Assessment of Fatality Rate using Distance between Accident Site and the Life-Saving Emergency Center, in Hokkaido, Japan

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Abstract: In the study, we focused on trends of a fatality rate for traffic accidents in Hokkaido, Japan. The fatality rate is defined as percentage of the number of fatal accidents to total of the number of fatal and serious accidents. The study examines an effect of distance between accident site and location of the Life-Saving Emergency Center on the fatality rate. We determined the shortest route and its distance according to a distance of each route measured by Google Maps route search function. There were 20,390 accident records from 1989 to 2009 occurred at all national roads in Hokkaido. The study could indicate that Emergency Medical Services in Hokkaido are becoming important components to reduce the fatality rate.

Keywords: Traffic Accident, Fatality Rate, Hokkaido, EMS, CHAID

1. INTRODUCTION

The number of road deaths in Japan has decreased simply as the period is updated from of the 1990's. In 1992, the number of road deaths in Japan, recorded by the police within 24 hours of an accident occurring, was 11,451. In 2011, number of road deaths was 4,612. As shown in the latest International Traffic Safety Data and Analysis Group (ITARDA) report, the number of road deaths per 100,000 motor vehicles in Japan is the fifth-smallest number among the countries for which data are available in 2006, and number of road deaths per 100,000 people is the seventh-smallest number among those countries. Hagita *et al.* (2010) described that the comprehensive nationwide traffic safety program was shown to be highly effective in reducing traffic fatalities. In addition, Hagiwara *et al.* (2010) indicated that traffic safety activity in Japan coordinated between many kinds of organization related to traffic safety had successful results. However, the number of road deaths in Japan showed a slowdown in the downward trend of recent years. Additional in-depth accident analysis is required to identify trends in the number of fatalities and the cases of traffic accident.

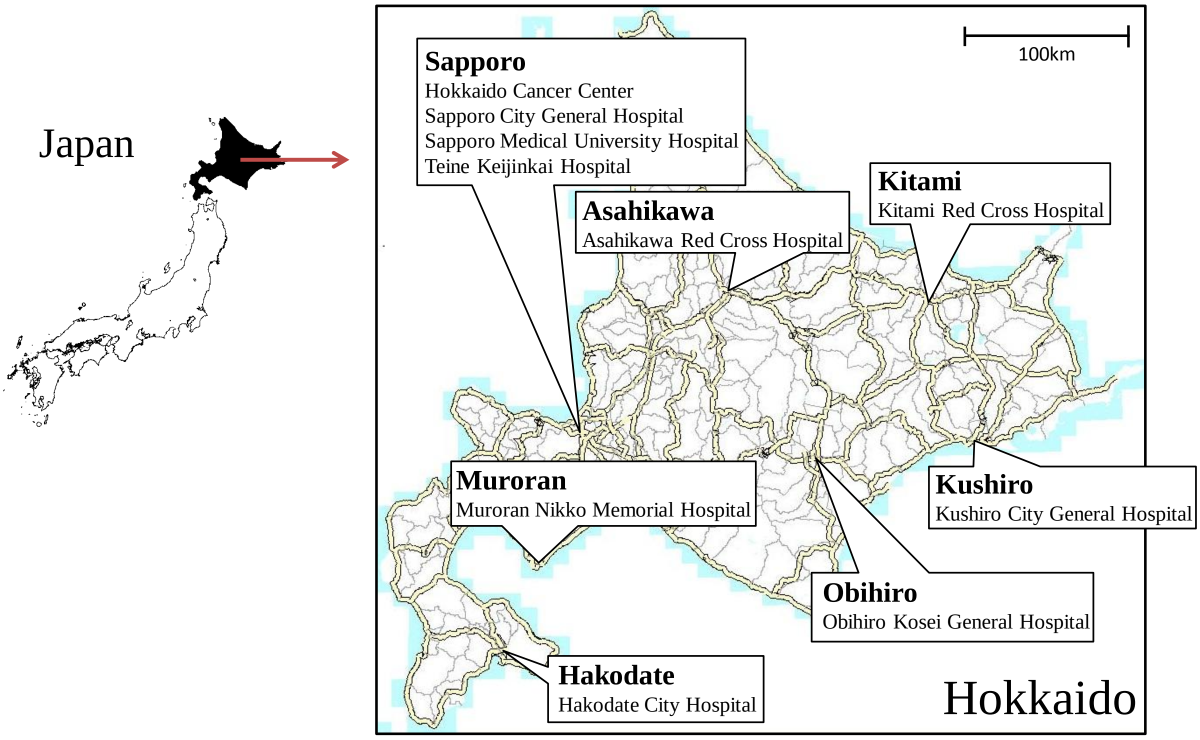

Figure 1. Map of Hokkaido and location of Life-Saving Emergency Center

In the study, we focused on trends of a fatality rate for traffic accidents occurred in Hokkaido, where is northern part of Japan shown in Figure 1. The fatality rate is defined as percentage of the number of fatal accidents to total of the number of fatal accidents and the number of serious accidents reported by the Hokkaido Prefectural Police. The fatality rate is 12.0% in Hokkaido in 2009. It is high compared with 8.5% fatality rate at the same year in Japan. Emergency medical services (hereinafter called “EMS”) are important components in the effort to reduce fatalities and serious injuries suffered in motor vehicle crashes (Nagata et al., 2011). In the past, we investigated the effect of area of Engineering, Education and Enforcement on reducing the number of road deaths mainly (Rengarasu *et al*., 2009; Rengarasu *et al*., 2010; Hirasawa *et al*., 2003; Hirasawa *et al*., 2006). However, there are a few papers to investigate how EMS affects changes of the fatality rate in Hokkaido (Hashimoto *et al*., 2002; Fujimoto *et al*., 2012; Munehiro *et al*., 2011).

It is a first step towards a better understanding of the contributions of EMS to reducing the injury severity outcome of motor vehicle crashes. Then, this study measured distances between accident site and location of the Life-Saving Emergency Center (hereinafter called “Distance2EMC”). It should be noted that this study did not determine time of EMS response, because the accident record contained only where traffic accidents occurred was available, and there were no available data regarding to show travel time or actual route to EMS from accident site, and no available data linked with hospital records regarding road traffic injured people. Distance2EMC could show accessibility to EMS and also hazard potential of accident site that is occurred further away from seven central cities in Hokkaido prefecture in Figure 1. These accidents are potentially more severe due to higher speed, poor road alignments, many hazard road facilities like tunnels and bridges, low traffic volume, weak cellular signal strength along roadways and so on. Distance2EMC can provide information contribute to planning EMS systems, and location of new trauma centers in future. Thus, the objective of this study is to investigate an effect of accident characteristics including Distance2EMC on the fatality rate used decision tree analysis and to understand the influence of accident site on the fatality rate in Hokkaido prefecture.

2. DATA AND METHODOLOGY

2.1 Fatal and Serious Injury Accidents Occurred at All National Roads in Hokkaido

Fatal and serious injury accidents occurred at all national roads in Hokkaido for the 21 years from 1989 were collected from the Traffic Accident Analysis System developed by Civil Engineering Research Institute for Cold Region. Figure 2 shows the number of fatal and serious injury accidents occurred at all national roads in Hokkaido from 1989 until 2009. In 1990, the number of fatal accidents was 270, which is the largest among these 21 years, and the serious injury accident was 920, and the fatality rate is 22.7%. The number of fatal accidents occurred at all national roads has decreased simply as the period is updated from of the 1990's. In 2009, the number of fatal accidents was 87, however the fatality rate was 18.3%. The change of the fatality rate occurred at all national roads in Hokkaido during 21 years was not so large compared with reduction of number of fatal accidents.

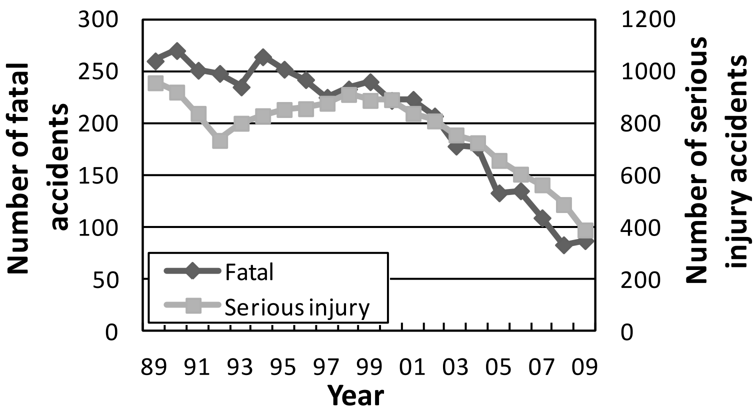

Figure 2. Number of fatal and serious injury accidents in Hokkaido

2.2 Accident Characteristics for Each Recorded Accident Record and Distance2EMC

During the study period, there are 20,454 records combined with fatal and serious injury accidents. The explanatory variables considered for decision tress are illustrated in Table 1. Hazard recognition speed is available as data pertaining to vehicle speed in case of crash. This is the traveling speed at which the driver recognizes a hazard, and is determined by police officers owing to information given by witnesses or from analysis of skid marks. Shimamura, M. et al (2005) performed the analysis of the correlation between hazard recognition speed and impact velocity, in case of crash and it revealed that the impact velocity was approximately 0.84 of the hazard recognition speed. In addition, the Distance2EMC is calculated using accident site data (kilo-post) recorded on the accident database. We used “Get directions” in Google Maps to determine the route from an accident site to EMC, and to measure a Distance2EMC. In the search field, click “Get directions”, then right-click on the map to input an accident site and to input location of EMC. Directions appear on the Google maps as a purple line. If there are multiple results, the minimum distance route going through expressways, national roads and major prefectural roads is selected by manually. We repeated the same process to find the minimum distance route to EMC from each accident site by manually. There were 20,454 accident records in the database, however, accident site of road traffic accident were recorded in 20,390. Thus, we lost 64 accident records for the following analysis.

Table 1. Accident characteristics

Variables	Categories
Accident severity	Fatal accident *1, Serious injury*2 and Light injury*3
Day /Night	Day *4 and Night
National route number	National route number in Hokkaido
Kiro-post	Accident site on the national route
Location	Urban, Suburban and Rural
Road Surface conditions	Dry, Wet, Icy, Snowy and Unpaved
Type of accident	Pedestrian-car, Car-to-car and Single car
Road type	Intersection, Near the intersection Tunnel, Bridge, Curve and Straight
Hazard recognition speed	This is the traveling speed at which the driver recognizes a hazard, and is determined by police officers owing to information given by witnesses or from analysis of skid marks.

Note:
*1: Die as a result of a traffic accident within 24 hours of its occurrence.
*2: An injury resulting from a traffic accident and requiring medical treatment for a month(30 days) or more.
*3: An injury resulting from a traffic accident and requiring medical treatment for less than a month (30 days).
*4: Day is the period of time from sunrise to sunset.

2.3 Life-Saving Emergency Center in Hokkaido

Emergency facilities in Japan are classified into three levels based on resources, administration, staff and education (Tanigawa and Tanaka, 2006). Primary emergency facilities provide care for walk-in patients, secondary emergency facilities provide in-hospital care for acute illnesses and trauma, and tertiary emergency facilities, called ‘‘Life-Saving Emergency Centers,’’ provide total care for critically ill and severely traumatized patients. Life-Saving Emergency Centers are also responsible for the education of medical personnel, including ambulance crews. There is approximately one regional primary and secondary emergency facility for every 50,000 residents, and at least one Life-Saving Emergency Center for each population of more than 1 million. As of December 2005, there are 189 Life-Saving Emergency Centers throughout Japan. In Hokkaido, seven cities shown in Figure 1 have the ten Life-Saving Emergency Centers (Hokkaido Health Care Planning, Hokkaido Emergency Medical Information System). Also, Table 2 shows period when each Life-Saving Emergency established. However, the Life-Saving Emergency Center in Muroran was closed in November 2007.

Table 2. Seven cities and ten Life-Saving Emergency center

City	Life-Saving Emergency Center	Establishe date	Closing date
Hakodate	Hakodate City Hospital	1981/4/1	
Sapporo	National Hospital Organization Hokkaido Cancer Center	1983/3/1	
	Sapporo City General Hospital	1993/4/1	
	Sapporo Medical University Hospital	2002/4/1	
	Teine Keijinkai Hospital	2005/3/25	
Muroran	Muroran Nikko Memorial Hospital	2005/2/1	2007/11/30
Asahikawa	Asahikawa Red Cross Hospital	1978/7/10	
Kitami	Kitami Red Cross Hospital	1992/4/1	
Obihiro	Obihiro Kosei General Hospital	1999/5/6	
Kushiro	Kushiro City General Hospital	1984/4/1	

2.4 CHAID Analysis

In this study a decision tree was used to determine the influence of accident characteristics including Distance2EMC shown in Table 1 on the fatality rate. Decision trees have been used in previous studies related to traffic accident analysis (Kanoshima, 1999). Richter et al. (2000) used them to isolate the predictive factors of whiplash-type neck distortion in restrained car drivers. Sohn and Shin (2001) used decision trees in pattern recognition for traffic accident severity in South Korea. Among the several widely used decision tree algorithms, the chi-square automatic interaction detection (CHAID) algorithm was selected for the study. The CHAID analysis can be used for finding the most persuasive explanatory variable among number of explanatory variables against the independent variable. The explanatory variable having the strongest association with the independent variable becomes the first branch. The CHAID analysis seeks to predict the impact of each explanatory variable on the independent variable. The process is repeated to find the explanatory variable on each leaf most significantly related to the independent variable, until no significant explanatory variables remain. The CHAID algorithm uses chi-square statistics to identify optimal split points. First, the most significant explanatory variable is selected with a chi-square independence test. Next, on the basis of chi-square statistics, optimal points are calculated. A database including the entire explanatory variable is divided into sub-databases along the optimal points. This ends one loop in the CHAID algorithm. In the next loop the same process is carried out, now in each of the sub-databases created in the previous loop. Decision tree growth is stopped when there is no significant difference in chi-square statistics. The nodes at the bottom of the decision tree are called leaf nodes. The number of categories in the categorical variable is equal to the number of leaf nodes in the corresponding tree. The fatality rate is represented by the average of the target variable (dependent variable) in the respective leaf node. The data mining software package IBM SPSS Modeler 15.0 was used to develop the CHAID decision trees.

3. RESULTS

3.1 Overall Fatality Rate According to Distance2EMC during 21 Years

Figure 3 shows the change of overall fatality rates as a function of ten-km Distance2EMC categories during 21 years from 1989 to 2009. Total number of 20,390 Distance2EMCs was classified into 10 ten-km categories. In Figure 3, the horizontal axis shows the ten-km Distance2EMC categories, and the vertical axis shows the averaged fatality rate per each ten-km Distance2EMC category. Average fatality rate in the ten-km Distance2EMC category from 0-10km is 12.7%. Afterward, average fatality rate is over 20% per each ten-km category. In case of the ten-km Distance2EMC category from 70-80km is 25.8%, which is the largest average fatality rate among that of 10 ten-km Distance2EMC categories.

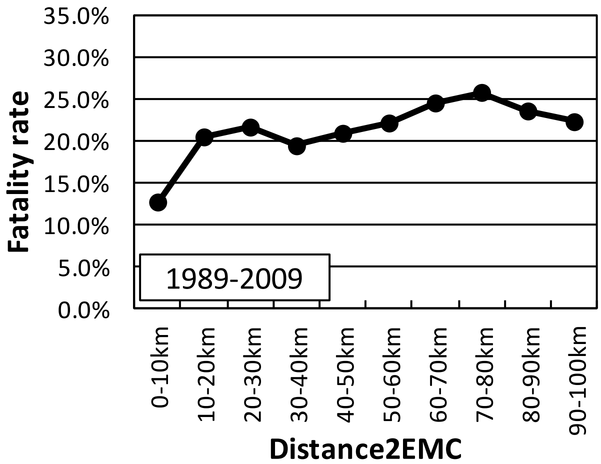

Figure 3. Fatality rate as a function of Distance2EMC from 1989 to 2009

Figure 4 shows the decision tree using Distance2EMC as a response variable. Four Distance2EMC categories, which are 0-5.1km, 5.1-10.8km, 10.8-59.0km and over 59.0km, were found to be significance at a chi-square level of 5%. Average fatality rate in the each Distance2EMC category is 11.2%, 14.8%, 20.9% and 24.8% respectively. Average fatality rate decreased as distance assigned to each Distance2EMC category decreased.

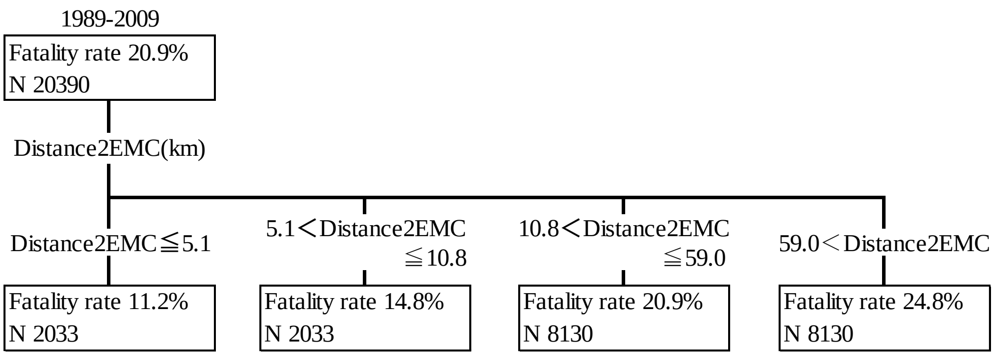

Figure 4. Decision tree to show an effect of Distance2EMS on the fatality rate

3.2 Change of the Fatality Rate per Each 5 Year Period According to Distance2EMC

Figure 5 clearly shows changes of trends of the fatality rate per 5-year period as a function of ten-km Distance2EMC categories in Hokkaido. Average fatality rates of the ten-km Distance2EMC categories less than 40km decreased as the 5-year period is updated. In 0-10km Distance2EMC category, average fatality rate is 16.8% in 1990-1994, and it reduced to 9.6% in 2005-2009. In 30-40km Distance2EMC category, average fatality rate in 2005-2009 reduced to less than 15.0%. However, average fatality rates of the ten-km Distance2EMC categories, which distance is over 40km, did not show decreasing trend as the 5-year period is updated. The average fatality rate kept over 20.0% with these ten-km Distance2EMC categories. Especially, average fatality rate of these long distance ten-km Distance2EMC categories in 2005-2009 still was over 20.0%.

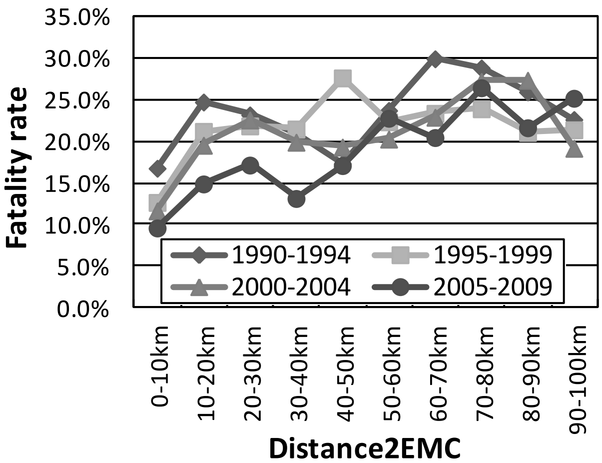

Figure 5. Fatality rate per 5-year period as a function of Distance2EMC

Figure 6 shows the decision tree using Distance2EMC as a response variable as a function of 5-year period in Hokkaido. There are a total of four 5-year periods, and each 5-year period had four Distance2EMC subgroups. In 1990-1994, four Distance2EMC subgroups, which are classified by 0-14.3 km, 14.3-28.2 km, 28.2-54.4 km and over 54.4 km, were found to be significance at a chi-square level of 5%. Average fatality rate in the each subgroup is 18.2%, 24.9%, 20.1% and 26.8% respectively. In 2005-2009, four Distance2EMC subgroups, which are classified by 0-3.7 km, 3.7-11.9 km, 11.9-47.6 km and over 47.6 km, were found to be significance at a chi-square level of 5%. Average fatality rate in the each subgroup is 5.9%, 11.7%, 20.9% and 25.4% respectively. Average fatality rate decreased as the distance assigned to each Distance2EMC subgroup decreased.

The shortest Distance2EMC subgroup is ranged from 0 to 14.3km in 1990-1994, 0 to 5.8km in 1995-1999, 0 to 4.6km in 2000-2004 and 0 to 3.7km in 2005-2009. As the period is updated, distance of the shortest Distance2EMC subgroup becomes short, and average fatality rate decreased. Also, distance of the second shortest Distance2EMC subgroup decreased as the period is updated except from 1995-1999. Distance of the second shortest Distance2EMC category in 2005-2009 is ranged from 3.7 to 11.9km, which is longer than that of the shortest Distance2EMC subgroup in 1990-1994. In addition, average fatality rate decreased as the period is updated. On the other hand, distances of the longest Distance2EMC subgroup did not change largely as the period is updated, and average fatality rates of these Distance2EMC subgroups did not change and kept large values over 25.0%.

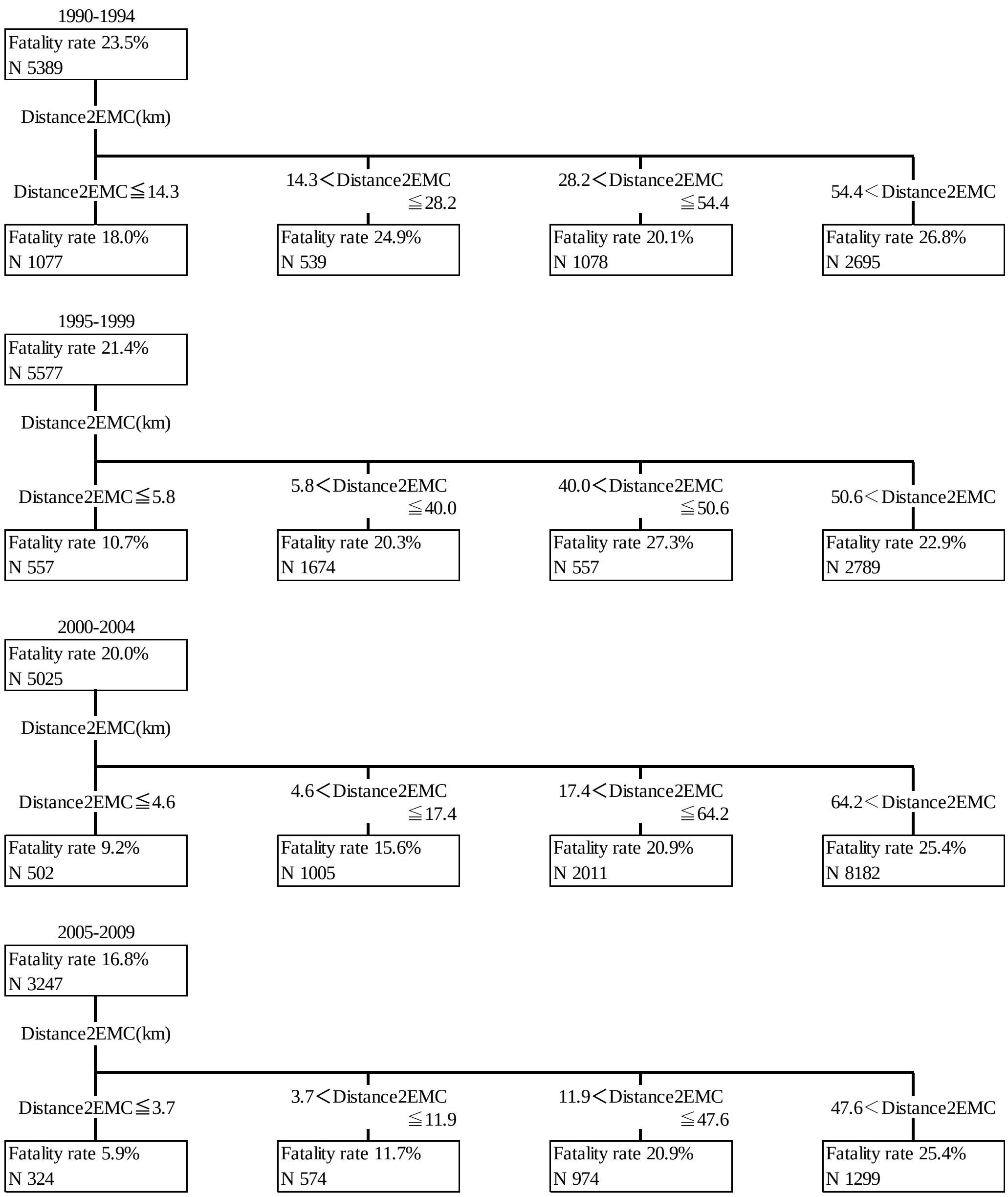

Figure 6. Decision tree using Distance2EMC as a function of 5-year period

3.3 Decision Trees per Using Accident Variables and Distance2EMC

A set of CHIAD analysis was run using fatality rate as the dependent variable. Figure 7 shows the decision tree developed to investigate effects of accident characteristics and Distance2EMC on fatality rate at all national roads in Hokkaido as a function of four 4-year period, which are 2002-2005 and 2006-2009. We focused on accident data after 2002, that the hazard recognition speed is available on record.

Figure 7(A) shows results of the decision tree in 2002-2005. Fifteen significant combinations of variables were found in the decision tree. “Hazard recognition speed” was found to have the most significant correlation with the fatality rate. There were five subgroups as a function of “Hazard recognition speed”. The fatality rate increased as the hazard recognition speed increased. “Hazard recognition speed less than 20.0km/h” had the lowest fatality rate (7.09%), “Hazard recognition speed over 70 km/h” was the highest fatality rate

(47.7%). After “Hazard recognition speed”, partitioning of the second level was trigged by different variables for different subgroups.

1) For “Hazard recognition speed less than 20km/h”, “Distance2EMC” was the second significant variable correlated with fatality rate. There are three subgroups as follows; less than 4.5km, 4.5 to 16.0km and over 16km. Fatality rate of each subgroup was 0.57%, 4.06% and 11.6% respectively.

2) For “Hazard recognition speed” was 20.0km/h to 40.0km/h, “Accident type” was the second significant variable. Fatality rate of “Pedestrian” was 19.5%, and “Car-to-car” and “Single car” was 8.26%. After “Cat-to-car” and “Single car”, “Day/Night” was selected as the third level variable. Fatality rate of “Day” was 10.0%, and “Night” was 4.41%.

3) For “Hazard recognition speed” was 40.0km/h to 50.0km/h, “Accident type” was the second significant variable. Fatality rate of “Pedestrian” was 30.7%, and “Car-to-car” and “Single car” was 14.6%.

4) For “Hazard recognition speed” was 50.0km/h to 70.0km/h, “Accident type” was selected as the second significant variable. Fatality rate of “Pedestrian” was 51.0%, “Car-to-car” was 24.7% and “Single car” was 11.2%. These fatality rates are very high compared with those for “Hazard recognition speed from 20.0km/h to 40.0km/h. After “Car-to-car”, “Distance2EMC” was selected as the third level variable. Fatality rate of “Distance2EMC less than 16.0km” was 13.0%, and “Distance2EMC over 16.0km” was 26.8%.

5) For “Hazard recognition speed” was over 70.0km/h, “Day/Night” was selected as the second significant variable. Fatality rate of “Day” was 42.3% and “Night” was 53.0%.

Figure 7(B) shows results of the decision tree in 2005-2009. Ten significant combinations of variables were found in the decision tree. “Hazard recognition speed” was found to have the most significant correlation with the fatality rate. There were five subgroups as a function of “Hazard recognition speed”. The fatality rate increased as the hazard recognition speed increased. “Hazard recognition speed less than 10km/h” had the lowest fatality rate (2.53%), “Hazard recognition speed over 70 km/h” was the highest fatality rate (41.7%). After “Hazard recognition speed”, partitioning of the second level was trigged by different variables for different subgroups.

1) For “Hazard recognition speed from 30.0km/h to 50.0km/h”, “Type of accident” was selected as the second significant variable correlated with fatality rate. Fatality rate of “Pedestrian” was 21.8%, and “Car-to-car” and “Single car” was 12.8%. After “Car-to-car” and “Single car”, “Distance2EMC” was selected. There were two subgroups by “Distance2EMC”. For “Distance2EMC less than 60.6km”, the fatality rate was 9.79, and “Distance2EMC over 60.6km” was 19.3%.

2) For “Hazard recognition speed from 50.0km/h to 70.0km/h”, “Type of accident” was selected as the second significant variable correlated with fatality rate. Fatality rate of “Pedestrian” was 49.3%, and “Car-to-car” and “Single car” was 23.7%. These fatality rates were twice as much as those in case of “Hazard recognition speed from 30.0km/h to 50.0km/h”.

3) For “Hazard recognition speed over 70.0km/h”, “Location” was selected as the second significant variable correlated with fatality rate. Fatality rate of “Urban” and “Rural” was 38.5%, and “Suburban” was 64.0%. This fatality rate is the largest among ten combinations.

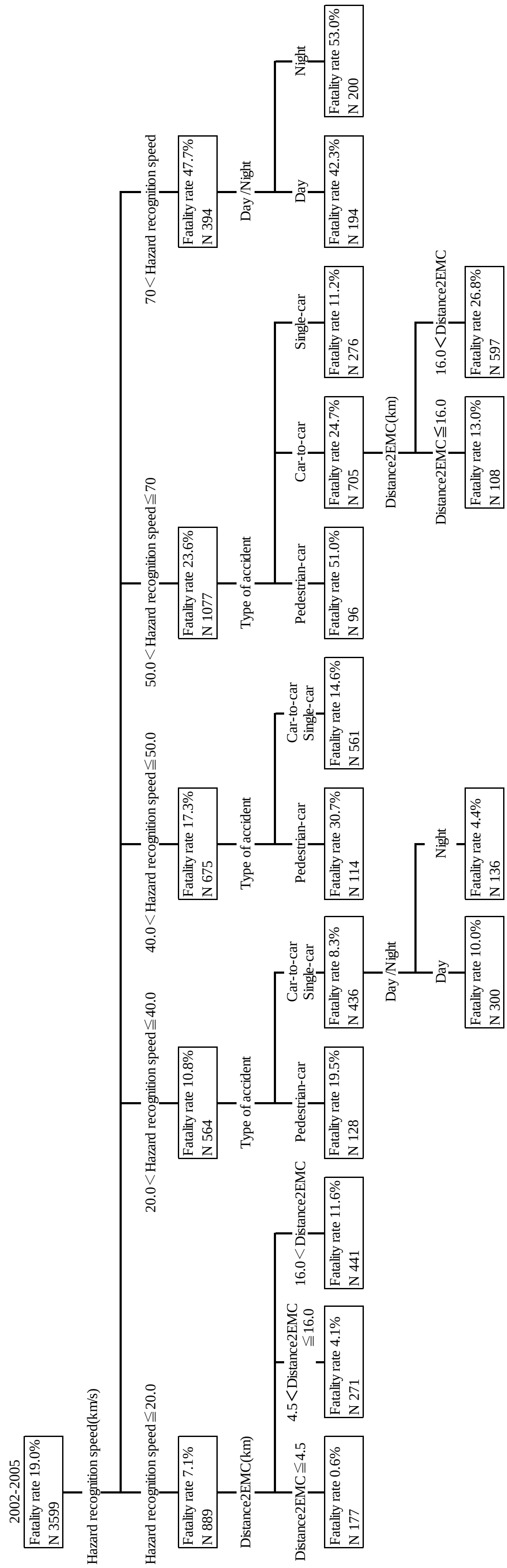

Figure 7(A). Decision tree developed to investigate with the fatality rate in 2002-2005

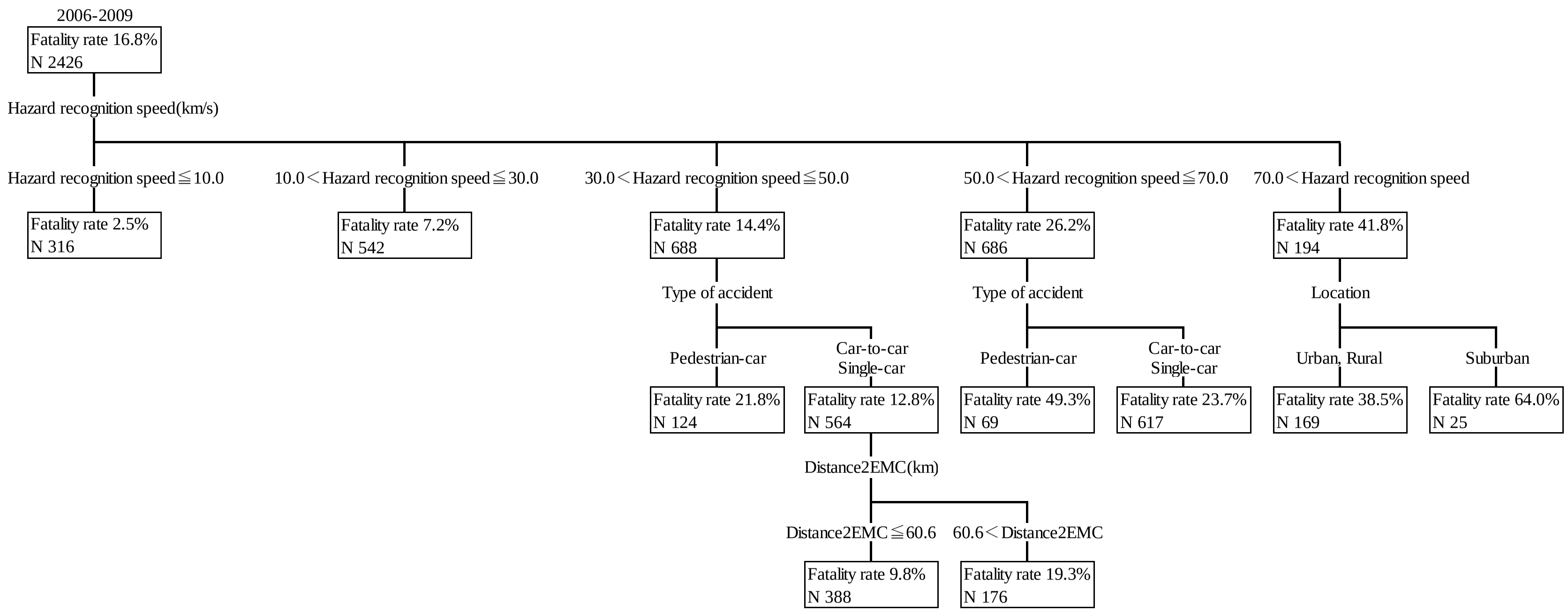

Figure 7(B). Decision tree developed to investigate with the fatality rate in 2006-2009

4. SUMMARY

In this study, we investigated effects of distance between accident site and location of the Life-Saving Emergency Center (Distance2EMC) on the fatality rate at all national roads in Hokkaido, Japan. Average fatality rate where Distance2EMC is less than 40km decreased as the 5-year period is updated. According to results of CHAID analysis, distance of the shortest Distance2EMC subgroup becomes short, and the fatality rate of that subgroup decreased as the period is updated. On the other hand, distance of the longest Distance2EMC subgroup did not change largely as the period is updated, and the fatality rate of that subgroup kept large values over 25.0% during 20 years. These results might indicate that the Distance2EMC has positive effect on reducing the fatality rate, and also this positive effect becomes dominantly as the period is updated.

Next, we examined an effect of accident characteristics including Distance2EMC on the fatality rate used decision tree. Decision tree in 2002-2005 was similar to that in 2006-2009. Variable of the first level was “Hazard recognition speed” in both periods. “Accident type” was mostly selected as the second level variable. The fatality rate was over 20% when “Hazard recognition speed” was over 50.0km/h in both of periods. Also, “Pedestrian” subgroup indicated larger fatality rate than that for “Car-to-car” and “Single car” subgroup within the same “Hazard recognition speed”. In 2002-2005, “Distance2EMC” was selected as the second level after “Hazard recognition speed less than 20.0km/h”. And, “Distance2EMC” was selected as the third level after “Accident type” with “Hazard recognition speed from 50.0km/h to 70.0km/h”. Also, in 2006-2009, “Distance2EMC” was selected as the third level after “Accident type” with “Hazard recognition speed from 30.0km/h to 50.0km/h”. In addition, in 2002-2005, “Distance2EMC” was selected as the third importance variable, and selected as the second importance variable in 2006-2009 next to “Hazard recognition speed”. Based on these results, the fatality rate increased as “Hazard recognition speed” increased, the fatality rate of “Pedestrian” was approximately twice as much as that of “Car-to-car” and “Single car” accident with the same hazard recognition speed subgroup, and “Distance2EMC” was selected as the secondary or thirdly significant variable to affect the fatality rate.

These findings could indicate that Emergency Medical Services in Hokkaido are becoming important components to reduce the fatality rate. According to these findings, it is possible to arrange the location of a new trauma center considering severe crash locations. However, there are several limitations to this study. It should be noted that the details of effects of Emergency Medical Services are not yet clear, we should conduct a new study using actual time of Emergency Medical Services response in near future. And, the accident data should be linked with hospital records, and clinical outcomes towards a better understanding of the contributions of EMS to reducing the injury severity outcome of motor vehicle crashes.

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