Traffic Accidents in Winter related to some Weather and road Conditions

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Abstract

This daper deals with accidents occurring in winter related to weather and rord conditions. In recent years, the snow removal of highways in Hokkaido has become increasingly extensive, as a result, road traffic in winter has become as heavy as that in summer and the characteristics thereof are similar to that in summer. An increasing trend of winter accidens and a rise in rate of incidence is seen and a comparison was run between those of summer accidents.

With special reference to the above, 7,000 accidents on national highways and 206 accidents on expressways in Hokkaido were analyzed by means of relative risk and relative skidding risk.

The findings from the analysis are as follows:

1. Accidents in winter were affected largely by snow fall and ice formation and snow covered road surfaces.
2. There are certain road conditions, certain types of accidents and certain vehicle types which have higher relative risk for traffic accidents.
3. Slipperiness of road surface such as ice and snow coverd road surfaces have a strong bearing on traffic accidents.
4. Driving experience and driving skill showed a significantly high influence on traffic accidents.

1. Preface

In Hokkaido since the oil shortage, traffic accidents have shown a considerable decrease, for example, the number of traffic accidents in 1974 decreased by 29.9% of the total accidents, 33.7% for fatalities and injuries as compared with those in 1973. Fig. 1 shows the trend of traffic accidents and Fig. 2 shows motor vehicle registration in Hokkaido. Table 1 shows the present situation of traffic accidents in Hokkaido from April 1974 to March 1975.

In this Table, the accidents from November to March are defined as accidents in winter, 38.8% of the yearly total accidents occurred in winter and the distinct feature of accidents in Hokkaido is that it is largely related to ice and snow.

Hence this paper deals with accidents in winter related to some weather and road conditions.

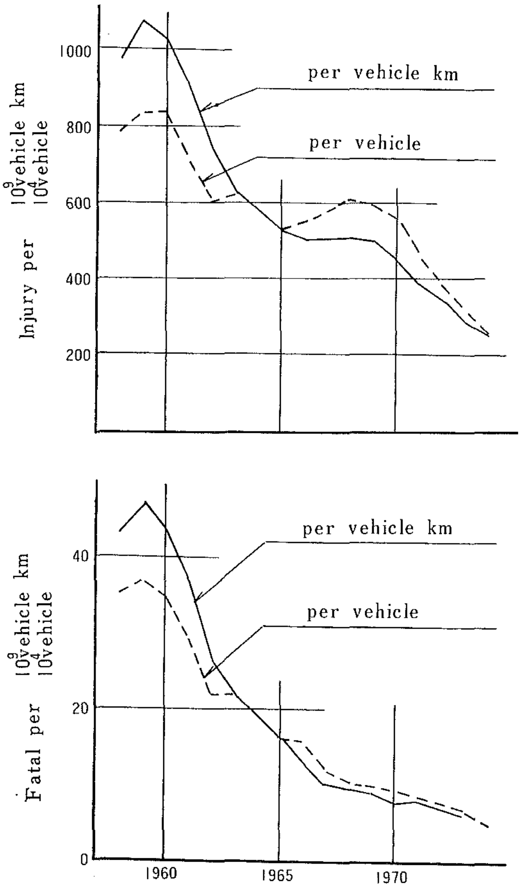

Fig. 1 Accibent trend in Hokkido

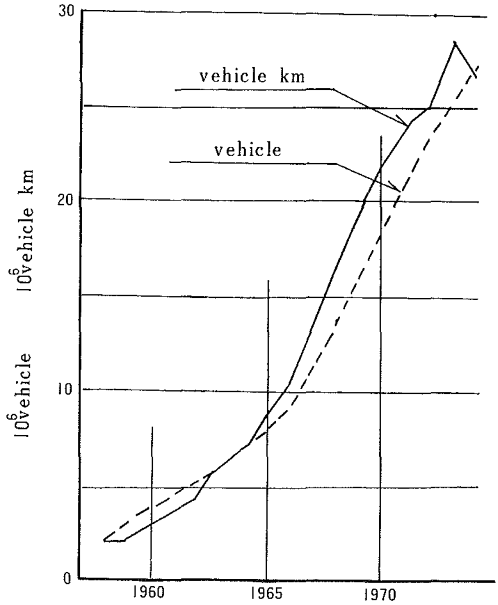

Fig. 2 Vehicle resistration and vehicle kilometer

Table 1 Present situation of traffic accidcnts in Hokkado

	Number	Injury	Fatalities
Apr. 1974 to Mar. 1975 (A)	16,468	24,422	464
Nov. 1974 to Mar. 1975 (B)	6,336	9.941	146
B/A	38.6%	40.7%	31.5%

2. The situation of road traffic in winter

In recent years, because snow removal from the road surface has extensively increased, the traffic volume does not diminish in winter. Under such conditions, the situation of the road traffic in winter are as follows:

2.1 Traffic volume

Fig. 3 and Fig. 4 show the ration of traffic in winter and summer. Fig. 3 is for urban areas and Fig. 4 is for rural areas. The ratio of traffic volume from winter ranges from about 50% to abont 90% and is on an average 69% for urban areas and 67% on an average for rural areas.

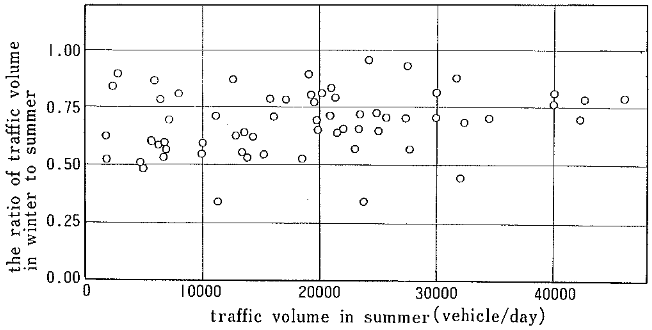

Fig. 3 The ratio of traffic volume in winter to summer (rural

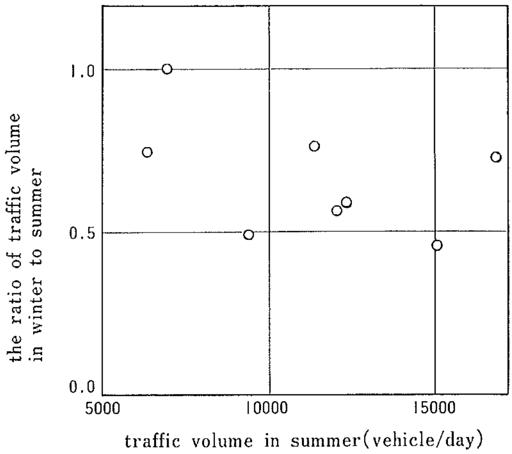

Fig. 4 The ratio of traffic volume in winter to summer (urban)

2.2 Speed

Fig. 5, Fig. 6 and Fig. 7 show the distribution of speed of traffic in winter as compared with that in summer. Fig. 5 is for urban areas, Fig. 6 is for rural areas and Fig. 7 is for the expressway from Sapporo to Chitose. Ther were hardly any difierences in speed between winter and summer althogh roadway conditions differed greatly from winter to summer. Table 2 shows that passing-through-speed at intersections in winters decreased considerably because of the slipperiness of the road surfaces and lowering of the road capacity in addition

Table 2 Passing through speed at intersections (km/hr)

season direction	summer			winter		
	S to N	E to W	W to E	S to E	E to W	W to E
P. C.	28.4	27.0	22.7	20.0	19.4	19.4
delivery	26.6	25.2	24.1	17.4	19.7	18.3
commereial	–	24.9	22.5	–	19.2	16.2
bus	27.2	23.8	24.7	16.8	18.2	17.6

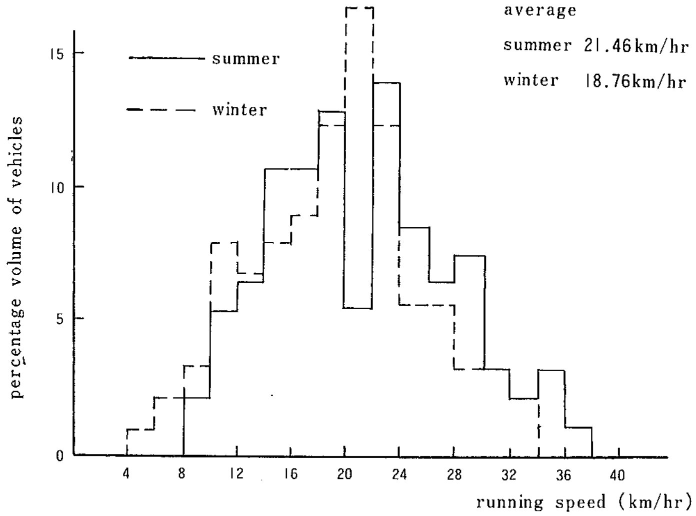

Fig. 5 Distribution of velocity of traffic (urban)

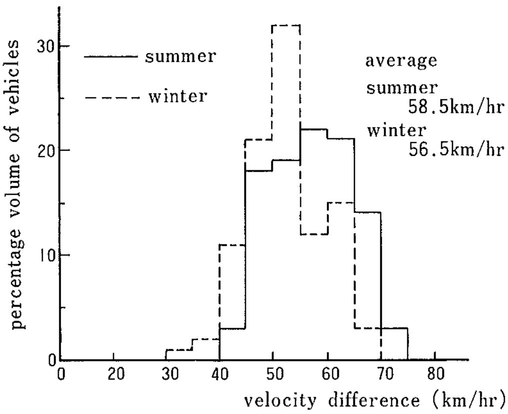

Fig. 6 Distribution of velocity of traffic (rural)

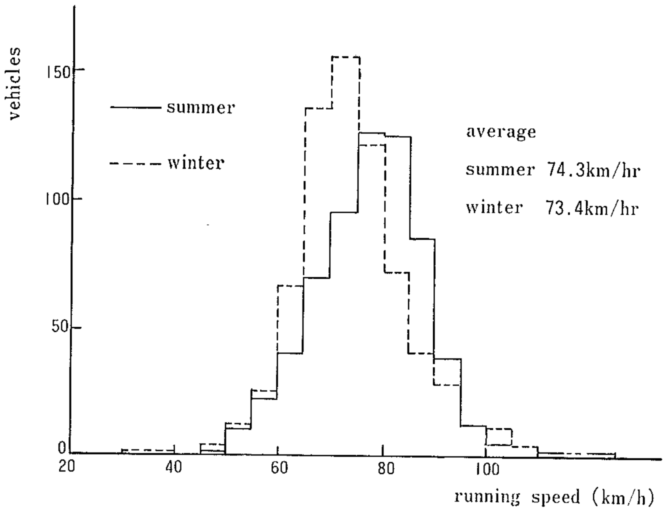

Fig. 7 Distribution of velocity of traffic (expressway)

to the snow banks and narrowed roadway.

2.3 Headway

Fig. 8 shows the relation bctween the speed difference of the vehicles and headway expressed by time for urban areas. Fig. 9 shows the distribution of headway for the expressway. In this case it is interesting to note that hardly no difference in the distribution of the headway is seen.

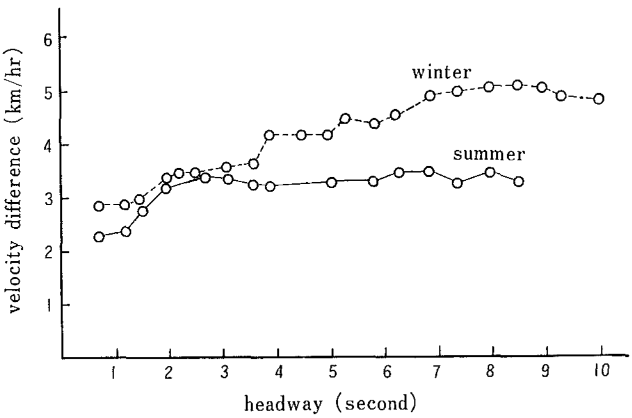

Fig. 8 Velocity difference of headway (rural)

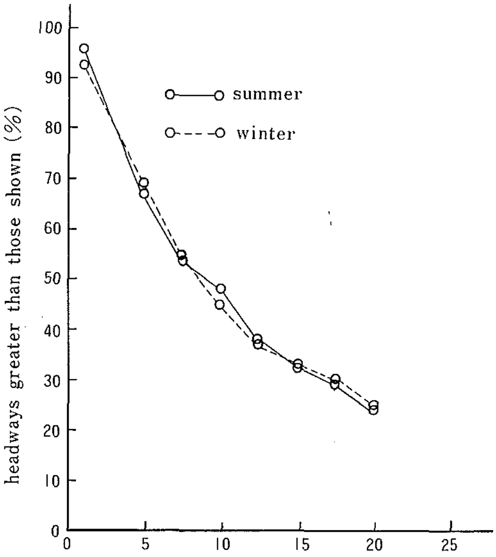

Fig. 9 Distribution of headway (expressway)

2.4 Acceleration and deceleration at atgrade intersections

Table 3 shows the acceleration and the deceleration at atgrade intersections in urban areas when the vehicles start and stop at stop lines. The decrease of these valnes in winter indicates the slipperiness of ice and snow covered road surfaces which causes much delay in the traffic flow in urban areas.

Table 3 Acceleration and deceleration at intersection (m/sec^2)

vehicle type	acceleration		deceleration	
	summer	winter	summer	winter
P. C.	1.38	0.94	1.64	1.26
delivery	1.32	1.01	1.95	1.17
commercial	1.12	0.81	1.52	1.16
bus	0.96	0.77	1.31	1.02

3. Traffic accidents in winter

The number of accidents decreased in winter but the accident rate exqressed by vehicle kilometers was higher than that in the summer months as shown in Fig. 10. The rate of accidents during the winter season to summer season has been increasing gradually year by as shown in Fig. 11 and Fig. 12 although the total yearly accidents show a decreasing trend. The traffic accidents in winter season are largely related to weather conditions and skidding on snow and ice

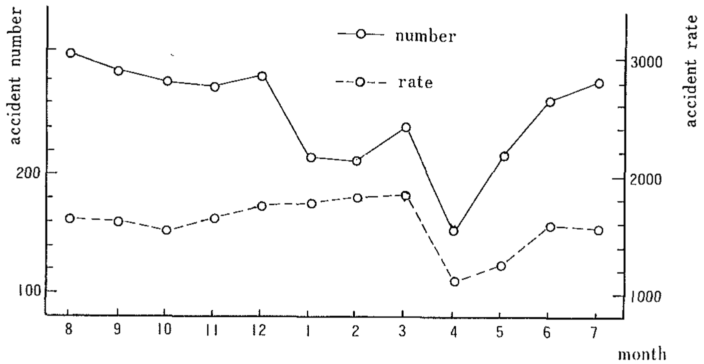

Fig. 10 Variation of accident rate by month in 1970

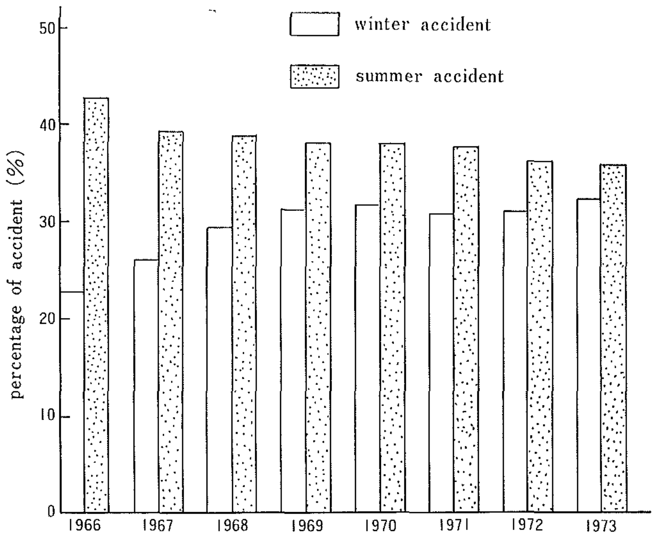

Fig. 11 Trend of acɔident in winter and summer

coverd road surfaces. An analysis was made by comparison with the relative risk and the relative skidding risk.

The results obtained were as follows:

3.1 Accidents vs weather and certain road conditions

The present research was made on approximately 4,000 accidents in winter and 3,000 accidents in summer which occurred on the national highways in Hokkaido and the data were grouped under three weather conditions and rord surface is as shown in Table 4. Table 5 shows the relation between the relative risks

Table 4 Accident number analyzed

season	summer	winter		
road surface	dry	dry	wet	ice & snow
weather				
fine and cloudy	3,027 (4,556)	1,212 (1,719)	426 (573)	1,516 (2,275)
rain	–	–	330 (484)	–
snowfall	–	–	–	621 (1,008)
total	3,027 (4,556)	1,212 (1,719)	756 (1,057)	2,137 (3,283)

Note: ( ) Nnumber of injuries

Table 5 Relative risk and the type of accident

season	summer	winter				
weather	fine & cloudy		fine & cloudy		snow	rain
road surface	dry	dry	wet	ice & snow	ice & snow	wet
type of accident						
pedestrian	1.00	1.15*	1.38*	0.90	0.83	1.24*
collision between vehicles	1.00	0.97	0.91	1.10*	1.11*	0.93
single vehicle	1.00	0.82	0.60	0.41	0.58	0.90
casuality rate	1.51	1.42	1.35	1.50	1.62	1.47

Note: * higher relative risk

Table 6 Relative risk and the site of accident

season	summer	winter				
weather	fine & cloudy		fine & cloudy		snow	rain
road sorface	dry	dry	wet	ice & snow	ice & snow	wet
site of accident						
at and near intersection	1.00	0.92	0.94	0.88	0.55	1.00
at and near pedest. cross.	1.00	2.33*	2.04*	1.00	1.25*	2.42*
grade section bend & curve	1.00	0.67	1.51*	2.47	2.80*	1.07*
tangential section	1.00	1.04*	0.95	0.97	1.22*	0.93

Note: * higher relative risk

Table 7 Relative risk and the form of accident

season	summer	winter				
weather	fine & cloudy	fine & cloudy			snow	rain
road surface	dry	dry	wet	ice & snow	ice & snow	wet
form of accident						
head on collision	1.00	1.20*	1.20*	2.25*	3.02	1.20*
rear end collision	1.00	1.14*	1.20*	1.17*	1.09	1.17*
turnings	1.00	0.81	0.83	0.45	0.37	0.76
light collision	1.00	0.73	0.57	0.64	0.74	0.95
others	1.00	0.78	0.55	0.68	0.53	0.56

Note: * higher relative risk

related to the type of accident and casuality rates which were a combination of weather and road conditions. The relative risks related to the place of accidents are shown in Fig. 6. Table 7 shows the relative risks related to the form of accidents between vehicles occurring on various road surfaces. From Table 5, it may be seen that higher relative risks existed on dry and wet road surfaces in winter between pedestrians and vehicles and ice and snow covered road surfaces for collision between vehicles. The relative risks on ice and snow covered road surfaces for single vehicle accidents were low due to the snow banks piled up on both sides of the road which exerts its presence by preventing overtuning or run off of vehicles. Casuality rate per accidents on ice and snow coverd road surfaces after new snowfalls showed the highest value. Table 6 shows that the relative risks for places other than intersections were higher, especially on gradients, bends or curves. It is clear that these locations are the most important sections for highway and road safety and road maintenance.

3.2 Skidding accidents on ice and snow covered road surfaces

The present work was conduched on 2,000 accidents which occurred on ice and snow covered road surfaces and these data were classified into skidding accidents and non skidding accidents regadless of wheather skidding was included when

Table 8 Relative skidding risk and the site of accident

site of accident	urban	rural
at intersection	0.94	0.75
on pedestrian crossing	1.19*	0.82
near pedestrian crossing	1.29*	0.82
on isolated pedestrian crossing	0.64	2.50*
near isolated pedestrian crossing	0.95	1.76*
railway crossing	–	1.26*
in tunnel	–	3.26*
graded section	1.99*	2.27*
curved section and corner	2.60*	2.26*
other	0.82	1.11*

Note: * higher relativeskidding risk

Table 9 Relative skidding risk and the type of vehicle

type of vehicle	urban	rural
bus	1.55*	1.12*
micro bus	2.55*	1.92*
P. C.	0.91	0.91
light vehicle**	0.86	1.89*
specific heavy truck	2.47*	0.96
heavy truck	0.90	0.89
light truck	1.04*	1.08*
light truck**	0.80	1.08*
motor cycle	0.81	0.60

Note: * higher relative skidding risk
** engine capacity less than 360 cc

Table 10 Relative skidding risk and the form of accident

form of accident	urban	rural
head on collision during passing	0.65	0.48
other head on collision	3.28*	1.72*
rear end collision	1.36*	0.74
collision upon meeting	0.54	1.23*
side collision at right turn	0.29	0.18
side collision at left turn	2.02*	2.42*
light collision during passing	0.97	0.39
light collision between passing vehicles	2.85*	1.23*
others	0.56	2.46*

Note: * higher relative skidding risk

Table 11 Relative skidding risk and driving experience

driving experience year	alignment of road		type of vehicle	
	curve & grade	straight & level	P. C.	truck
1	1.40*	1.19*	1.34*	1.11*
2	1.02*	0.83	0.81	1.05*
3	1.02*	1.24*	0.95	1.52*
4	0.94	0.87	0.85	1.00
5	0.95	0.94	0.94	0.96
6	0.95	0.76	1.04*	0.59
7	1.05*	1.13*	1.36*	0.92
8	0.59	0.79	0.69	0.60
9	0.96	1.03*	1.25*	1.01*
10 over	0.84	1.01*	0.98*	0.91

Note: * higher relative skidding risk

accidents occurred or when both types are involved as compare with relative skidding risks. The average was 22.7%. The results are shown in Table 8 to 11. Table 8 shows relative skidding risks related to the site of accidents, Table 9 shows relative risks related to the type of vehicles and regions, Table 10 indicates the relative skidding risks related to the form of accidents and Table 11 expresses the relative skidding risks related to the driving experience of drivers, road features and type of vehicles. Table 8 shows that higher relative skidding risks existed at or near pedestrian crossings at intersections in urban areas; at pedestrian crossings far from intersections in rural areas; on gradients, bends and curves in both urban and rural areas. Although the highest value existed in tunnels and railroad crossings, these values were less significant due to lack of data. Table 9 shows that the relative skidding risks were higher for buses and trucks in rural areas.

In Table 10 the results showed clearly distinct features in the form of accidents in winter, namely, head on collision, side collision at left turns, and light collision during passing were distinct. This result points out that the undivided tow lane road are highly dangerous from a point of view of traffic safety in winter and complex driving manouevers such as sudden stops, passing etc are connected directly with serious traffic accidents.

4. Summary

The summary is as follows:

(1) The characteristics of traffic flow in winter did not differ so much with those in summer except for a few special features.

(2) The accidents in winter were affected largely by weather and slippery road surface conditions as may be expected.

(3) The geometric design of highway considerably affected the accidents in winter related to the ice and snow covered road surfaces.

(4) The site of accident, the type of accident, the form of accident, the type of vehicle and driver which had higher relative risks and relative skidding risks existed.

5. Winter accidents on Expressways

The expressways in Hokkaido are the Sasson Expressway which runs from Sapporo to Otaru (24.4 km) and Do-o Expressway which runs from Sapporo to Chitose (23.3 3km) opened in December 1971. Table 12 shows the standard of geometric design of these expressways. An accident analysis was made on 468 injury and property damage accidents occuring from December 1971 to August 1974 on these two expressways. Table 13 shows the accidents as analyzed.

Table 12 Design standard of Expressway

route	Sasson*	Do-o
design speed	80 km/hr	120 km/hr
lane width	3.5 m	3.5 m
median width	3.0 m	4.5 m
minimum radius of curve	450 m	2,700 m
maximum grade	3%	2%
speed limit in summer	60 km/hr	100 km/hr
speed limit in winter	60 km/hr	80 km/hr

Note: * two lane operation

Table 13 Accident analyzed

route	Sasson	Do-o
casualty accident number	85	50
casualty number (fatal)	159(1)	110(4)
propety damage accident number	181	152
acciddent total	256	202
vehicle kilometer $\times 10^8$	2.178	1.802
accident rate	39.03	27.75
casualty rate	73.00	61.04

5.1 Monthly variation of accidents

Fig. 12 shows the monthly variation of accident rate per vehicle km. The winter accident rate from November to March were higher than other months. The average accident rate was 122.1 for Sasson Expressway and 112.1 for the Do-o Expressway. For injury accidents, the rate for Sasson Expressway was 39.0 and Do-o Expressway was 27.8. The rate for the former was higher by 40% than the latter. This reflects the difference in the standard of geometric design an two lane operation until October 1973 from opening of the Sasson Expressway.

5.2 Accident vs weather and certain road surface conditions

Fig. 13 shows the distributien of accidents vs. weather and road surface condi-

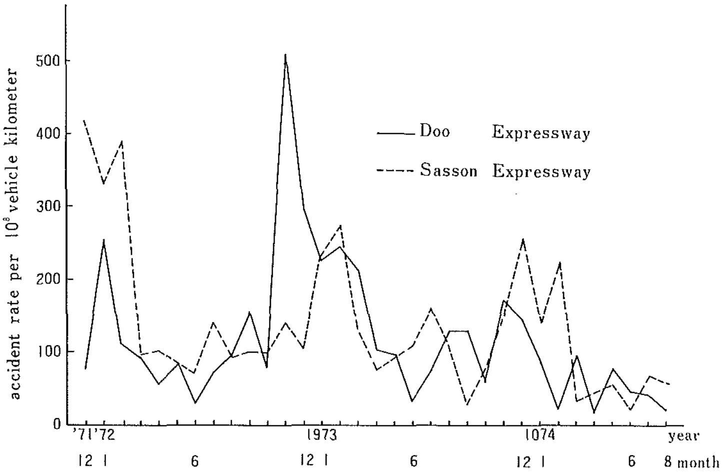

Fig. 12 Monthly variation of accident

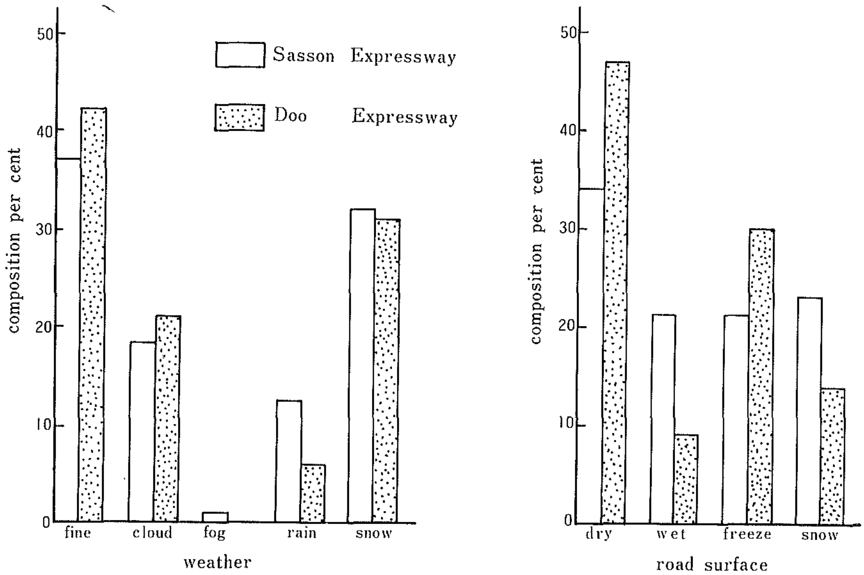

Fig. 13 Distribution of accident vs. weather and road surface condition

tions. For Sasson Expressway, 70% of the total injury accident occurred during snowfall from December to March. 84% of the total injury accidents for Sasson Expressway and 72% for Do-o Expressway occurred on ice and snow covered road surfaces. From these results it was obvious that snowfall and slippery road surface largely affect traffic safety.

5.3 Site of accidents

Table 14 snows the difference between the site of accidents. There were no accidents in service areas and parking areas on both expressways but in Sasson Expressway. a large number of accidents occurred in the tagential section, especially on ice and snow covered road surfaces.

Table 14 The site of accident

route	Sasson Expressway		Do-o Expressway	
road surface	dry	ice & snow	dry	ice & snow
through lane	110(88.7%)	109(93.2%)	52(75.5%)	71(78.9%)
interchange	14(11.3%)	8 (6.8%)	17(24.6%)	19(21.1%)
tangent level	90(72.6%)	79(67.5%)	56(81.2%)	73(81.1%)
tangent grad	6 (4.8%)	7 (6.0%)	1 (1.4%)	1 (1.1%)
curve level	20(16.1%)	20(17.1%)	4 (5.8%)	5 (5.6%)
curve grade	8 (6.5%)	11 (9.4%)	8(11.6%)	11(12.2%)
total	124 (100%)	117 (100%)	69 (100%)	90 (100%)

5.4 The type of accident

The type of accidents can be divided into four groups according to road surface conditions which are snow in Table 15. For Sasson Expressway on ice and snow covered road surfaces, the accidents between vehicles occurred mostly through lanes. On the other hand, single vehicle accidents occurred in about half of all accidents on dry road surfaces. It is assumed that the reason for the above is due to two lane operation. For Do-o Expressway, single vehicle accidents occurred mostly but the accidents between vehicles showed a trend to increase on both dry and snow covered road surfaces.

Table 15 The type of aeeident

route	Sasson Expressway		Do-o Expressway	
road surface	dry	ice & snow	dry	ice & snow
between vehicles thr. lane	46(37.1%)	91(77.8%)	10(14.5%)	21(23.9%)
between vehicles interchange	13(10.5%)	6 (5.1%)	10(14.5%)	14(15.8%)
single vehicle	61(49.2%)	20(17.1%)	45(65.2%)	51(58.0%)
peculiar accident	4 (3.2%)	–	4 (5.8%)	2 (2.3%)
total	124 (100%)	117 (100%)	69 (100%)	88 (100%)

5.5 The form of accident

To analyze the difference mentioned above, a comparison was made by comparing

Table 16 The form of accident between vehicles

route	Sasson Expressway		Do-o Expressway	
road surface	dry	ice & snow	dry	ice & snow
hed on collision	2 (4.3%)	24(26.4%)	–	1 (4.8%)
light collision with oncoming vehicle	6(13.0%)	12(13.2%)	1(10.0%)	2 (9.5%)
rear end collision	25(54.3%)	40(44.0%)	7(70.0%)	12(57.1%)
light collision when marging and diverging	1 (2.2%)	1 (1.1%)	–	–
light collision during passing	7(15.2%)	2 (2.2%)	1(10.0%)	1 (4.8%)
rear end collision to the parked vehicle	–	7 (7.7%)	–	4(19.0%)
others	5(10.9%)	5 (5.5%)	1(10.0%)	1 (4.8%)
total	46 (100%)	91 (100%)	10 (100%)	21 (100%)

Table 17 The form of accident of single vehicle

route	Sasson Expressway		Do-o Expressway	
road surface	dry	ice & snow	dry	ice & snow
overturning and run off	11(18.0%)	4(20.0%)	5(11.3%)	6(11.7%)
collision to the median	1 (1.6%)	-	21(47.7%)	22(43.1%)
collision to the side fence	26(42.6%)	8(40.0%)	15(34.1%)	18(35.3%)
collision to the toll island	2 (3.3%)	2(10.0%)	1 (2.3%)	2 (3.9%)
collision to the structures	17(27.9%)	3(15.0%)	2 (4.5%)	1 (2.0%)
others	4 (6.6%)	3(15.0%)	-	2 (3.9%)
total	61 (100%)	20 (100%)	44 (100%)	51 (100%)

the form at accidents. The results are shown in Table 16 and Table 17. The most frequent accident was rear end collision in accidents between vehicles, but for Sasson Expressway, an increase of head on collisions on ice and snow covered road surfaces is outstanding. In the case of single vehicle accidents, collision with the median showed the highest rate in Do-o Expressway, for Sasson Expressway collision with the side rail showed the highest rate.

5.6 Factors affecting winter accident

Next, the Factors affecting winter accidents was studied. The winter factors were divided into four groupes: (1) bad visual field (2) slipping on the slippery road surface (3) collision with snow removal vehicles (4) wheel ruts on snow covered road suface and improper steering techniques. The results are shown in Table 18. From this Table, the rate of accident affecting winter factors were 57% for Sasson Expressway and 88% for the Do-o Expressway. The highest rate was the slipperiness and the second was the decrease in visibility. Some injury accidents due to the above factors are shown in Table 19.

5.7 Summary

The summary is as follows:

a. The accident rate in winter was higher than those in summer.

b. The accident occurence rate was four fold during snowfall and two fold on ice and snow covered road surfaces as compared with the rate of incidence on national highways.

c. Accidents occurring on through lanes and accidents between vehicles

Table 18 Winter factors affecting winter accidents

winter factor	Sasson Expressway	Do-o Expressway
1	19(16.4%)	14(15.6%)
2	41(35.3%)	42(46.7%)
3	3 (2.6%)	-
4	3 (2.6%)	14(15.6%)
none	50(43.1%)	20(22.2%)
total	116 (100%)	90 (100%)

Table 19 Some winter accidents affected by winter factors

winter factor	weather	road surface	site of accident	form of accident	accident circumstances
1	snow	frozen	level tangent	rear end collision	The vehicles which did not run at suitable speeds and driving manner in response to snow storms collided the preceeding vehicle which had slowed down according to the bad weather conditions.
1	snow	snowed	level tangent	rear end collision	The vehicle which did not slow down in snow storm collided with stationary vehicle on through lane.
2	fine	frozen	level curved	head on collision	The slipping vehicle which applied brakes without any consideration to others on a frozen road surface collided with vehicle stationary on thro-ugh lane.
2	snow	snowed	exit ramp	rear end collision	The skidding vehicle which applied sudden brake to slow down during passing collided with the preceeding vehicle.
3	snow	snowed	tangent graded	rear end collision	The vehicle colliding the preceeding vehicle which suddenly stopped to avoid hitting plows of snow removal vehicle.
4	snow	snowed	level tangent	collision with median	The skidding vehicle due to the wheel pass collided with median.
4	snow	snowed	tangent graded	deviation	Vehicle which lost steering cnotrol due to the slippery road surface during passing diviated to the cutting slope.

showed an increasing trend but a decrease for single accidents was also noted.

6. Conclusion

From the analysis mentioned above, the traffic feature in winter does not differ from that in summer although the road surface becomes extremly slippery and the visual field is in a very bad state. As a result, the traffic accident in winter shows an increasing trand.

Countermeasures to decrease traffic accident in winter from the research results are as follows:

(1) The most perfect measure for traffic safety and highway maintenance in winter, is to ensure bare pavement maintenance. But as a practical problem, the application of de-iceing chemicals or the installation of electric road heating at dangerous slippery road sections covered with snow and ice, in particular, during the period when driver has not became accustomed to winter driving on slippery road surfaces or at the beginning of snow falls in early winter.

(2) An information system should be established to communicate weather or road surface conditions to the driver, especially on the expressway. The arterial highway in the snowy district should be designed and constructed with a median to divide the traffic directions.

(3) In driver education, the techniques to drive on the slippery road surface should be taught by driving schools.

The research aims which should follow the present work must include (1) precise analysis in winter traffic flow and traffic accident, (2) skidding resistance between tire and ice and snow coved road surfaces, especially at high speed (3) geometric design of highway considerring with ice and snow covered road surfaces.

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