lowland and highland regions. The location as a case study is Malang District (located at East Java Province). The results shows that the changing of traffic characteristics and road geometry could significantly increase or decrease the accidents occurrence rate, however the different results were obtained from different types of topography. In this study, several black spot locations in highland and lowland regions and some important accident characteristics in Malang District were identified.

Keywords: accident characteristics, accident rate relationships, lowland and highland regions

1. INTRODUCTION

There are several factors that may result in a road accident, such as law violations and improper behavior of road users, road conditions, and vehicle conditions. In most cases, the occurrence of accident is not caused by a single factor, but contributed by combination of two or more factors. To reduce the occurrence of the road accidents, various solutions could be used, such as two approaches (Gladwell, 2001): (i) by reducing the damage effect that occurs in a crash, particularly for vehicle occupants, with building crash protection in roadways (wider shoulders, break-away light standards, etc.) and in vehicles (increased vehicle weight, energy absorbing vehicle design, air bags, etc.); and (ii) by requiring vehicle occupants to use seatbelts, child restraints, motorcycle and bicycle helmets.

Other researchers analyzed the influence of road safety furniture/devices, proper road design and geometry on road safety improvement. Zegeer et al (1996) noticed that the presence of a shoulder is related with a significant accident reduction for certain lane width. Swift (1997) also explained that 20,000 police accident reports from the City of Longmont, Colorado were reviewed, and it was found that the street design contributed to the accidents. The most significant relationships to injury accidents were found to be street width and street curvature.

This paper presented the influence of road geometry and traffic characteristics at different land topographies on road safety. Two types of land topography were evaluated, that is, highland and lowland regions. The different characteristics between highlands and lowlands could influence on how the road is designed, and then it will affect the behaviour of drivers traveling on that road. In this study, Malang District (located at East Java Province) was selected as location of case study. Malang District is one of the pilot projects of Indonesian Ministry of Transportation for the enactment of Road Safety Strategies. For this purpose, a road safety audit is required to find the solutions. To support the audit, a preliminary study is necessary to be carried out. This study is aimed to compare the accident characteristics between highlands and lowlands in order to determine black spot location and the correlation between accident rate and road geometry or traffic characteristic. This research, therefore, is a basis to manage and decrease accident rate, and to improve road geometry concerning with driver safety.

2. ILLUSTRATION OF THE CASE STUDY

Malang District is the second biggest city of East Java Province. This makes the city growing fast and it becomes one of trade and tourism centers in the region. Consequently, high traffic flows burden the road network. If the road infrastructure cannot provide a good level of service for the traffic flow, then some problems, such as traffic jams and accidents, will increase. As a city with high economic activities, Malang also faces these problems where road accidents increase anually. The total fatalities in Greater Malang region (i.e. Malang District, Malang Municipality, and Batu City) in three consecutive years (2003 – 2005) are 5,064; 5971; and 6,078 respectively, of which 40% of total traffic accidents occurred in Malang District. In 2007, according to Malang Police accident reports, there were 353 traffic accident cases, 91 of which were resulting to fatalities. The total traffic accident cost was estimated as 361 billions rupiah (around US$ 36.2 million).

Malang District encompasses 33 Sub Districts located at elevation ranging from 0 to 1500 m above sea level (Fig.1). Lowland regions (below 500 m Mean Sea Level or MSL) lie in southern part (19 Sub Districts), while the highlands (above 500 m MSL) are in the North (3 Sub Districts), West (5 Sub Districts), and East (6 Sub Districts). The capital of Malang District, i.e. Kepanjen, located in the middle of the lowlands (see Figure 2).

The wide different elevation among the Sub Districts thus impacts the characteristics of the road networks, and furthermore, the characteristics of the accidents. The road network of the lowlands stretches out from the middle up to the southern part of Malang District, near the Hindian Ocean. The road width at highlands is commonly wider than that at lowlands. For instance, the road network northward from Kepanjen to Surabaya (the capital of East Jave Province) could be 14 meter wide, while the road networks at lowlands, such as the Eastward roads to Lumajang District, the Westward roads to Blitar District and the Southward roads to the Hindian Ocean, are generally only 7 meter wide (see Figure 3).

Figure1 Position of Malang District in East Java Province, Indonesia

Figure2 Topographic condition and road network of Malang District

(a) (b)

Figure 3 The difference of road condition in highland and lowland regions:
(a) Turen - Lumajang KM 033 - 034 (highlands);
(b) Malang- Kepanjen KM 106 -107 (lowlands)

2. METHODOLOGY

2.1 Classification of Roads studied

Firstly, a classification of roads involved in accident records in Malang District based on type of road and topography was conducted. Table 1 explains the group of road segments with accident occurence record.

Table 1 Location of road segment with accident occurrence record in Malang District

Type of road	Road segment	
	Highland	Low-land
Provincial road	Turen-Lumajang	Kepanjen-Gondanglegi
	Malang- Pendem	Malang-Kepanjen
	Karangploso-Pendem	Kepanjen-Blitar
	Pendem-Kediri	Malang-Turen
	Purwodadi-Karanglo	Kepanjen-Turen
Municipal road	Tumpang-Tajinan	Talok-Sendangbiru
	Wagir-Pandanrejo	Ngliyep-Sumbermanjing
	Wagir-Mulyorejo	Kalipare-Karang kates
	Balaikambang-Sumbermanjing	Kalipare-Donomulyo
	Kromengan-Wonosari	Kromengan-Slorok
		Kromengan-Ngadirejo
		Ngajum-Kepanjen
		Malang-Sumbermanjing
		Gondanglegi-Pagelaran

2.2 Data collection

The data collected in this study consisted of: (1) primary data, which is traffic data on main roads in Malang District, and (2) secondary data (accident data and highway network). The traffic data consists of traffic volume (ADT/annual daily traffic), traffic composition, and speed, which were collected at black spot locations. ADT and speed data for all road networks in years 2000 - 2004 are also referred. The accident data includes accident location, time of incident, and drivers and victims characteristics (sex, age, education, occupation, and total of accident). The highway network data contains road classification, road geometry (the number of lane, lane width, shoulder width, and separated lane), and other inventory data around the road corridor.

There were three primary surveys performed, i.e. traffic counting (to obtain traffic volume and composition), measuring travel speed and collecting road inventory data. In order to understand the accident characteristics (such as level of accident fatality, type of accident, vehicle involved, accident time, characteristics of the drivers and victims), an investigation of accident data was carried out by collecting accident data from years 2000 to 2005 from Central Hospital and Malang District Police Resort.

2.3 Data Analysis

There are three analyses of the collected data describe in the following sub-sections: (i) calculation of accident rate, (ii) determination of accident black-spots and (iii) developing relationships between accident rates and traffic characteristics and road geometry.

2.3.1 Calculation of Accident Rate

The accident rate can be calculated based on the number of population, the number of registered vehicles, and the number of vehicle trips. The other factors for accident rate calculation are total of vehicle trip, traffic volume, and road length on certain time. All of them are used to analyze the total accidents occurred. The accident rate is described as the number of accidents predicted to occurr at certain period of time, based on road length and traffic volume in the segments per 100 millions vehicle-km, and formulated as follows.

$$R_{sc} = \frac{A \times 100.000.000}{\left(365 \times ADT \times T \times L\right)} \quad (1)$$

where R_{sc} is the number of accidents happened per 100 millions vehicle-km, A is the number of accident at the observation period, ADT is the average daily traffic volume (vehicle/ day), T is the observation period, and L is the length of lane (km).

Furthermore EAN (Equivalent Accident Number) is calculated by characteristic/rate of accident victims per kilometer. The common equation for EAN is given by equation (2)

$$\text{EAN} = W_1 * \text{fatality} + W_2 * \text{seriously injured} + W_3 * \text{lightly inured} + W_4 * \text{property damage} \quad (2)$$

where W_1, W_2, W_3 and W_4 are the scaling values from Transport Research Laboratory/Institute of Road Engineering (TRL/IRE, 1997) and equal to 12, 3, 3 and 1 which is respectively are fatality, seriously injured, lightly injured and property damage.

2.3.2 Determination of Accident Black-spot

A location is considered as an accident black-spot location if the location could fulfill one of the following criteria:

a. the location has the highest accident number in its kilometer,
b. the accident number correspond to the accident rate at the location should exceed a value namely the upper limit,
c. the number of accident involved at the location per 100 million vehicle kilometer should exceed the upper limit.

The upper limit is obtained by equation (3):

$$\textit{The upper limit} = C + 3\sqrt{C} \tag{3}$$

where C is the accident rate approximation (corresponds to the observed accident rate, either EAN or R_{sc}).

2.3.3 Developing Relationships between Accident Rate and Traffic Characteristics and Road Geometry

It is neccessary to develop the equation that shows a relationship between accident rate and traffic characteristics and road geometry. The relative performance of the relationship can be evaluated based on its coefficient of determination, R^2.

3. RESULT AND ANALYSIS

3.1 Accident Characteristic

The investigation conducted showed that the characteristics of accident include the number of accident, type of collision, types of vehicle involved, time of accidents, sex of victims, educational background, occupation and age of drivers.

The number of the accidents from years 2000 to 2004 tended to decrease (195, 188, 145, 59, and 27 cases respectively). The local government tried to reduce accident by employing some simple treatments of the road infrastructure, such as road lighting, pavement condition, traffic management, road marks and road signs. The characteristics of the accidents occurred in Malang District during those five years are as follows (Police Department of Malang District, 2005):

- Based on the severity of accident victims, there were 13.69% fatalities, 19.57% light-injured victims, 2.43% heavy-injured victims and 0.53% properties damage for high-land regions, while for low-land regions there were 16.41% fatalities, 16.33% light-injured victims, 3.07% heavy-injured victims, and 0.57% properties damage.
- The types of accident collisions were categorized as 35.11% single-accident, 7.2% multiple- accident, and 4.23% series-accident (for highlands) and 42.09% single-accident, 6% multiple- accident, and 5.37% series-accident (for lowlands).
- The types of vehicle involved were dominated by motorcycles (55.4%), followed by trucks (15.3%), cars (14.8%), paratransits (10.5%), and buses (3.8%). There is no specific difference of types of vehicles involved in accidents whether in highland and lowland, but in highlands is dominated by motorcycles (29.45%) and cars (9.25%) more than those in lowlands 25.95% (motor cycle), and 5.55% (car).
- 68.8% accident occurred on weekdays, and the rest on weekends. Most of the accidents happened in the morning until afternoon (36% accident occurred at 06.00 - 12.00 and 35.6 % occasion were at 12.00 - 18.00). 18.1% accident occurred at 18.00 - 00.00, and the rest occurred at 0.00 - 06.00. The difference of accident occurrence in highlands and lowlands was not significant, except accident occourence at 12.00 - 18.00 and 00.00 - 06.00, where the total of accident occurred in highlands at those time periods was higher than occurred in lowlands.
- Most drivers involved were male (96.1%). The younger drivers (17 - 25 years old) were the highest proportion (33.9%), followed by the 26 - 35 cluster (28.9%), and 36 - 45 cluster (23.4%). The drivers aged between 17 and 25 years old are generally active, but careless and demonstrative.

- In term of education background of the drivers, the percentage of the drivers graduated from senior high school and junior high school were 62.2% and 29.1%, respectively. These groups have more opportunity for various occupation and activities, so that they have high mobility. And finally, the highest proportion in profession category was private employees (52.5%).
- The dominant characteristic of the victims were also male (74.7%) of which 33.7% of them were at age group of 17 - 25 years old. They graduated from senior high school (56%), and work on private companies (59.5%).

3.2 Analysis of Accident Rate and Black spot

In this study, black-spots are determined based on three categories, i.e. the accident occurrence rate, accident rate (EAN) and number of accident involved per 100 million vehicle kilometer (R_{sc}). Once one of the indicators in a road segment exceeds the upper limit, the segment would be categorized as a black-spot. The evaluation performed resulted in 100 black-spot locations over Malang District during 2000 - 2004. Most of the black-spots (about 70%) are located in provincial road network (64 black-spots in highlands and 22 black-spots in lowlands), and the rest are in municipal road. Table 2 presents the highest rank black-spot locations in Malang District based on each category and each region.

Table 2 The highest rank of black-spots in Malang District based on category and region.

Road Segment		km	Acc. Occ.
High Land	Purwodadi-Karanglo	079-080	14
	Purwodadi-Karanglo	076-077	11
	Purwodadi-Karanglo	075-076	9
	Purwodadi-Karanglo	070-071	8
	Purwodadi-Karanglo	077-078	8
	Purwodadi-Karanglo	072-073	7
	Purwodadi-Karanglo	074-075	7
Low-land	Malang-Kepanjen	106-107	8
	Malang-Kepanjen	096-097	8
	Malang-Turen	026-027	6

Road Segment		km	EAN
High Land	Purwodadi-Karanglo	078-079	183
	Purwodadi-Karanglo	076-077	153
	Purwodadi-Karanglo	075-076	138
	Purwodadi-Karanglo	072-073	108
	Purwodadi-Karanglo	071-072	105
	Turen-Lumajang	033-034	90
Low-land	Malang-Turen	026-027	108
	Malang-Turen	027-028	93
	Malang-Kepanjen	106-107	84
	Malang-Kepanjen	097-098	78

Road Segment		km	R_{SC}
High Land	Turen-Lumajang	033-034	73,7
	Turen-Lumajang	031-032	49,2
	Turen-Lumajang	032-033	36,9
	Turen-Lumajang	028-029	36,9
	Pendem-Kediri	001-002	33,7
Low-land	Talok-Sendangbiru	012-013	39,5
	Kepanjen-Blitar	115-116	33,2
	Kepanjen-Blitar	109-110	33,2
	Kepanjen-Blitar	114-115	33,2
	Kepanjen-Turen	008-009	30,8

Purwodadi - Karanglo segment is the location of black-spot with the highest number of accidents (109 accidents in 16 black-spots). The length of the road is only 16.01 km, but the highest number of accident and the highest accident rate occurred at about a half of this segment. The road itself is a secondary arterial road in highland region, which connects Malang District and Surabaya. More than 30.000 passenger car units pass through this segment everyday, with average speed about 70 kph.

Road segment Purwodadi-Karanglo at KM 079-080 is a 4/2D (4 lanes two-way divided) road, having a straight and flat geometry. Vehicles travel in high speed. On this road segment, there are intersections with high traffic volume and heavy vehicles crossing. At KM 073 – 075, there are intersections with poor combination of horizontal and vertical alignment (straight but excessively declining), so that vehicles tend to run with high speed. The presence of mixed traffic among motorcycles, light vehicles and heavy vehicles worsens this situation.

Road segments with the highest number of accidents in lowland regions are Malang-Kepanjen (60 accidents in 13 black-spots) and Kepanjen-Blitar (47 accidents in 14 black-spots). The geometric of Malang-Kepanjen segment at KM 096 - 097 is straight and flat, so that drivers tend to speed up. High traffic volume and high side friction makes the traffic condition very crowded and uncontrollable. This circumstance is worsened by poor pavement condition. The other road segment at KM 109 – 110 also has poor pavement condition, many curves, and numerous motorcycles.

3.3 Relationship between accident and traffic characteristic or road geometry

A high speed traveling increases the possibility of the accident. The drivers who drive faster than the average speed may have higher accident risks. Based on works by Nilsson (1982) in Sweden, a change in average speed of 1 kph will result in a change in accident numbers ranging between 2% for a 120-kph road and 4% for a 50-kph road. A similar relationship was assumed in Britain, based on empirical studies by Taylor et al. (2002), which with a 1-kph change in speed, the change in number of accidents vary between 1% and 4% for urban roads and 2.5% and 5.5% for rural roads, with the lower value reflecting good quality roads and the higher value poorer quality roads.This phenomenon, however, has not been proven yet for drivers who drive at slower speed. Litman and Fitzroy (2005) noticed that to reduce road accident, one effective approach is to post a speed limit. To evaluate the effect of speed on accident risk, a relationship between speed and accident risk was established. This is applied for various speeds of all roads.

Another component of traffic characteristics evaluated in the relationship is traffic flow/ADT. Besides, road geometry (i.e. lane and shoulder width) was also employed in this study to analyze the effect of this parameter on accident risk. Since the ADT obtained from secondary data exhibited a wide range values, a group of ADT was proposed in this study to ease the analysis. A preliminary analysis using regression analysis was conducted to select the manner to present the ADT and it was found that the use of group of ADT gave better coefficient of determination than that of individual ADT data.

A correlation analysis was performed for each component of traffic characteristic and road geometry with respect to parameter of accident rate, i.e. accident occurrence rate, as shown in Tables 3a and 3b.

Table 3a Correlation between Accident Occurrence Rate and Components of Traffic Characteristic and Road Geometry of highland region

	Acc. Occ. Rates	Lane width (m)	Shoulder width (m)	Speed (kph)	ADT (veh/h)
Acc. Occ. Rates	1				
Lane width (m)	-0.193516	1			
Shoulder width (m)	0.892876	-0.50801	1		
Speed	0.979663	-0.05401	0.795422	1	
ADT(veh/h)	0.804731	0.136596	0.585757	0.792882	1

Table 3b Correlation between Accident Occurrence Rate and Components of Traffic Characteristic and Road Geometry of lowland region

	Acc. Occ. Rates	Lane width (m)	Shoulder width (m)	Speed (kph)	ADT (veh/h)
Acc. Occ. Rates	1				
Lane width (m)	0.751562	1			
Shoulder width (m)	-0.279556	0.038836	1		
Speed	-0.225808	0.001042	0.906969	1	
ADT(veh/h)	0.593415	0.147318	0.242219	0.349396	1

It was found that in Malang District highlands, the accident occurrence rate has a good correlation with traffic flow, speed and shoulder width, while the correlation between lane width and occurrence rate indicated low values. In highlands, there are many side frictions which make the tendency of the drivers for speeding decrease. In lowlands, the accident occurrence rate has a good correlation with traffic volume, and lane width, however, the correlation between occurrence rate and shoulder width or speed showed low values. It means that in lowlands, the road user seems to be more careless and tend for speeding because of roads with wide lane.

The relationships between the three accident rate parameter and the components of traffic characteristic and road geometry are also examined in the term of coefficient of determination (R^2), as seen in Figs. 4 - 7. Figure 4 shows that in highland and lowland region, the accident occurrence rate tends to increase when the traffic volume increases. On both regions, the 10% increasing of ADT will raise the accident occurrence rate about 7 - 8%. The slope of the number of accident in highland region is steeper than that of lowland region.

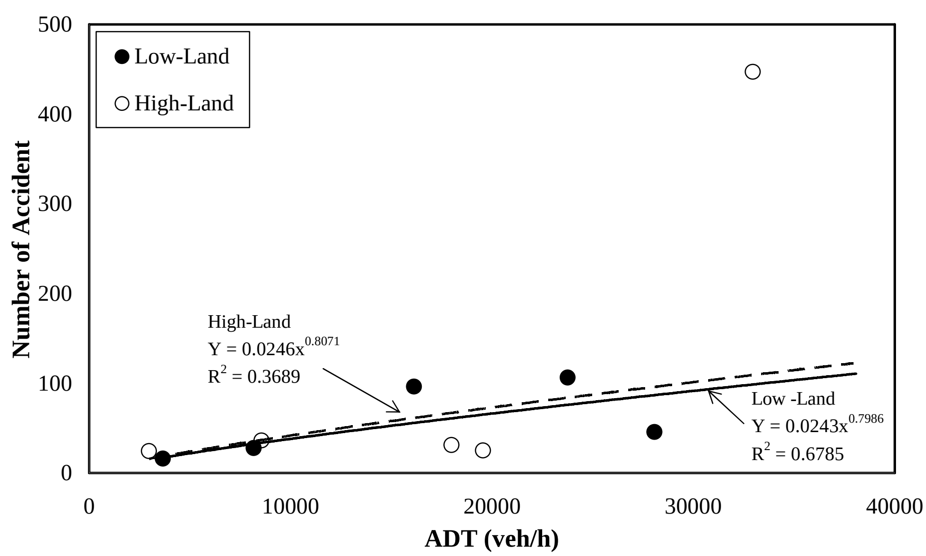

Figure 4 Relationship between accident and ADT

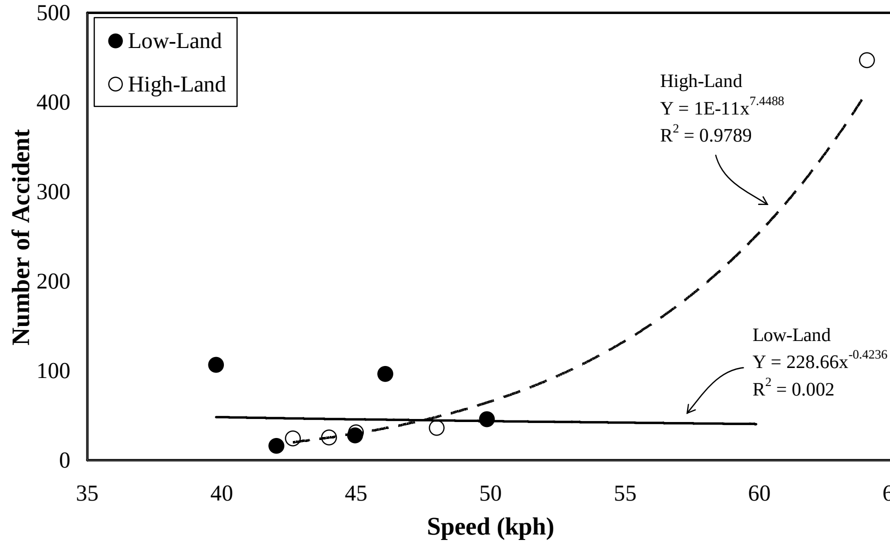

Figure 5 Relationship between accident and speed

Figure5 presents a relationship between accident occurrence rate and speed. The chart shows that in highland region with low-volume roads, due to the increase of speed, the accident occurrence rate decreases in the first part of the curve, but after it reaches an optimum point, accident occurrence rate will increase. The optimum speed resulting in minimum number of accident is found around 40 kph for accident occurrence rate. While, the relationship between accident occurrence rate and speed in lowland region indicated that there is a little dependence between speed and accident occurrence rate on this type of topography.

It is interesting to know that Figs. 4 and 5 can be used to explain why roads in highland region such as road segment Purwodadi - Karanglo (with ADT more than 30,000 vehicles per day and average speed around 70 kph) has a high accident occurence rate and EAN. Another example is road segment Turen - Lumajang (also locates in highland region) with AADT 5,600 vehicles per day and average speed about 52 kph has a high R_{sc}.

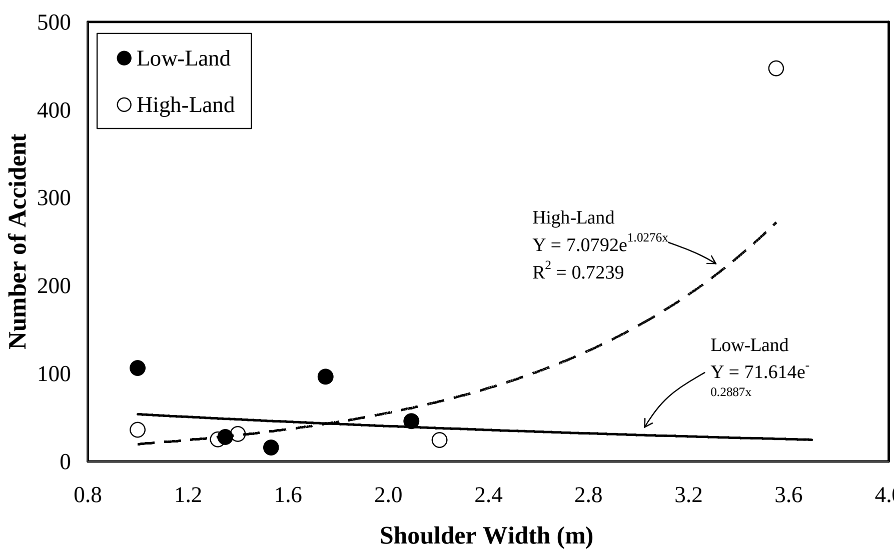

Figure 6 Relationship between accident and shoulder width

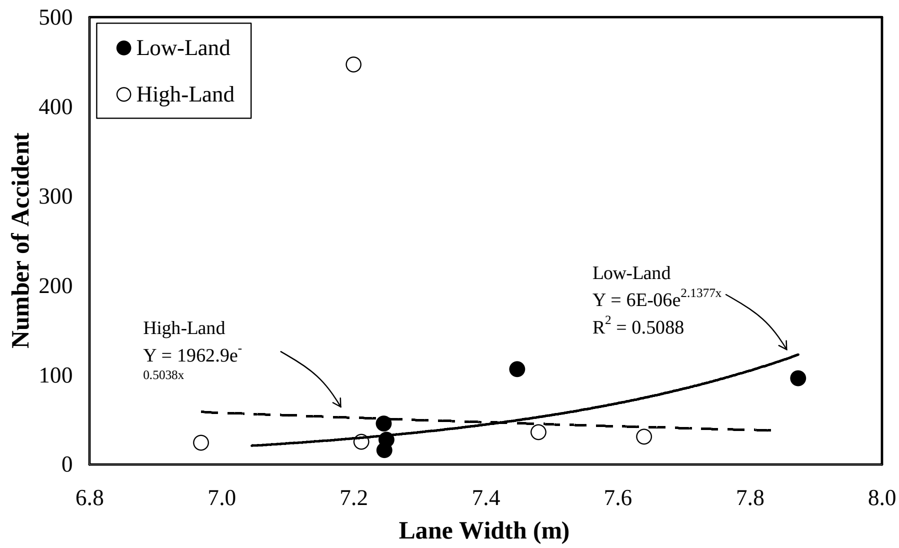

Figure 7 Relationship between accident and lane width

Figure 6 shows the relationships between shoulder width and the number of accident rates. It can be seen that in lowland region, there is a tendency that the wider the road shoulder is, the lower the accident rates will be. For highland region, the relationship between the number of the accident rates and the road shoulder showed an opposite trend. In Figure 7, a relationship between the number of accident and lane width is established. It can be revealed that road segments with wide lane width in lowland region have higher accident occurrence rate than that with narrow lane width. This is because road users tend to speed on the road with wider lane. This phenomenon does not occur on roads in highlands (as shown in the Figure 7) that the lane width only has little effect on the number of accident.

4. CONCLUSIONS

1. The number of accidents in Malang District in 2000 - 2004 decreased; however, the fatality rate was still high. The most common type of accident was the multiple vehicle accident. The type of vehicle involved in accidents is dominated by motorcycles. The most common drivers and victims of the accidents were males aged between 17 – 26 years old. The accidents generally occurred in the morning and afternoon with the number of accidents at weekdays is twice more than that of at weekends.
2. The prone-areas of traffic accident in lowland region are located at Bululawang, Dampit, Gondanglegi, Kepanjen, Pakisaji, Sumberpucung and Turen, while Lawang, Singosari and Pakis are such areas in highland region. There were more than 20 incidents of these areas during the last six years. In Malang District, there are 88 sensitive areas of accident transpired. Three road segments with the highest number of black-spots are Purwodadi – Karanglo (109 accidents at 16 black-spots), Malang – Kepanjen (60 accidents at 13 black-spots) and Kepanjen – Blitar (47 accidents at 14 black-spots). The first segment is located in highland region, while the rest two are in lowland region.
3. The analysis of the effect of traffic characteristics on the accident rates showed that in highland and lowland regions, the accident occurrence rate tends to increase as traffic volume rises. The relationship between speed and number of accidents was different in two types of topography evaluated. In highland region, the accident occurrence rate will

decrease until it reaches an optimum speed and then increases afterwards. On the other hand, in lowland region, the different speed did not affect much the number of accidents.

4. The analysis of the effect of road geometry on number of accidents in lowland region indicated that the wider the lane width and the narrower the shoulder width are, the higher the accident occurrence rate will be. An opposite trend was found on road segments in highland region.

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