Correlation Analysis between Pavement Condition Indices in Korean Roads

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Abstract

The Korean road network has been aging rapidly. It is necessary to assess the pavement conditions of various road networks in order to come up with proper rehabilitation strategies against the aging road networks. Pavement management system is an essential tool for road management, and each road management organization has developed its own pavement condition index for assessing the road conditions. Nonetheless, because the pavement condition of various types of roads could not be represented by a single pavement condition index, it was difficult to comprehend the condition of the entire roads of Korea and its changing trend at a glance. Moreover, there has been a limitation on the persuasion of the justification for the use of road management and rehabilitation budget at national level to the people and the budget office of Korea. This study derived the relationship among the pavement condition indices of Korean expressways, Korean national highways, and Seoul city roads so that those pavement indices can be represented by one unified pavement condition index. A sensitivity analysis of how variables of pavement distress (roughness, rut depth, and crack ratio) influenced each of the pavement condition index was carried out. Then, correlation equations between the pavement condition indices were developed in order to represent them by a single pavement condition index (NHPCI) through a statistical analysis of the pavement condition monitoring system data over 8 years, and its application plan is proposed.

Keywords: pavement condition index, pavement management system, correlation equation, crack ratio, roughness, rut depth

1. Introduction

Pavement Management System (PMS) has been first introduced in Korea since 1987 (National Construction Test Center, 1992) for the management of national highways. After that, Korea Highway Corporation, Seoul metropolitan city, Korea Airport Corporation, Busan metropolitan city implemented their own PMS. PMS is a decision supporting system to efficiently manage large highway network, and its importance has been emphasized more since recent aging of highway infrastructure.

Pavement condition index is a combined index to represent various distress conditions of the pavement such as rut depth, crack ratio, roughness, etc. and is considered the most essential index of PMS.

Pavement condition index has been in use as developed by each pavement management organizations to fit in their specific purpose. Pavement condition indices of Korea include NHPCI (National Highway Pavement Condition Index) for national highway, HPCI (Highway Pavement Condition Index) for expressway and SPI (Seoul Pavement Index) for Seoul city roads (Korea Institute of Construction Technology, 2008; Seoul Metropolitan City, 2001; Korea Expressway Corporation Research Institute, 2000). HPCI and NHPCI were developed by selecting various conditions of pavement sections and panel rating consisted of pavement experts and engineers. The model equations of those indices were obtained by correlating the panel rating results and associated pavement conditions. However, SPI was developed using MCI (Maintenance Control Index) of Japanese pavement condition index as the basis model, and its coefficients were customized through the discussion of the panel experts.

Since each road management organization uses its own pavement condition index, the pavement condition of various types of roads could not be represented by a single pavement condition index. Therefore, it is difficult to comprehend the condition of the entire roads of the nation and its changing trend at a glance. Moreover, there has been a limitation on the persuasion of the
justification for the use of road maintenance and rehabilitation budget at national level to the people and the budget office of the government.

Many developed countries also uses various pavement indices, yet they can also be represented by one unified pavement condition index, so that they can be compared each other.

European countries have tried to develop uniform European performance indicators for road pavement through the program of COST 354 “Performance Indicators for Road Pavement”. Their aim was to develop a guideline for assessing the present and future needs for pavement maintenance and rehabilitation at both national and European level through quantitative assessment of performance indicators (COST, 2008).

United Kingdom have managed its roads at national level by using Road Condition Indicator (RCI) through SCANNER (Surface Condition Assessment for the National Network of Roads) survey. Official annual announcement of Road Conditions in United Kingdom publishes road pavement condition and the road sections requiring maintenance and rehabilitation and has been implemented since 2007 to facilitate the communication between road managers and users (UKDOT, 2015).

USA has systemized the PMS concept from its inception (Haas and Hudson, 1978), and there are various Pavement Condition Indices, which have been developed by DOT of each State including PSI of 1960 (Carey and Irick, 1960).

The annual publication of Highway Statistics of FHWA, USA since 1945 records not only motor vehicle registration and highway mileage but also pavement condition (FHWA, 2013). The pavement condition is represented by uniform indices of PCR (Pavement Condition Rating) and IRI (International Roughness Index) regardless of the road type, i.e. Interstate Highway, Principal Arterial, Minor Arterial, etc. This method is used to establish a budget allocation strategy by finding out the general pavement condition of the extensive road network and the change of pavement condition with time.

In fact, since expressway is designed for comfortable high speed driving, a performance indicator with more weight on riding comfort is more urgent for expressway in comparison to national highway or city road. Thus, different performance indicators are necessary to accomplish the objectives of different road types.

Nonetheless, a uniform index is necessary to represent the pavement condition of all roads regardless of the road type in order to indicate the overall pavement condition of all the roads. In other words, although each pavement condition index can be used for its specific purpose, a uniform indicator is necessary to indicate the overall condition of all the road networks. This will make the task of budget allocation easier as well as being used as a communication measure between road users and tax payers.

The purpose of this research is being the first step to develop a uniform pavement condition index. It aims at converting HPCI of expressway and SPI of Seoul metropolitan city to NHPCI of national highway, by analyzing the relationship between these indices. It entails the following detail tasks.

(1) Sensitivity analysis of each pavement condition index
Sensitivity analysis of each index to various distresses (rut depth, crack ratio, and roughness) were performed to find out how each index is affected by each distress.

The pavement condition data from the National Highway Monitoring System were examined to determine the actual range of each distress. Then, an analysis of which distress affects each index most within the predetermined range of each distress was performed.

(2) Development of a correlation equation between pavement condition indices
Correlation equations were developed to convert HPCI and SPI to NHPCI so that all indices can be represented by NHPCI. Using the correlation models it is analyzed how differently each index is computed for the same pavement condition.

(3) Comparison of maintenance and rehabilitation guideline of each pavement maintenance authority.

The pavement condition level, which requires maintenance and rehabilitation of each maintenance and rehabilitation authority, was analyzed through the comparison of maintenance and rehabilitation guidelines of pavement condition evaluation indices so that the influence of the road types on the maintenance and rehabilitation level could be determined.

2. Pavement Condition Indices of Korea

2.1 NHPCI (National Highway Pavement Condition Index)
NHPCI was developed in 2008 by regression analysis model of the relationship between panel ratings of pavement experts and measurable pavement distresses obtained from visual inspection and equipment survey (Korea Institute of Construction Technology, 2008).

The process involved visual and equipment survey of 40 locations in national highway. Panel rating of 10 people from government, academics, and industry was obtained through field inspection and walking visual survey of the investigated locations. An automated pavement condition survey equipment was also used for the quantification of the pavement condition. The results were subjected to multiple regression analysis to develop NHPCI model with independent variables of crack ratio, rut depth, and international roughness index as shown in Eq. (1).

\[
NHPCI = \frac{1}{(0.33 + 0.003 \times X_{cr} + 0.004 \times X_{rd} + 0.0183 \times X_{ir})^{2}}
\]

where, \(X_{cr}\) = Crack ratio (%)
\(X_{rd}\) = Rut depth (mm)
\(X_{ir}\) = International roughness index (m/km)

2.2 HPCI (Highway Pavement Condition Index)
HPCI was developed by a similar method to develop NHPCI. The panel members carried out actual test driving on various distressed sections of highway and suggested their subjective ratings. The correlation between the panel ratings and various