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An Analysis on Traffic Accidents on Undivided Expressway in Cold and Snow Area

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Abstract: Some fatal accidents occur on two lanes expressway in cold and snow area in Japan and no rigid median strip causes more damage to passenger in cars. It is very important to find effective countermeasures that reduce the number of these tragic traffic accidents. However, general characteristics and factors of traffic accidents on undivided expressway have not been clarified sufficiently yet. We apply a discriminant analysis to traffic accidents data for five years in order to find some crucial factors for traffic accidents especially in snow cold region. Two categories, fatal or serious and slight injury, are used as a dependent variable. On the other hand, weather, road circumstance, and cruising speed are used as independent variables. We also propose some useful countermeasures to reduce the miserable traffic accidents on undivided expressway.

Key Words: *Traffic accident, Head-on collision, and Rural two lane expressway*

1. INTRODUCTION

It is March 9th, 2007, when a passenger car overran center line and had a head-on collision with a big lorry. All three passengers including two children were killed at the traffic accident. The accident site had only two lanes (two ways) and no rigid median strip, which caused fatal accidents. As ordinal expressway in Japan has four lanes or more and rigid divided median strip, no car can invade into the opposite lane and crashes. Some expressways in local area with low traffic have only two lanes without rigid divided median strips because of the cost reduction. It is very important to find effective countermeasures that reduce the number of these tragic accidents. However, general characteristics and factors of accidents on undivided expressway have not been clarified sufficiently yet. Then, in this research, we try to find some crucial factors for traffic accidents especially in snow cold region and propose some useful

countermeasures to reduce the miserable traffic accidents on undivided expressway.

The total length of undivided expressway is 1647.0 km among the total length of expressway in Japan is 7,377.9 km and the proportion is 22.3% in 2005. Figure 1 shows a section of typical undivided expressway, where simple plastic poles are used as median strips. Vehicles cannot overtake by using the opposite lane but some cars overran the center line by slipping or failure of driving.

Figure 1 Undivided Expressway

Figure 2 shows the number of traffic accidents occurred on both divided and undivided expressway in Niigata Prefecture for 5 years. The number of traffic accidents occurred at undivided sections is less than that at divided sections. However, the percentage of fatal traffic accident at undivided expressway occupies 16.9% and the proportion is much higher than 3.8% at divided expressway. Recognition of factors for traffic accidents at undivided expressway is very useful in order to reduce the number of fatal or serious traffic accidents

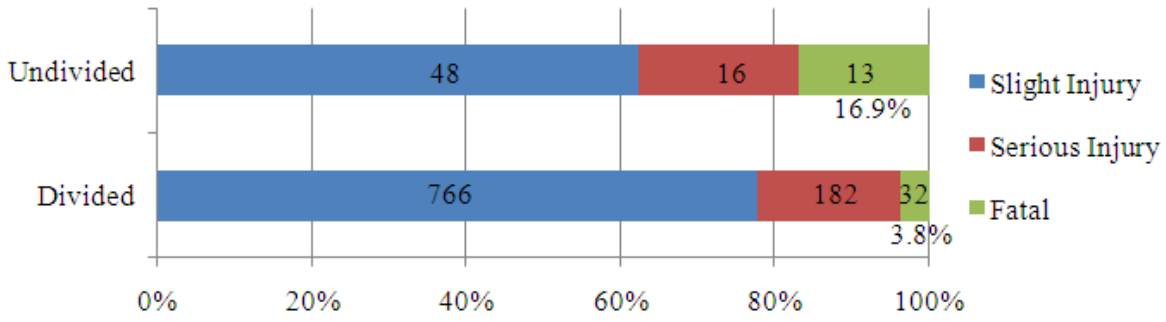

Figure 2 Number of traffic accidents on expressway in Niigata Prefecture

There are some previous researches with related to head on collision at undivided two lanes

roads. Some researches focus on human factors and others focus on road geometry and weather factors. Garder P. (2006) showed that majority of head-on crashes on two-lane at rural roads were caused by drivers making errors or misjudging situations. Hagiwara *et al.* (2005) mentioned that lack of attention of drives mainly caused accidents while slippery and rutted road surface were also important factors. Chen Zhang *et al*. (2005) showed that speed limit, SACRH (sum of absolute change rate of horizontal curvature), MAXD (maximum degree of horizontal curve), and SACRV (sum of absolute change rate of vertical curvature) significantly influenced the incidence of head-on crashes. Terrance M. RENGARASU *et al.* (2007) also identified the casual factors of head-on collisions in cold area and proposed effective countermeasures for them.

The purpose of this research is to examine the factors for traffic accidents at undivided expressway in cold and snow area. The target is similar to the research of Hagiwara et al. (2007). However, their research doesn't focus on traffic accidents on expressway but national road in Hokkaido. In fact, Vehicle behaviors on expressway are much different from that on national road because of the difference of their cruising speed. Speed limits on expressway are mainly 100km/h or 80km/h: the former is applied to one at flat area with good geometry design and the later is applied to one at mountain area. Most of speed limits on national roads are 50km/h and 60km/h is used for only high standard national roads. As one of the most important factors of traffic accidents is cruising speed, we believe that analyzing traffic data on express is very important to reduce the number of fatal traffic accidents.

2. TRAFFIC ACCIDENT

Table 1 shows statistic about traffic accidents that occurred on expressway in Japan from 2004 to 2008. The proportion of fatal accident on undivided expressway is 7.2% and it is much higher than that on divided expressway. The proportion of killed people among casualties on undivided expressway is also higher. Once a traffic accident occurs on undivided expressway, it is apt to cause serious damage. It is very important to know factors of traffic accidents on undivided expressway in order to reduce serious traffic accidents and victims

Table 1 Statistic about traffic accidents in Japan

		2004	2005	2006	2007	2008	Total
Undivided	Number of Traffic Accident [1]	235	313	287	244	222	1,301
	Number of Fatal Traffic Accident [2]	14	23	23	19	15	94
	Proportion of Fatal Accident [2]/[1]	6.0%	7.3%	8.0%	7.8%	6.8%	7.2%
	Number of casualties[3]	485	669	614	592	552	2,912
	Number of killed people [4]	19	27	29	29	29	133
	Proportion of killed people [4]/[3]	3.9%	4.0%	4.7%	4.9%	5.3%	4.6%
Divided	Number of Traffic Accident [1]	14,090	14,413	13,796	13,748	13,575	69,622
	Number of Fatal Traffic Accident [2]	313	313	267	287	257	1,437
	Proportion of Fatal Accident [2]/[1]	2.2%	2.2%	1.9%	2.1%	1.9%	2.1%
	Number of casualties[3]	23,063	23,608	22,598	22,420	21,896	113,585
	Number of killed people [4]	348	362	309	322	300	1,641
	Proportion of killed people [4]/[3]	1.5%	1.5%	1.4%	1.4%	1.4%	1.4%

2.1 Traffic Accident Data

Among traffic accidents occurred on undivided expressway, head-on collisions caused by cars passing center line directly cause serious damage. Table 2 shows the number of head-on collisions occurred on Japanese expressway from 2000 to 2004 by each expressway. Ban-etsu Expressway and Joushin-etsu Expressway dominant over others with related to the number of fatal accidents.

Table 2 Head-on collision by expressway in Japan

	Total	Fatal	Fatal/Total
Ban-etsu Expressway	30	8	26.7%
Joushin-etsu Expressway	24	9	37.5%
Shikoku-jyukan Expressway	18	1	5.6%
Toukai-Hokuriku Expressway	15	3	20.0%
Shikoku-oudan Expressway	14	1	7.1%
Akita Expressway	11	2	18.2%
Yamagata Expressway	11	2	18.2%
Yonago Expressway	9	2	22.2%
Others	4	2	50.0%
Total	136	30	22.1%

Table 3 shows the length of each expressway in Niigata prefecture. As Niigata prefecture has five expressways including Ban-etsu and Joushin-etsu Expressway, we focus on traffic accidents occurred in Niigata prefecture. As Niigata prefecture is located to north of Japan, it has much snow in winter. The number of traffic accidents occurred on expressways in Niigata from 2002 to 2006 is 1,130 in total. 985 accidents occurred on divided expressway, the number of accidents that occurred on undivided express way is 77, and the number of accidents that occurred at other locations such as ramps or interchanges is 68. In this research, we ignore the last accidents and only focus on accidents on divided or undivided expressway. In addition, we

use the disaggregate database that has date, day of the week, time, the number of deceased and injured, weather, location information with geometric structures, the number of lanes, cruising speed, type of violation of traffic regulation, and personal attributes such as age, sex, and drive experience.

Table 3 Expressway in Niigata prefecture

Expressway	Length(km)
Hokuriku Expressway	193.8
Kan-etsu Expressway	93.6
Ban-etsu Expressway	46.5
Joushin-etsu Expressway	36.9
Nihonkai-tohoku Expressway	34.0
Total	404.8

2.2 Accidents Analysis

In this section, we use 1,130 traffic accidents data occurred in Niigata prefecture from 2002 to 2006

Figure 3 shows the proportion of traffic accidents by road surface conditions such as Dry, Wet, Snow and Frozen. It is easy to see that the proportion of fatal traffic accidents is highest in frozen road surface conditions on un-divided road. This mean frozen road surface on un-divided expressway is apt to cause many fatal traffic accidents. The reason is that the drivers are very difficult to control their cars on frozen road surface during the winter in snow regions.

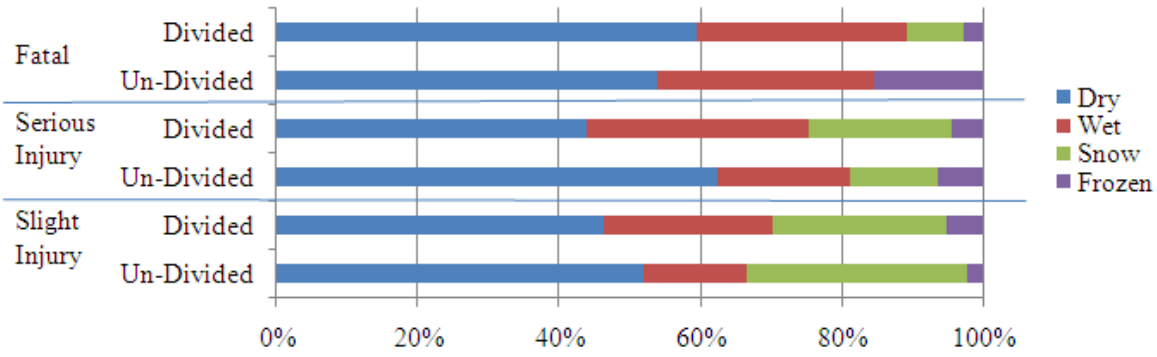

Figure 3 Traffic accidents by road surface conditions

Figure 4 illustrates the proportion of traffic accidents by weather conditions. It is straightforward to see that many fatal accidents on un-divided expressway occur in sunny days. The reason is that they can drive faster in good weather conditions. However, they often cannot respond appropriately with the high speed when the fatal accidents happen suddenly.

On the other hand, they cannot drive faster in bad weather conditions and they often sustain slight injury relatively.

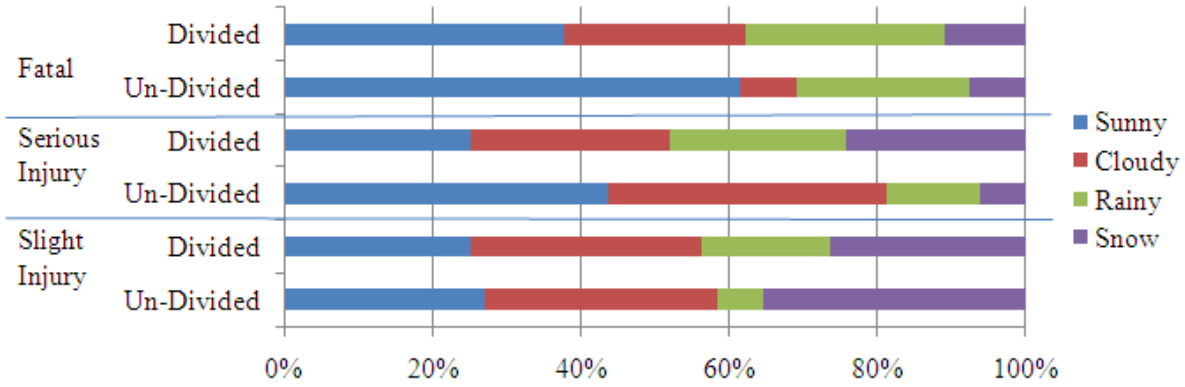

Figure 4 Traffic accidents by weather conditions

The proportion of traffic accidents by geometry factors are shown in Figure 5. From the following figure, the differences between divided and undivided sections are not significant with related to geometry factors. Slight injured more fluently occurs at straight or large radius sections compared with fatal or serious injury.

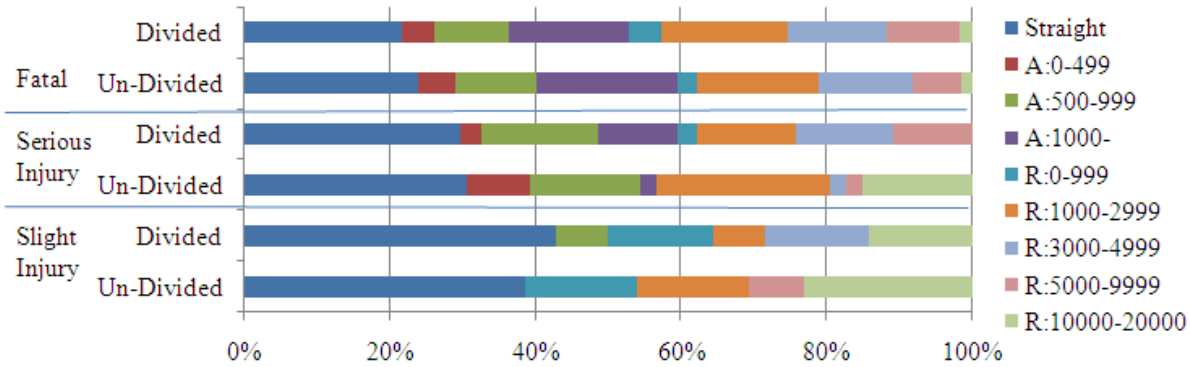

Figure 5 Traffic accidents by geometry factors

Figure 6 indicates the proportion of traffic accidents by gradients. Many fatal traffic accidents occur at un-divided sections with longitudinal gradient.

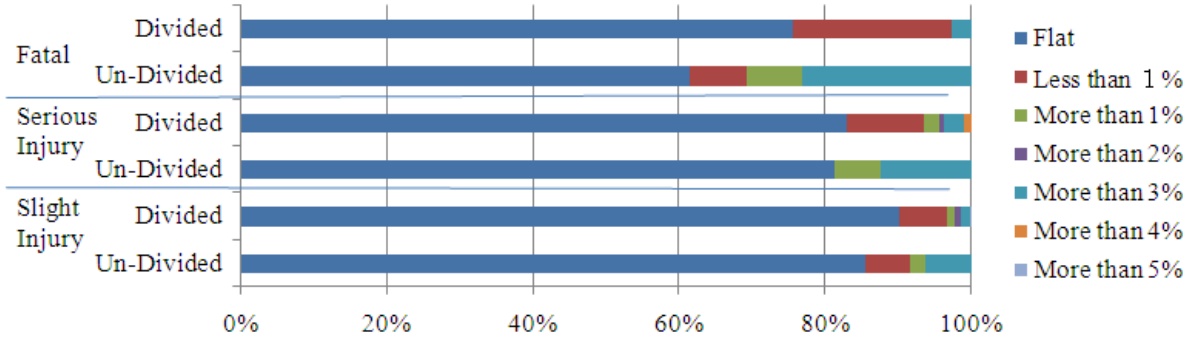

Figure 6 Traffic accidents by gradients

The traffic accidents by factors are summarized in Table 4. The factors that belong to the road surface conditions include Dry, Wet, Snow and Frozen. The factors that belong to the Weather conditions include Sunny, Cloudy, Rainy and Snow. The percentages of traffic accidents by these factors are expressed in the following table.

Table 4 Traffic accidents by factors

		Slight Injury		Serious Injury		Fatal	
		Un-Divided	Divided	Un-Divided	Divided	Un-Divided	Divided
Road Surface	Dry	52.1%	46.3%	62.5%	43.9%	53.8%	59.5%
	Wet	14.6%	23.9%	18.8%	31.6%	30.8%	29.7%
	Snow	31.3%	24.6%	12.5%	20.3%	0.0%	8.1%
	Frozen	2.1%	5.1%	6.3%	4.3%	15.4%	2.7%
	Total	100%	100%	100%	100%	100%	100%
Weather	Sunny	27.1%	25.1%	43.8%	25.1%	61.5%	37.8%
	Cloudy	31.3%	31.1%	37.5%	26.7%	7.7%	24.3%
	Rainy	6.3%	17.3%	12.5%	23.5%	23.1%	27.0%
	Snow	35.4%	26.4%	6.3%	24.1%	7.7%	10.8%
	Total	100%	100%	100%	99%	100%	100%
Velocity[km/h]		65.8	72.9	82.9	87.5	81.9	94.9
Number of Accidents		48	940	16	187	13	37

3. ACCIDENT ANALYSIS

In this chapter, we use 1,130 traffic accidents data occurred in Niigata prefecture from 2002 to 2006

3.1 Discriminant Analysis

In this section, we apply a discriminant analysis method to this traffic accidents data and find important factors causing fatal or serious accidents. Discriminant analysis is a technique for classifying a set of observations into predefined classes. It also clarifies the factors affecting to

classifying. In Japan, traffic accidents are generally categorized into three groups such as fatal, serious injury and slight injury. In this research, we combine fatal and serious injury and apply discriminant analysis to these two groups: 1) fatal or serious injury and 2) slight injury. We assume the linear discriminant function and adopt some factors related with road surface conditions, weather, vehicle speed, geometry factors, and accident types. Road Surface (Wet) and Surface (Frozen) are dummy variables compared with dry surface. Cloudy, Rainy, and Snow are also dummy variables compared with Sunny. Left Curve and Right Curve are dummy variables compared with straight road sections. Table 5 shows the estimation results of the discriminant analysis method.

Table 5 Estimation results of the models

Variables	Parameters
Road Surface (Wet) [0,1]	-0.48
Road Surface (Frozen)[0,1]	-0.98
Cloudy [0,1]	2.64
Rainy [0,1]	0.54
Snow [0,1]	3.45
Velocity [km/h]	-0.05
Gradient [%]	-0.75
Left Curve [0,1]	2.37
Right Curve [0,1]	1.77
Head on Collision [0,1]	-2.64
Constant	2.12
F-Value	5.02
Hit-Ratio	83.3%

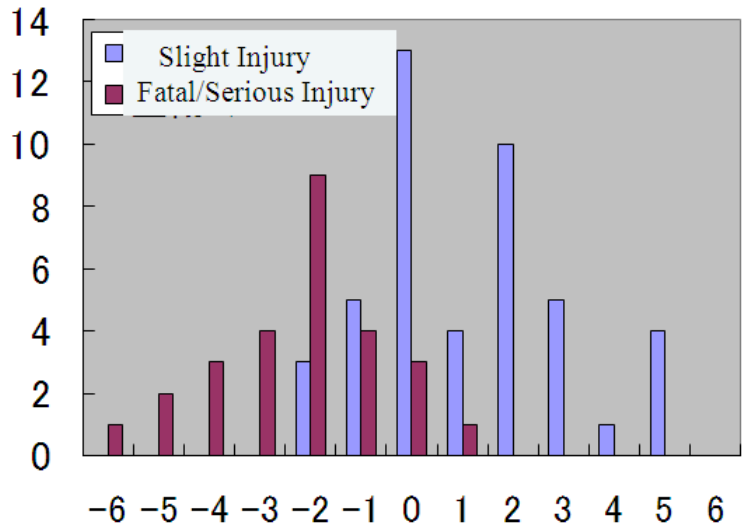

Figure 7 Distribution of Discriminant Score

Furthermore, the distributions of discriminant score of each sample are illustrated in Figure 7. The scores of samples belonging to serious injury should be higher.

Frozen surface is the most dangerous and wet surface is the second from the view points of fatal or serious traffic accidents. Cars slipped on frozen or wet road causes fatal or serious traffic accidents. Snow prevents fatal or serious traffic accidents because drivers cannot drive with high speed and concentrate on their own driving. Higher speed and steeper slope cause more serious damage to drivers. Right curve sections are more dangerous than Left curve sections, though it is often said that driving at right curve sections are easier than left one in countries with left-hand traffic. Drives may reduce speed prevent them from invading opposite lane and it may cause less fatal or serious traffic accidents. We have to admit that this discriminant analysis is not good enough because some variables have correlations with speed of vehicles. We will get more sample data and clear the contribution of each variable.

3.2 Head-on Collision Accidents Analysis at Un-divided Expressway

In the previous section, some factors causing serious traffic accidents were clarified. In this section, we focus on head-on collision which is one of the factors causing serious traffic accidents.

Figure 8 shows the proportion of head-on collisions at undivided express way. It is straightforward to see that the proportion of fatal and serious traffic accidents in Head on collision is higher than that of others. This means that Head-on collisions cause fatal or serious traffic accidents.

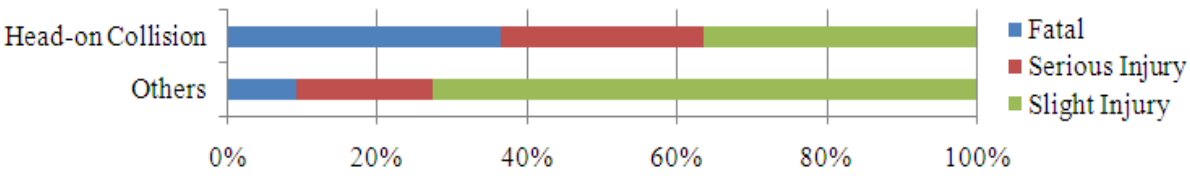

Figure 8 Head-on collision at undivided expressway

Figure 9 illustrates the proportion of traffic accidents by road surface conditions at undivided express way. Dry and wet road surface causes fatal traffic accidents.

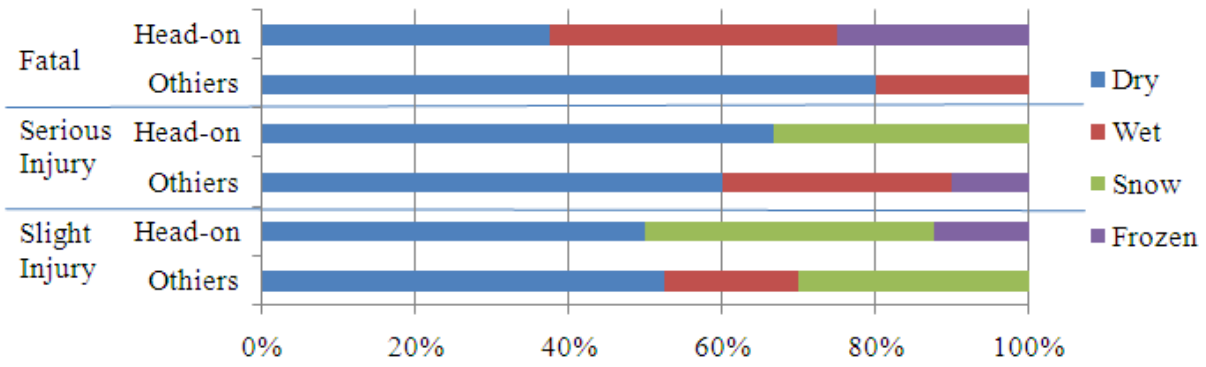

Figure 9 Traffic accidents by road surface conditions

The proportions of traffic accidents by weather conditions at undivided express way are shown in the Figure 10. From the figure, the proportions of fatal and serious traffic accidents in Head on collision are larger in sunny days. In contrast, these proportions are small in bad weather conditions such as snow and cloudy days.

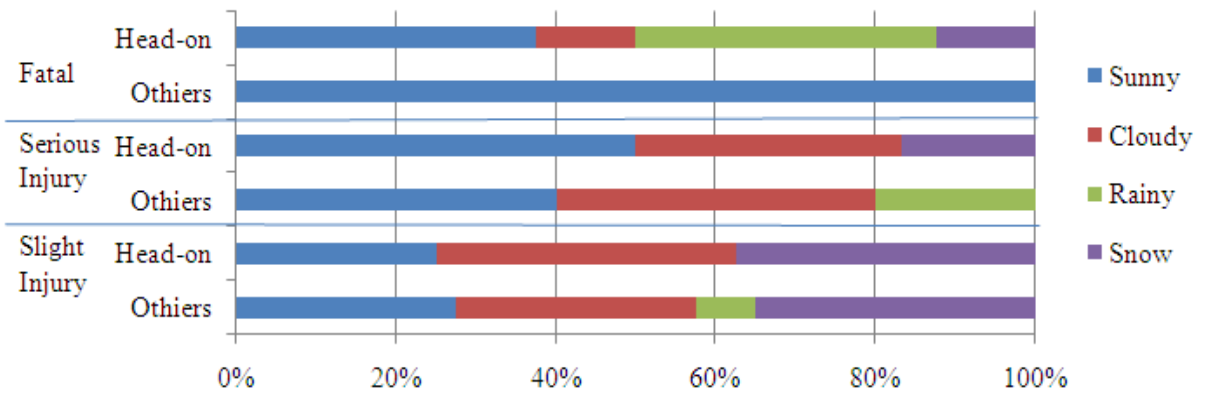

Figure 10 Traffic accidents by weather conditions

Figure 11 shows the proportion of traffic accidents by geometric factors at undivided expressway. Fatal head-on collisions happen at curve sections.

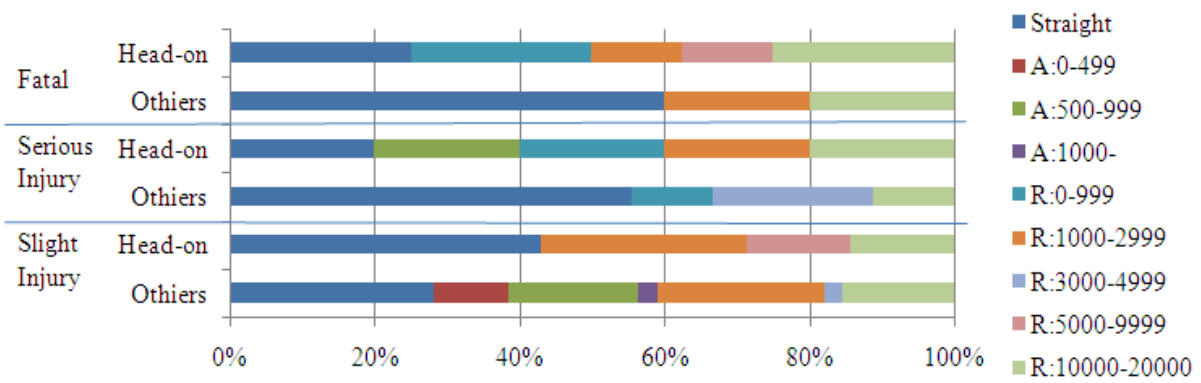

Figure 11 Traffic accidents by geometry factors

Figure 12 shows the proportion of traffic accidents by gradients at undivided expressway. Fatal head-on collisions do not happen at flat sections.

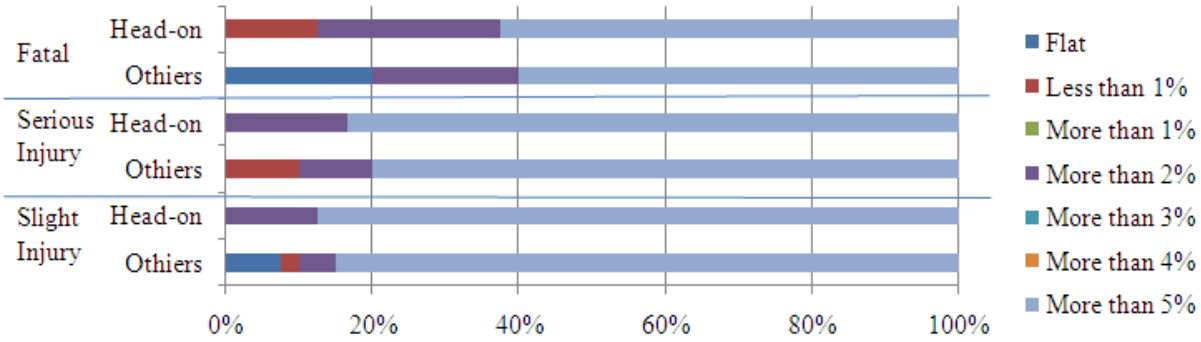

Figure 12 Traffic accidents by gradients

Table 6 indicates the total road length and the total number of head-on accidents by geometric factors on undivided expressway. Revised proportion of accidents has been circulated considering the traffic volume on each section. We could not find the fact that small radius (R) or parameters of clothoid curve (A) caused head-on accidents. Among 6 accidents occurring at mid-large radius section sections, 4 accidents occurred at the same site with 500m length. We should focus on this section and obtain specific factors there.

Table 6 Total road length and number of accidents by geometric factors

Road Type	Section Length	Proportion of Length	Number of Accidents	Proportion of Accidents	Revised Proportion of Accidents
Straight Section	196,688	24.7%	7	26.9%	29.2%
A: 0-500	33,164	4.2%	1	3.8%	4.2%
A: 500-1,000	101,212	12.7%	1	3.8%	4.2%
A: 1,000-	100,236	12.6%	0	0.0%	0.0%
R: 0-1,000	44,891	5.6%	2	7.7%	7.0%
R: 1,000-3,000	149,849	18.8%	5	19.2%	20.5%
R: 3,000-5,000	89,628	11.2%	2	7.7%	9.3%
R: 5,000-10,00	65,744	8.2%	2	7.7%	6.9%
R: 10,000-20,000	16,413	2.1%	6	23.1%	18.9%
Total	797,825	100.0%	26	100.0%	100.0%

Revised Proportion = Proportion of Accidents*traffic volume by type/average traffic volume

The proportions of road length and head-on accidents on undivided expressway are illustrated in Figure 13. The accident ratio is lower at A500-1000 and A1000- sections and higher at R10,000-20,000.

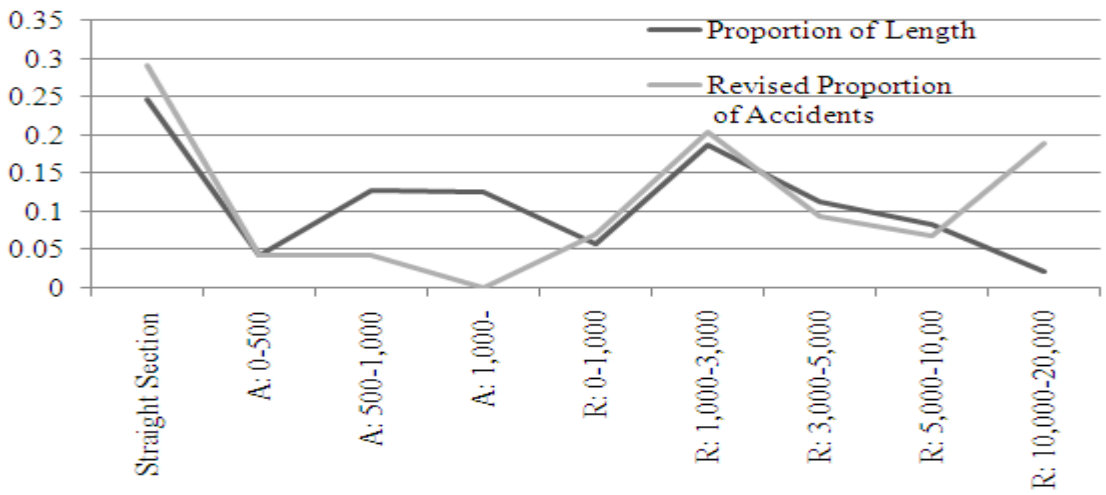

Figure 13 Proportion of road length and head-on accidents on undivided expressway

4. COUNTERMEASURES

We propose some countermeasures for both short and long term period to prevent traffic accidents at undivided expressway. Considering the facts that frozen surface and over speed cause many fatal or serious traffic accidents, we propose comparatively short term countermeasures as follows:

1) Utilization of the pavement which it is difficult to freeze,
2) Quick transmission of road surface information to the driver
3) Marking for the speed control.

However, these methods are not drastic countermeasures to reduce fatal or serious traffic accidents on undivided expressway. As a long term countermeasures, only rigid median strip could protect fatal accidents. However, it is very difficult to construct rigid median strips at the existing road section. Though the standard road section has 10.5 meter width (Figure 14), road section of the most of the expressway in snow area has 12.0 meter for snow accumulation space (Figure 15). We can set rigid median strips and a large-size car can pass the other in case of some accidents.

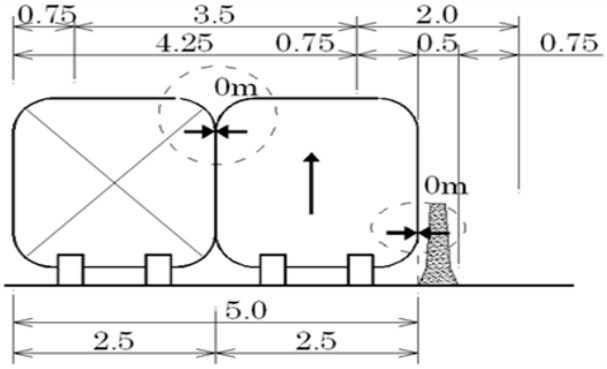

Figure 14 Standard road section

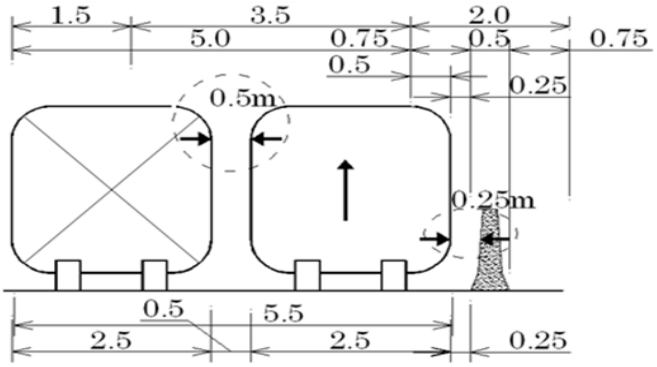

Figure 15 Road section in snow area

5. CONCLUSION

This research has found some crucial factors for traffic accidents on undivided expressway in cold and snow regions. Furthermore, to find the important factors causing fatal and serious accidents, the discriminant analysis method is applied to analyzing the traffic accidents data for five years. The more specific conclusions of this study are expressed as follows:

- Wet or Frozen road surface, good weather conditions, high speed, steep slope, and head on collision cause serious traffic accidents.
- We find that many fatal or serious traffic accidents are apt to occur at both right and left curve sections. However, we cannot find that head-on collision accidents including fatal and serious injury are apt to occur at curve sections.
- Some useful countermeasures are proposed to reduce the miserable traffic accidents on undivided expressway.

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