Analysis of the Safety Performance of Drainage Pavement focusing on Pavement Age

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1. Introduction

This study analyzes the influence of pavement age on safety performance of drainage pavement. The roadway system provides mobility and access to a range of users. Pavements are an integral part of the roadway network, and their primary function is to provide a smooth riding surface with sufficient surface friction. However, factors such as traffic, environmental and time affect pavement performance during its service life, and timely maintenance is important [1]. Previous studies [2,3] identified that the current pavement management system is based on indices related to physical deterioration. However, the current practice does not consider the safety performance of the pavement, which hinders planning of the pavement management scheme considering the user safety.

This study aims to identify the relationship between safety performance of drainage pavement with its age. Safety performance is defined as accident risk and it is evaluated for different driving environment conditions. The finding will be useful in developing an asset management scheme, which considers not only the cost of construction and repairs, but also the cost of traffic accidents.

2. Methodology

Accident risk is defined as the number of accidents normalized by the vehicle kilometer traveled (VKT). It is calculated considering the driving environment conditions as equation (1). The temporal and spatial resolution of the analysis is 1 hour and 100 meter, respectively. The driving environment conditions are defined by factors such as pavement age, weather and road horizontal geometry as detailed below. The contribution of each factor to accident risk is statistically analyzed based on the Poisson regression model equation (2) and (3).

$\lambda_i = (y_i/L_i) \times 10^8$ (1) where, λ_i: Traffic accident risk [accidents/100million VKT]; y_i: Number of accidents; L_i: Exposure to accidents [Veh.×Km]; $P(Y = y_i|\lambda_i L_i)$: Probability to observer an accident given the conditions.

$P(Y = y_i|\lambda_i L_i) = (e^{-\lambda_i L_i}\,(\lambda_i L_i)^{y_i})/y_i!$ (2) $\lambda_i L_i = \exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n)\, L_i$ (3)

3. Driving environment factors

Pavement age is the number of years since the road opening date for traffic, and it is given by the difference of dates normalized by the average days of a year, equation (4). Weather condition is categorized into wet if precipitation greater or equal to 0.5 mm, otherwise dry condition. Horizontal road geometry is categorized into curve if the road segment radius is less than or equal to 1000 meter, otherwise straight segments. This study considers the basic freeways segments only.

$Y_s^t = \text{int}\,(t - t_s^C)/365.25$ (4) where, Y_s^t: Pavement age [years]; t_s^C: Opening date for traffic; 365.25: Average days of a years

4. Data and study site

Data from Hanshin expressway routes in Osaka, Japan, are used in this study. The total length of the study routes is 331.1 km. The data study includes the following six sources; a) Traffic volume data from April 2010 to March 2016 provides an aggregated traffic flow every 5-minute interval. b) Accident data from April 2010 to March 2016 provides information such as date, time and accident location. c) Road construction from 1964 to 2016 provides information such as location, period of construction, and pavement material. d) History of the safety measure data gives information of location and period of safety measure. This study considers only those segments which have never experienced a safety measure. e) Road

geometry data gives the curvature radius of each segment. f) Weather data from April 2010 to March 2016 provides the precipitation level in a scale of 0.5 mm per hour.

5. Results

Accident risk is calculated for different pavement ages considering the weather and horizontal geometry as summarized in fig. 1. The result shows an increasing trend of the accident risk under the wet weather on curve segments. Accident risk on straight segments does not show a considerable difference with respect to the weather condition for the first three years.

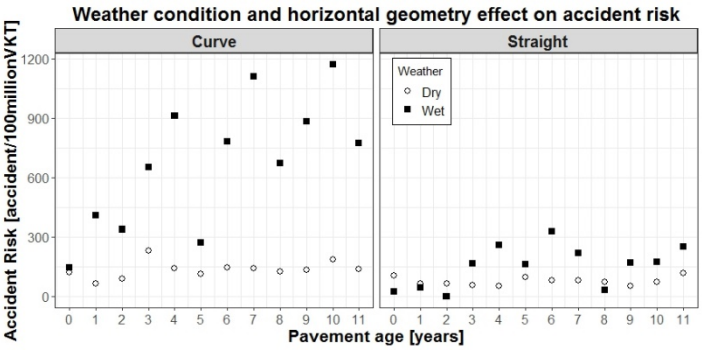

Figure **1**. Relationship between pavement age and accident risk

Results of the Poisson regression model Table 1 indicate that the coefficient of pavement age that represents the effect of pavement age on straight segment in a dry condition is not significant. On the other hand, Curve segments shows to be of the greater risk than straight segments, however, from the interaction terms of pavement age and curve segment, the coefficient shown that the effect of pavement age under dry weather is not significant for accident risk. The coefficients of interaction terms of pavement age, wet condition and curve segments show that when pavement age increases by one year the accident risk subsequently increases by 11.9%, and 20.8% on straight segments and curve segment respectively.

Table **1**. Model result

Independent Variables	Coefficients	
	Parameter	T_value
Constant	-2.16	-21.747*
Pavement Age [years]	-	-
Curve [100-m] (dummy)	0.367	2.618*
*Pavement-Age*Curve*	-	-
*Pavement-Age*Wet*	0.119	5.462*
*Pavement-Age*Curve*Wet*	0.089	3.338*
Observations		5338
Initial log-likelihood		-2343.382
Final log-likelihood		-2208.932
McFadden's Rho-squared		0.057
*Not relevant; Significance level * p<0.05*		

6. Conclusion

In this study, the effect of the age of drainage pavement on accident risk is analyzed. From data analysis, we found that the age of drainage pavement has effect on accident risk. However, the impact of the age varies according to the road horizontal geometry and weather condition. The effect of the age on curve segments are more remarkable than straight segments. Under dry weather condition, the age of drainage pavement effect on accident risk is not significant. Also, on the straight segments, the difference between the accident risk of dry and wet weather condition is not noticeable for the first three years (0, 1 and 2). Further works will focus on developing the management system of drainage pavement, considering the age of the pavement. acknowledgement

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