Study on Predictive Modeling of Traffic Accident Incidence of Traffic Accident Statistics and Weather Conditions

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Abstract: Depending on the weather conditions, the ratio of traffic accident casualties will be different. When injured casualties, serious injury, were compared by placing the death, the proportion of deaths was higher when the rain and snow came. To reduce the number of traffic fatalities, depending on weather conditions in the number of traffic accidents occur, it is necessary to predict. In this paper, it proposes a model to predict the incidence of traffic accidents caused by weather conditions. And, in the proposed model, to predict the incidence of traffic accidents, it was compared with the number of occurrences in practice. As a result, it was confirmed that the predicted and actual values are similar. In this paper, there will be to help the development to traffic accident policy for the weather conditions.

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1. Introduction

Of the traffic accident, the effect of weather conditions have on the traffic accident casualties is large. Table 1 show the 2012 standard, according to the weather is the number of car accident casualties. Road traffic accident data from Korea Transportation Corporation was using the public a statistical report [1].

Table 1. 2012 traffic accident casualties according to the weather conditions (unit: people)

Weather Condition	The number of traffic accidents	Casualty		
		Death	Injury	Serious injury
Sunny	185,850	4,250	285,597	95,024
cloud	14,035	516	22,248	7,247
rain	21,296	593	34,970	11,628
fog	598	37	964	407
snow	3,867	89	6,887	2,026

Based on the data of Table 1, it analyzed the percentage of casualties of traffic accidents of weather conditions. Figure 2 shows the analysis results. As a result, casualties of road accidents, it can be seen that the rate at which the rain and snow came high. Studies on the relevance of traffic accidents and current weather conditions have been made, but the study of the prediction is lacking. To reduce the number of traffic accident casualties, it is necessary to predict a traffic accident occurs depending on weather conditions. In this paper, it was presented a model to apply the weather conditions, to predict the incidence of traffic accidents.

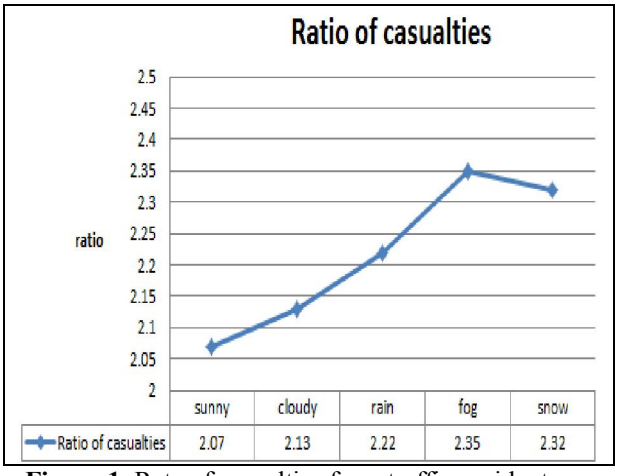

Figure 1. Rate of casualties from traffic accidents caused by weather conditions

And, applying actual data to predict the incidence of traffic accidents, it was compared with the number of occurrences in practice. Predictive modeling was applied to the theory of Markov processes. This paper is organized as follows. Chapter 2 discusses the related research. Chapter 3, there was proposed a prediction model of the number of traffic accident incidence of applying the weather

conditions. In Chapter 4, traffic accident data was applied to Modeling. Finally, the conclusions and discusses future work.

2. Related Work

2.1 Studies on the relevance of traffic accidents and weather conditions

There had collected the data of weather conditions and traffic accident that occurred in Ottawa, Canada. Then, there was the study of the risk of collision accident in accordance with the data in the weather conditions [2]. Using weather data, there had been investigate traffic accidents occurred on a rainy day. Winter storms, hurricanes, floods, etc. The mobility and safety of the transportation system, the user can influence. So, there is a paper that studied the effects of the weather has on the flow of traffic [3]. Besides that, there is a study on the relevance of traffic accidents and weather conditions vary, but research to predict the traffic accidents caused by weather conditions are lacking.

2.2 Markov Process

According to the weather conditions to predict the traffic accidents were applied theory of Markov processes. Markov process is widely applied to various studies to predict the future. Markov process is a state transition between the states depends on the previous n refers to the process. Random time $t_1 < t_2 < \cdots < t_k < t_{k+1}$ for the X(t) refers to a discrete value, the Markov chain is referred to.

$$P[a < X(t_{k+1}) = x_{k+1} \mid X(t_k) = x_k, \cdots, X(t_1) = x_1] \quad (1)$$
$$= P[X(t_{k+1}) = x_{k+1} \mid X(t_k) = x_k]$$

Then, the above equation

t_k : Present, t_{k+1} : Future, $t_1, \cdots, t_{k+1}$: Past

3. Predictive modeling of traffic accident according to the weather conditions

In this paper, by applying the following two factors, weather conditions traffic accident applying predictive modeling was constructed.

First: car accident classification according to the weather conditions

Second: Apply Markov Process.

Two factors are then applied to predictive modeling of traffic accidents in Figure 2.

Each step is as follows.

First: the number of traffic accidents is collected.

Second: the number of traffic accidents divided as follows.

ⓐ Total number of traffic accidents that occur every year.

ⓑ Every year weather conditions (eg, fog, snow, rain, etc.), the number of traffic accidents occurred.

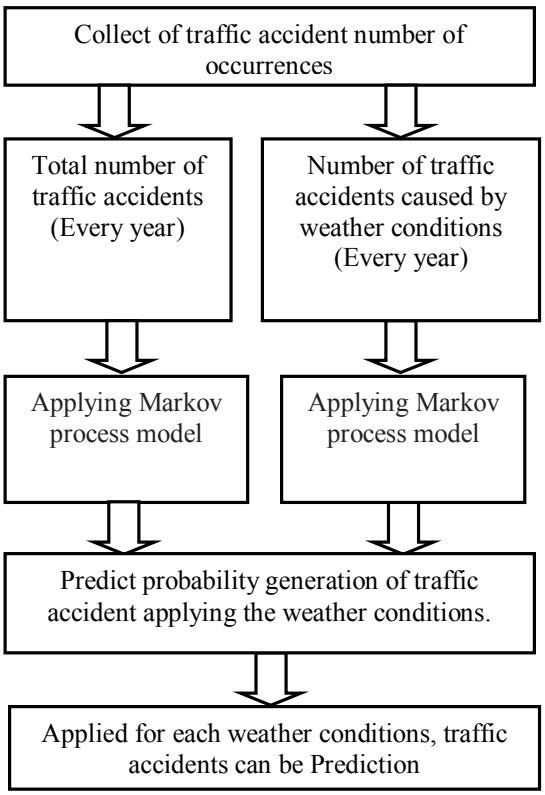

Figure 2. Applying weather conditions to traffic accidents predictive modeling

Third: Markov processes are applied the number of each traffic accidents. Markov process is threshold value, the set of states, the initial probability transition matrix consist.

◈ The set of states: State means the range of the traffic accident data. This is based on the statistical data, and to set an appropriate threshold. State defines a set threshold. In this paper, it has defined the state in two.

◈ Initial probability: The initial probability is a probability that the initial state can have the entire state of traffic accident prediction modeling. Occurred recently in the state is used as the initial state. As defined in equation (2).

$$P(S_1, S_2, \cdots S_n) = P(\frac{a}{F}, \frac{b}{F}, \cdots, \frac{c}{F}) \quad (2)$$

Then, a, b, c : Data of the number of occurrences of state $(S_1, S_2, \cdots, S_n)$

F : The sum of the a, b, c

Initial probability of the sum total is 1. Satisfy the equation (3)

$$\sum_{i=1}^{N} P(S_i) = 1 \quad (3)$$

(S : the state)

◈ Transition matrix: Transition matrix shows the probability between the states of the transition state. The state lists the state by mapping to a set of data over time. The listed state is counting to transition the number of times from one state to another the state. And this transition is represented as a matrix.

- Column: Columns from one state to another state is a probability.
- Rows: Row to the probability sum is 1.

Equation (4) of the following transition matrix of the conditional expression (5) is satisfied.

$$P = \begin{pmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \cdots & \cdots & P_{ij} & \cdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} \end{pmatrix} \quad (4)$$

$$\sum_{i=1}^{n} P_{1i} = 1 \sum_{i=1}^{n} P_{2i} = 1, \cdots \sum_{i=1}^{n} P_{nj} = 1, \sum_{i=1}^{n} P_{ij} = 1$$

$$P_{ij} \geq 0 \quad i = 1,2,\ldots,n \quad (5)$$

Predicted probability of traffic accidents prediction model is applied to a Markov process. Markov process in equation (6) is as follows.

$$P(S_k) = \sum_{i=1}^{n} P(S_i) P_{ik} \quad (6)$$

$P(S_i)$:Initial probability, P_{ik}: Transition matrix

In this study, two types of prediction probability calculated.

ⓐ A: Prediction probability of traffic accidents (Applies the number of traffic accidents whole that occurred every year)

ⓑ B: Prediction probability of traffic accidents caused by weather conditions(Number of traffic accidents that occur according to the weather conditions(Eg, cloudy, rain, snow, etc.) of the every year)

Fourth: predictive modeling of traffic accidents to which is applied a weather condition is as follows. In the third phase, the calculated probability values ⓐ ⓑ of equation (7) applies. Equation (7) is the probability of occurrence of each of traffic accidents in weather conditions.

$$WTAP = \frac{A+B}{2} \quad (7)$$

WTAP: (Weather condition Traffic Accidents Probability) Probability of traffic accidents by weather conditions in each.

Finally, it is predict the incidence of traffic accidents that occurred in next year. Equation (8) is a formula for the expected number of traffic accident of weather conditions of each.

$$PNTAWC = \sum_{i=1}^{n} WTAP(S_k) WTM(S_i) \quad (8)$$

PNTAWC: The predictive number of traffic accidents caused by weather conditions

WTM: Of the number of traffic accidents that occurred in each weather conditions each year occurs, the maximum value.

4. Predictive modeling of traffic accident according to the weather conditions applied

4.1 Weather condition Traffic Accidents Probability of each

South Korea has four seasons. So, it can be divided into the snow and the rainy seasons. The number of traffic accidents of the weather conditions was predicted.

- Weather conditions in the snow and rain
- The weather conditions are depending on the seasons which are rain and snow. So one year increments predicted. Using the data from 2003 to 2011, it is the number of traffic accidents in 2012 predict to occur.
- The predicted data and the actual number of traffic accidents that occurred were analyzed.

Table 2 shows the statistics of traffic accidents by analyzing the data of weather conditions [1].

Table 2. The number of occurrences traffic accidents (Unit: Year)

Year	The number of occurrences traffic accidents		
	totality	Rain	Snow
2003	240,832	32,439	2,844
2004	220,775	21,463	2,532
2005	214,711	17,361	3,057
2006	213,745	20,168	1,732
2007	211,662	20,704	1,328
2008	215,822	15,920	1,773
2009	231,990	18,766	2,002
2010	226,878	21,296	3,867
2011	221,711	20,704	1,913
2012	223,656	21,460	2,774

4.1.1 Types of traffic accidents (all traffic accidents)

By analyzing the total number of traffic accidents, the threshold was defined as the extent and condition.

◈ Thresholds ranges:

S_1: 0~230,000 S_2 : 230,000~260,000

◈ A traffic accident occurring state (S):

$S = \{S_1, S_2\}$

In this paper, the probability of the initial was defined as the number of traffic accidents that occurred in 2010, in 2011. The initial probability is calculated by applying equation (2) data. Equation (9) is the initial probability equation.

P (S_1: 2, S_2: 0) P(1, 0) (9)

Table 2, the total number of traffic accidents caused by mapping the threshold ranges, lists conditions are as follows.

S_1 S_1 S_2 S_1 S_1 S_1 S_1 S_1 S_2

A number of Transitions should count the number of times each transition from one state to another state. And equation (4) is applied, the transition probability is calculated. Transition matrix is equation (10).

$$\begin{array}{c} \\ S_1 \\ S_2 \end{array} \begin{array}{c} \begin{array}{cc} S_1 & S_2 \end{array} \\ \begin{pmatrix} 0.71 & 0.29 \\ 1 & 0 \end{pmatrix} \end{array} \quad (10)$$

State transition diagram (equation (10)) is shown in figure 3.

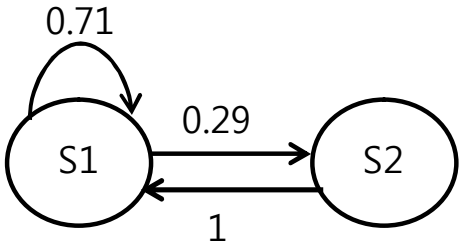

Figure 3. State transition diagram (all traffic accidents)

The predicted probability of traffic accidents, it is obtained by applying equation (6) the transition matrix probabilities and the initial probabilities. Equation (6), a traffic accident occurrence probability can be determined.

$$(1 \quad 0)\begin{pmatrix} 0.71 & 0.29 \\ 1 & 0 \end{pmatrix} = (0.71 \quad 0.29) \quad (11)$$

Equation (11) is 0.71. The State (S_1) is the probability of traffic accidents occur next year when the highest 0.71. The highest probability predicted probability of 0.71 was applied to traffic accidents.

4.1.2 Types of traffic accidents (weather conditions: Rain)

The number of traffic accidents was analyzed of Rainy weather condition. So, the threshold was defined as the range and state.

◈ Thresholds ranges:

S_1: 0~20,000 S_2 : 20,001~35,000

◈ A traffic accident occurring state (S):

$S = \{S_1, S_2\}$

In this paper, the probability of the initial was defined as the number of traffic accidents that occurred in 2010, in 2011. The initial probability is calculated by applying equation (2) data. Equation (12) is the initial probability equation.

P(S1: 0, S2: 1) P(0, 1) (12)

Table 2, the number of traffic accidents (weather condition: Rain) caused by mapping the threshold ranges, lists conditions are as follows.

S_2 S_2 S_1 S_1 S_2 S_2 S_1 S_2 S_2

A number of Transitions should count the number of times each transition from one state to another state. And equation (4) is applied, the transition probability is calculated. Transition matrix is equation (13).

$$\begin{array}{c} \\ S_1 \\ S_2 \end{array} \begin{array}{c} \begin{array}{cc} S_1 & S_2 \end{array} \\ \begin{pmatrix} 0.33 & 0.67 \\ 0.4 & 0.6 \end{pmatrix} \end{array} \quad (13)$$

State transition diagram (equation (13)) is shown in figure 4.

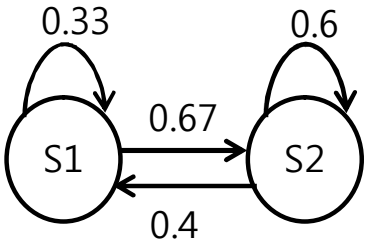

Figure 4. State transition diagram (weather condition: Rain)

The predicted probability of traffic accidents, it is obtained by applying equation (6) the transition matrix probabilities and the initial probabilities. Equation (6), a traffic accident occurrence probability can be determined.

$$(0 \quad 1)\begin{pmatrix} 0.33 & 0.67 \\ 0.4 & 0.6 \end{pmatrix} = (0.4 \quad 0.6) \qquad (14)$$

Equation (14) is 0.6. The State (S_2) is the probability of traffic accidents occur next year when the highest 0.6. The highest probability predicted probability of 0.6 was applied to traffic accidents.

4.1.2 Types of traffic accidents (weather conditions: Snow)

The number of traffic accidents was analyzed of Snow weather condition. So, the threshold was defined as the range and state.

◈ Thresholds ranges:

S_1: 0~2,000 S_2 : 2,001~4,000

◈ A traffic accident occurring state (S):

$S = \{S_1, S_2\}$

In this paper, the probability of the initial was defined as the number of traffic accidents that occurred in 2010, in 2011. The initial probability is calculated by applying equation (2) data. Equation (15) is the initial probability equation.

$P(S_1: 1, S_2: 1)$ $P(0.5, 0.5)$ (15)

Table 2, the number of traffic accidents (weather condition: Snow) caused by mapping the threshold ranges, lists conditions are as follows.

S_1 S_2 S_2 S_1 S_1 S_1 S_2 S_2 S_2

A number of Transitions should count the number of times each transition from one state to another state. And equation (4) is applied, the transition probability is calculated. Transition matrix is equation (16).

$$\begin{array}{c} \\ S_1 \\ S_2 \end{array} \begin{array}{c} \begin{array}{cc} S_1 & S_2 \end{array} \\ \begin{pmatrix} 0.5 & 0.5 \\ 0.25 & 0.75 \end{pmatrix} \end{array} \qquad (16)$$

State transition diagram(equation(16)) is shown in figure 4.

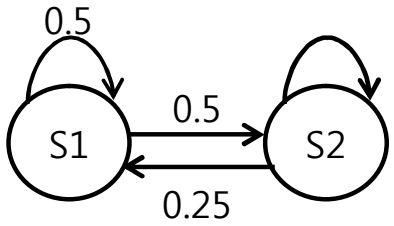

Figure 5. State transition diagram (weather condition: Snow)

The predicted probability of traffic accidents, it is obtained by applying equation (6) the transition matrix probabilities and the initial probabilities. Equation (6), a traffic accident occurrence probability can be determined.

$$(0.5 \; 0.5)\begin{pmatrix} 0.5 & 0.5 \\ 0.25 & 0.75 \end{pmatrix} = (0.37 \quad 0.63) \qquad (17)$$

Equation (17) is 0.63. The State (S_2) is the probability of traffic accidents occur next year when the highest 0.63. The highest probability predicted probability of 0.63 was applied to traffic accidents.

4.2.2 The predictive number of traffic accident, according to weather conditions

Table 3 is a predictability of traffic accidents was calculated in the previous step.

Table 3. The traffic accidents probability according to the weather conditions

	Whole State	Weather conditions (Rain)	Weather conditions (Snow)
Probability	0.71	0.6	0.63

The values in Table 3 are calculated by substituting equation (7).

◈ Weather conditions (Rain): 0.66
◈ Weather conditions (Snow): 0.67

It is Traffic Accidents Probability according to Weather condition. Table 4 shows the equation (8) that is to predict the number of traffic accidents according to weather conditions.

Table 4. The number of predicted traffic accidents according to weather conditions (2012).

	WTAP (Weather condition Traffic Accidents Probability)	WTM (The maximum value to the number of traffic accidents)	PNTAWC (The predictive number of traffic accidents caused by weather conditions)
Weather conditions (Rain)	0.66	32,439	21,410
Weather conditions (Snow)	0.67	3,867	2,591

Table 5 shows was compared the predicted number traffic accidents with the actual number of traffic accidents that occurred in 2012.

Table 5. Compare the predict number of traffic accidents to the actual incidence of traffic accidents

	Predict the number of traffic accidents	The actual incidence of traffic accidents in 2012	Ratio
Weather conditions (Rain)	21,410	21,463	0.99
Weather conditions (Snow)	2,591	2,774	0.93

5. Conclusion

Weather conditions affect to traffic accident and traffic accident casualties. In order to reduce the number of casualties of traffic accidents in accordance with weather conditions, it is necessary to predict a traffic accident. In this paper, it has proposed a model to predict the traffic accidents caused by weather conditions. And the proposed model in this paper was experimented applying the actual data. As a result, the results of modeling and incidence of traffic accidents, it was the similar of 90% or more. Model presented in this paper, is expected to help in the formulation of policy to prevent traffic accidents that occur every year. In the future, it will be research on the various factors that affect the traffic accident.

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