AN ANALISIS OF THE EFFECT OF ROAD PAVEMENT MATERIALS AND THEIR AGES ON THE ACCIDENT RISK ON HANSHIN EXPRESSWAY

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This study aims to assess the relationship between the age of road pavement and traffic accident risks. The current state of practice of the pavement maintenance is planned based on the physical damage on road surface. The indices for the physical damage shows the structural healthiness and the driving comfort, but they do not measure the traffic safety levels of the pavement. This limitation hinders planning the pavement management scheme in order to achieve safer driving environment.

This study empirically analyzes the effect of the pavement conditions on the accident risks. The pavement conditions are represented by the pavement age – the years since construction or last repair of the pavement. The number of accidents is modeled based on the Poisson regression analysis. The model estimation results show that the age of road pavement has a positive effect on the accident risk.

Key Words : *traffic accident risk, pavement material, pavement ages,expressway, Poisson regretion.*

1. INTRODUCTION

This study aims to empirically reveal the relationships between the age of road pavement and traffic accident risks. Traffic accidents are a big concern of society in many countries. Traffic accidents have three major causes: human behavioural factors, vehicle mechanical factors, and driving environmental factors. Among these three, the driving environment has been a major interest to road authorities concerning the road safety. The driving environmental is characterised by various elements, such as traffic conditions, weather, road geometries and pavement conditions, each of which have significant influence on the other two factors in many ways; moreover, the elements of driving environment can be controlled to increase the road safety level by devising traffic safety measures. Therefore, many studies have evaluated the driving environment elements on the traffic accident risks by developing accident risk estimation models based on the family of Poisson regression models, Bayesian networks and decision trees. While most study have successfully identified the impact of road geometries, weather and traffic conditions on the accident occurrence, the impact of road pavement age has not been investigated[1,2].

In the current state of the practice, the pavement is repaired based on road surface surveys conducted every few years. The survey measures three main indices related to the road pavement damage: rut depth, crack ratio and International Roughness Index (IRI). They represent the degree of physical damages on the road pavement, and are good indicators to measure the structural healthiness. However, the current indicators do not consider the traffic safety aspect, which hinders planning the pavement management scheme considering the driver safety[3,4].

This study aims to empirically analyze the relationships between the pavement conditions and accident risks. The pavement conditions are represented by the pavement age – the years since construction or last repair of the pavement. This study considers the road geometry types, weather, and pavement material in relating the pavement age to accident risks, in order to identify when and where to repair the pavement for increasing the traffic safety levels. The finding will be a useful input to developing an asset management scheme, which considers not only the cost of construction and repairs, but also the cost of traffic accidents.

2. METHODOLOGY

(1) Definition of accident risk

Accident risk is defined by the total number of accidents normalized by the vehicle kilometer travelled (VKT).

The equation (1) shows the mathematical definition of the accident risk.

$$R_i = \frac{y_i}{L_i} \times 10^8, \quad (1)$$

Where: R_i: traffic accident risk in road environment category i [accidents/100 million VKT], y_i: number traffic accidents in road environment caterogy i [accidents], L_i: total vehicle kilometer traveled in road environment category i [VKT].

(2) Accident risk estimation model

Because traffic accident is a rare event, it is assumed that number of accidents uring a time interval (e.g., an year) follows the Poisson distribution. Therefore, Poisson regression model will be applied to model the number of accident in each road environment category i.

Assuming that the number of accidents is proportional to the exposure, the response variable is defined as follow.

$$P(Y = y_i|\lambda_i t_i) = \frac{e^{-\lambda_i t_i}(\lambda_i t_i)^{y_i}}{y_i!}, \quad (2)$$

$$\lambda_i t_i = exp\,(a + b_1 x_1 + b_2 x_2 + \cdots + b_n x_n) t_i, \quad (3)$$

Where:

$P(Y = y_i|\lambda_i t_i)$: the probability of observing y_i accidents , λ_i: expected number of accidents per unit VKT in [accidents/100 million VKT], t_i: exposure variable (i.e., VKT), x_k: road accident factors ($k = 1 \sim n$), and a, b_k: unknown parameters ($k = 1 \sim n$).

3. STUDY SITE AND DATA

(1) Study site

The study site is in Ikeda and Higashi-Osaka routes in Hanshin Expressway network.

(2) Data

For this study, five data sources are employed: road construction data; traffic accident data; traffic volume data; road geometry and weather data. All data, except for the weather data, is provided by Hanshin Expressway Co., Ltd. The data period is from April 2010 to March 2016 unless otherwise mentioned.

Road construction data contains road construction and maintenance record from 1964. The record provides information such as: start and end date of pavement repair works held between 1964 to 2016. As well, it contains the information on pavement material, route name and kilopost (KP).

Regarding the pavement material, there are three types in the study site: dense particle size gap type ascon (DPSGTA), dense particle size ascon (DPSA) and drainage pagvement (DP)

- Dense particle size gap type ascon pavement (DPSGTA) the surface of this pavement is basically constituted by micro-texture defined by the composition of different aggregate size ranging from 13mm to 2mm. Due to the surface composition, this pavement has a very poor drainage hability, on the other hand, micro-texture provides to to the pavement a good friction capacity.
- Dense particle size ascon (DPSA) constituted by the macro-texture on the surface due to the size of the aggregrate (~13mm) diameter. Due to the surface characteristic this pavement provides a good lateral drainage what allows to the pavement e good skid resistance while in the rainy season.
- Drainage pavement (DP) this is a very particular pavement material, which is not distinguishied by the texture of the pavement surface. This particular paement has a permeability function. The rainwater falling on the road surface is conducted through the pavement surface pores. Due to this absorption capacity, drainage pavement enhances the skid resistance of the pavement during rainy weather.

Traffic accident data includes the date and time of accident occurrence; accident location defined by the route name, direction, and KP; and accident types.

Traffic volume data, measured by fixed ultrasonic detectors placed along the network, provide vehicles counting. The traffic data includes traffic volume of five minutes interval.

Road geometry data includes information of the vertical and horizontal aligments of every 100m (0.1KP) of the study site. Vertical aligment describes the slope of the road in percentage. Horizontal aligment defines the level of the road curvature. In the horizontal curvature, three levels are defined: straight section, where the radius of curvature is graeter than 3,000 meter; curve section the radius is graeter or equal to 500 meters and less than 3000 meter; and tight-curve when the curvature radius is lesser than 500 meters.

Weather condition describe the precipitation level, measured by study site nearest weather station. The precipitation is provided at a temporal resolution of 1 hour. Two categories are defined: rainny when the precipitation is graeter than 0 mm otherwise, sunny.

(3) Data processing

The road environment category for VKT and number of accidents is defined by pavement material, pavement age, weather condition and road geometry.

The pavement ages "$Age_{s,t}$" is determined based in the difference of the accident occurrence date "$d_{s,t}$" by the end date of road construction or maintanence "$d^r_{s,t}$" for each of 100 meters "s" of the road. As it is shown in the equation below.

$$Age_{s,t} = int\left(\frac{d_{s,t} - d_{s,t}^{r}}{365.25}\right), \quad (4)$$

The denominator 365.25 stands for the average number of days a year.

4. RESULTS

According to the model estimation result (**Table 2**), in general, the age of the pavement has a positive and significant effect on the accident risk. The risk of the accident increases by 4% with pavement age, asuuming that all other factors remain constant. The interaction terms between the pavement age, rain and curved sections reveals that the age of the pavement plays an important role in the traffic safety. Moreover, the effect of pavement age on accident risk under the rainy condition varies depending on the radius of the curvature of the road section; the tighter the curve is, the higher the risk become.

Despite the positive effect of the age of the pavement on accident risk, the risk of accident decreases by 9% on the curve section peved with dense particle size ascon (DPSA). While the risk decreases by 11% on tight-curve sections paved with dense particle size gap type ascon pavement (DPSGTA). The decrease in the accident risk on curve and tight-curve sections paved with DPSA and DPSGTA respectively could be associated with pavement surface friction increment[2] but also to the driver's awareness of the danger for driving on curve sections.

5. CONCLUSION

In this study the effect of the pavement age their ages in the accident risk are been explored. Three pavement materials: drainage pavement (DP), dense particle size ascon (DPSA) and dense particle size gap type ascon paement (DPSGTA) are compared.

The model estimation results showed a positive and significant effect of the pavement age on the accident risk in general, although the impact is small under the normal weather. On the other hand, under the rainy condintion, the effect of the pavement age becomes more noticeable on curve section depending on the radius of curvature.

An interesting result is also found in the curve and tight-curve sections paved with DPSA and DPSGTA, where the pavement age has negative effect on accident risk. This effect might be associated with driver's awareness of the danger and also to the friction increseasing along the time for section paved with DPSGTA.

Future research needs include identifying the effect of of cumulative traffic volume since the last repair on accident risk.

Table 2. Accident risk model estimation

Explanatory variable	Coef.	Z-value	P-value
Constant	1.97	58.00	0.00
Pavement material factor			
Drainage pavement (DP)			
DPSA	1.86	27.00	0.00
DPSGTA	2.39	54.40	0.00
Interaction terms with Pavement Age factors			
Pavement Age [years]	0.04	6.90	0.00
Pavement Age*Curve*Rain (dummy)	0.10	7.50	0.00
Pavement Age*Curve*DPSA (dummy)	-0.09	-6.40	0.00
Pavement Age*Tight Curve*Rain (dummy)	0.15	6.90	0.00
Pavement Age*Tight Curve*DPSGTA (dummy)	-0.11	-5.70	0.00
Weather factors			
Rain	0.47	7.10	0.00
Road Geometry factors			
Flat sections	-1.00	-7.60	0.00
Number of sample	404		
Log-likehood (ρ^2)	0.457	5% significant	

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