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Application of the Main Algorithm of Pavement Management System For the Korea Expressway System

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Abstract

Maintenance cost for managing the whole network of Expressway system in Korea increases rapidly with the increase of the total length of the system. Implementation of the Pavement Management System(PMS) is essential for efficient management of the Expressway with a limited budget. The purpose of this study is to develop the main algorithm of PMS for Korea Expressway System and to associate the algorithm with database and the Highway Geographic Information System(HGIS) recently developed. Emphasis is laid on developing the algorithm as easy as possible, so that the users can use the PMS without practical difficulty. PMS is not the decision maker, but just a supporting system for the user. The algorithm is designed in such a way that the users can modify the decision criteria, if necessary. The user is the one who makes the final decision of the priority and the maintenance alternatives. The users can also inquire the current condition of the whole Expressway network in detail by association of the database and the algorithm with HGIS.

Keywords : *Expressway , Pavement management system(PMS), Prioritization decision, M&R decision*

요 지

해를 거듭할수록 증가하는 고속도로 연장과 함께 전체 고속도로 유지보수 비용은 급증하는 추세에 있다. 제한된 유지보수 예산으로 전체 고속도로망을 효율적으로 유지관리하기 위해 포장관리시스템(PMS, Pavement Management System)의 운영은 필수적이라 할 수 있다. 본 연구는 PMS의 핵심기능인 보수 우선순위 및 공법결정 논리를 개발하여 실무자들의 PMS 활용도를 높이기 위한 연구로서, 실무자들이 친숙하게 사용할 수 있도록 PMS의 기본기능에 충실하여 쉽게 운영 가능한 시스템을 구성하는데 역점을 두었다. PMS의 주 논리인 보수우선순위 및 보수공법결정에 관련된 각 항목들의 criteria는 기술자의 판단에 의해서 쉽게 수정할 수 있도록 하여 좀더 유연한 운영을 할 수 있도록 하였고, 보수공법 결정에 있어서도 기계적인 알고리즘에 의한 보수공법결정체계의 경직성을 보완하기 위해, 제시된 보수공법의 적절성을 PMS운영자가 직접 확인하고 필요시 현장실사 또는 정밀조사를 통해 보수공법을 조정할 수 있도록 하였다. 도로 일반현황조회에 있어서는 운영자가 쉽게 포장의 상태를 파악할 수 있도록 HGIS와의 연계를 통해 현황조회 기능을 강화하였다. 고속도로 PMS의 전산화는 각 고속도로 포장과 관련된 모든 정보에 대한 데이터베이스를 기반으로 하여 실무자들이 쉽게 이해하고 편리하게 사용하는데 중점을 두어 개발하였으며 정량화된 객관적인 정보를 실무자에게 제공하여 포장을 효율적으로 관리할 수 있도록 하였다.

핵심용어 : 고속도로, 포장유지관리체계(PMS), 보수우선순위 결정, 보수공법결정

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1. INTRODUCTION

The total length of the Korean expressway system has kept on increasing and it reached to 2000Km at the year of 2000(Table 1). Maintenance cost for managing the whole network of Expressway system in Korea increases rapidly with the increase of the total length of the system. Implementation of the Pavement Management System(PMS) is essential for efficient management of the expressway with a limited budget(1). The purpose of this study is to develop the main algorithm of PMS for Korea Expressway System and to associate the algorithm with database and the Highway Geographic Information System (HGIS) recently developed. Emphasis is laid on developing the algorithm as easy as possible, so that the users can use the PMS without practical difficulty.

Table 1. Increasing Trend of the Total Length of the Korea Expressway System

Year	Total length (Km)
1970	550.9
1980	1224.6
1990	1550.7
1998	1996.3
2004(planned)	3700
2011(planned)	5000

2. Basic Principles of the PMS Development

Basic principles of the PMS development for the expressway can be summarized as follows :

- simple and flexible algorithms,
- engineers' input to the final decision,
- standardized pavement condition survey results, and easy presentation of current condition using GIS.

2.1 Simple and Flexible Algorithm

There are lots of algorithms available for prioritization and alternative selection of M&R (Maintenance and Rehabilitation), such as the use of decision tree or simple matrix, life cycle cost analysis, neural network analysis and so on. In general, simple algorithms such as decision tree are easy to understand and operate, although the output from the algorithms may not be the theoretically optimum results. On the other hand, highly developed algorithms might give better results in terms of optimization of the whole roadway network. However they are

Table 2. Comparison of the Algorithms for Prioritization and Alternative Selection for M&R

Algorithms	Simple Algorithms - decision tree - matrix	Advanced algorithm - life cycle cost analysis - benefit cost analysis - neural network analysis
Advantages	- easy to understand - simple input variables	- network optimization expected
Disadvantages	- lack of network level optimization	- difficult for engineers to understand - too many input variables necessary - verification for Korean condition necessary
Remark	selected	

usually difficult for the engineers to understand and some of them are not even verified yet.

Algorithm itself may be ideal. Since, however, there may be too many complicated input variables, it is sometimes impossible, from the practical point of view, to use the algorithm accurately. Therefore the algorithms of the PMS are designed to be as simple as possible and to be flexible so that engineers can modify any of the decision criteria if necessary.

2.2 Engineers Input to the Final Decision

Any sophisticated algorithm cannot cover all the cases of the real situation. For instance, decision trees could include rutting and cracking in their M&R alternative selection algorithm, but they cannot cover local failures such as partial settlement, flushing and pothole. And sometimes it may be necessary to assign certain sections of the highway to a higher priority from the political point of view. In order to make up for the limitation of the human made algorithm, complementary procedures are included in the PMS. The procedure includes manual check of M&R selection resulted from the PMS and modification if necessary as shown in Figure 1.

2.3 Standardized Pavement Condition Survey Results

Pavement condition is an essential input parameter in operating the PMS. In the previous version of the PMS, it was designed to work with a specific survey equipment(ARAN). Without the equipment or when it was not working, PMS could not work.

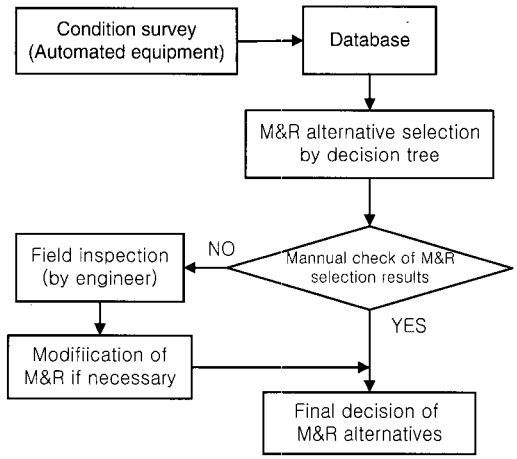

Figure 1. Engineers Complementary Procedures for M&R Alternative Selection

The purpose of standardization of the pavement condition survey results is that, regardless of the survey equipment, PMS could be operated if the survey results are available. In case that a certain survey equipment is not working, a substitute or manual survey can be used if the result can be presented in the standard format. Figure 2 and Table 3 shows the conceptual diagram of the standardization and the standard format used, respectively.

2.4 Easy Presentation of Current Condition Using GIS

Inquiry of current condition is not a mandatory component of PMS. However, rapid development of

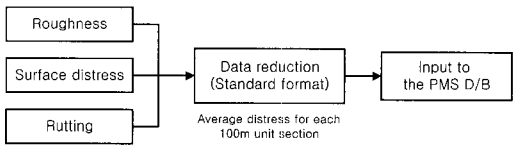

Figure 2. Standardization of the Pavement Condition Survey Results

Table 3. Standard Format of the Pavement Condition Survey Results

Condition Index *	Unit	100m Average	Pavement Type		Remarks
			PCC	AC	
HPCI	-	○	○	○	
IRI	m/Km	○	○	○	Surveyed through RWP
RD	cm	○		○	
CR	m/(100W)m² W:lane width	○	○	○	
P	m/(100W)m² W:lane width	○	○		

* HPCI : Highway Pavement Condition Index (A combined index developed for the Korean Expressway)
IRI : International Roughness Index, RD : Rut Depth,
CR : Crack, P : Patching
RWP : Right Wheel Path

recent GIS technology enables the condition of the whole expressway system to be presented at a glance.

3. Database

Database is an essential component of PMS. The selection of the detail fields and the features of each field in the database are also important for effective operation of the PMS. Components of the database related to the PMS consists of general inventory, section description, maintenance history, pavement condition, traffic volume, environmental condition and so on.

The whole network of the expressway is divided into every 100m unit section and each lane is considered separately. Each 100-lane-meter section makes a record in the database.

4. Quantification of the Pavemant Condition

Pavement conditions to be surveyed include roughness (IRI), rut depth, crack and patching. For the prioritization purpose, a single combined type index representing the various pavement distress is needed. To meet this need, HPCI (Highway Pavement Condition Index) is developed using panel rating and pavement condition objectively measured in the expressway. The HPCI models(2, 3) for asphalt and concrete pavement are as follows :

• Concrete pavement

$$HPCI = 7.35 - 4.65\ 10\mathrm{Log}(1 + IRI) - 1.06\mathrm{Log}(10 + \frac{10}{B} C) - 0.32\ 1Log(10 + \frac{10}{B} P) \quad (1)$$

where ,
IRI = international roughness index (m/km)
B = lane width surveyed (m)
C = total length of cracks within 100m section of a surveyed lane (m/(B100)m^2)
P = total area of full depth repair within 100m section of a surveyed lane (m/(B100)m^2)

• Asphalt pavement

$$HPCI = 4.564 - 0.348IRI - 0.36RD - 0.01\sqrt{5(TC + AREA)} \quad (2)$$

where ,
IRI = international roughness index (m/Km)
RD = rut depth (cm)
TC = total length of cracks within 100m section of a surveyed lane (m/(B100)m^2)
AREA = total area of alligator cracking and patching (m^2/(B100)m^2)

HPCI varies within the ranges of 0.85~4.56 and 0.95~5.67 for asphalt and concrete pavement respectively, when the pavements conditions are in the practically reasonable ranges shown in Table 4. Within the ranges, a sensitivity analysis of HPCI was conducted and gave the results shown in Figure 3.

Table 4. Ranges of Pavement Conditions Used for the Sensitivity Analysis

Asphalt Pavement		Concrete Pavement	
IRI	0.0~5.0m/Km	IRI	0.0~5.0m/Km
RD	0.0~5.0cm	C	0~36(m/(B100)m^2)
TC+AREA	0~60 (unit neglected)	P	0~60(m^2/(B100)m^2)

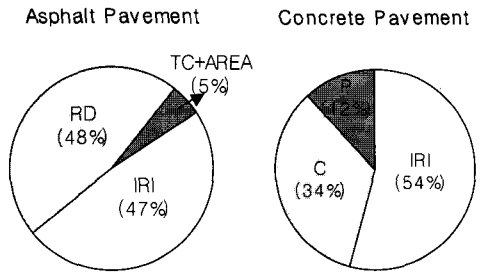

Figure 3. Influence of Each Pavement Distress Parameters on HPCI

5. Prioritization and Decision of Maintenance and Rehabilitation(M&R)

One of the basic principles of the PMS development is to make the algorithm simple and flexible. In other words, all of the algorithms are easy to understand and each criteria of the trigger values for decision making are designed to be easily modified if it is necessary.

Table 5. Prioritization matrix

		Traffic Volume (AADT per lane)		
		<10,000	10,000~20,000	>20,000
Pavement condition (HPCI)	>4.0	DN	DN	DN
	3.5~4.0	DN	DN	6
	3.0~3.5	7	5	4
	<3.0	3	2	1

DN : Do Nothing

Table 5 shows the prioritization matrix consisting of the pavement condition (HPCI) and traffic volume. The criteria for the each category shown in the Table 5 are default values and they can be modified depending upon the engineers experiences.

Table 6 and 7 represents the decision matrix of M&R for asphalt pavement and concrete pavement respectively. Like the prioritization matrix, criteria values in the Table 6 and 7 can also be modified if necessary.

One thing to note is that the tables do not give

Table 6. Decision Matrix of M&R (Asphalt Pavement)

Pavement Condition				RD(cm)		
				2>	2~3	3<
IRI (m/km)	3 >	Crack m/(B100)m2	10>	DN	DN/LR	OL
			10~30	DN/LR	LR	OL
			30<	LR	LR/OL	OL
	3~5	Crack m/(B100)m2	10 >	DN/LR	LR/OL	OL
			10~30	LR	LR/OL	OL
			30 <	LR	LR/OL	OL
	5 <	Crack m/(B100)m2	10 >	OL	OL	OL
			10~30	OL	OL	OL
			30 <	OL	OL	OL

DN : Do Nothing, LR : Local Repair,
OL : Overlay, B : Lane Width

Table 7. Decision Matrix of M&R(Concrete Pavement)

Pavement Condition		Crack(m/(B×100)m^2)		
		10 >	10~60	60 <
IRI(m/Km)	3 >	DN	DN/LR	LR
	3~5	DN/LR	LR	LR/OL
	5 <	LR/OL	LR/OL	LR/OL

DN : Do Nothing, LR : Local Repair
OL : Overlay, B : Lane Width

any specific M&R methods such as the thickness and materials to be applied. The specific decision is reserved for the engineers.

6. Operation Procedure of the PMS

6.1 Determine the Sections to be Surveyed

Expressway sections to be surveyed each year are selected based on the following two considerations.

- request by the branch engineer
- programmed survey schedule

Branch engineers are the best source of information about the actual condition of the pavements. Therefore their requests for survey, due to the poor condition, are considered in determining the sections to be surveyed.

If only the branch engineers' opinion is considered, there could be sections in which no survey is conducted for a long time due to good condition. To solve this problem it is designed to automatically enter those sections not surveyed for more than 3 years into the list of survey sections.

6.2 Pavement Condition Survey

List of survey sections are sent to the pavement condition survey team. Using automatic pavement

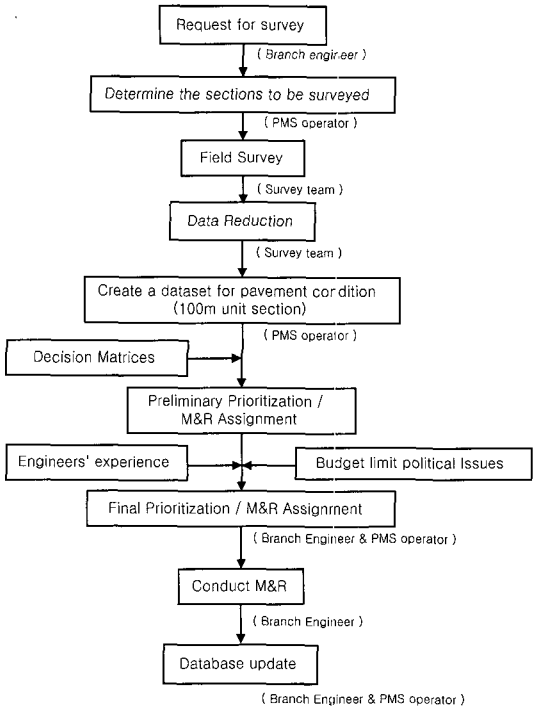

Figure 4. Flowchart of the PMS Operation Procedure

condition survey equipment such as ARAN or ARIA, surface roughness, cracking, and rut depth are measured on the sections listed. For the survey efficiency, the beginning point and the end point of the survey are at the interchanges.

Through the necessary data reduction process, all the survey results are summarized for every 100m unit section in an EXCEL file which is relatively easy for most engineers to work with and is easy to export to the PMS database.

6.3 Prioritization and M&R assignment

A dataset for prioritization and M&R assignment is created using the data imported condition survey results. Each record of the dataset represents each 100-m unit section.

A preliminary prioritization and M&R assignment is carried out using the decision matrices shown in Tables 5 to 7. Decision making by the decision matrices has some limitations, which include followings.

Site specific distresses such as settlement or pothole could be neglected since they are not considered in the M&R assignment matrix.

It is hard to consider political issues in prioritization.

It is hard to include variety of new M&R techniques in the M&R assignment.

Therefore the PMS is designed to consider engineers opinion to make a final decision of prioritization and M&R assignment.

6.4 Database Update

The list of sections to be maintained and rehabilitated is sent to each branch with recommended M&R strategy and the priority of each section. Branch engineers conduct the maintenance and rehabilitation within the priority and fund allocated. Works actually conducted might not be exactly the same as the prescribed by the PMS.

Branch engineers are responsible for reporting the M&R works actually conducted and the reported information is used to update the database of the PMS.

7. Conclusion

In this study, the main algorithm of PMS for maintaining 2000Km of Korean expressway network is developed. The features of the PMS can be summarized as follows.

The general algorithms are designed to be as simple as possible and to be flexible so that engineers can modify any of the decision criteria or final output of the PMS if necessary.

Pavement condition survey results are standardized so that any type of survey equipment or even the manual survey can be used in the condition survey data collection.

Variety of inquiry functions of the current condition of the expressway network is employed using the Geographic Information System (GIS) tools.

A combined type index of the pavement condition, HPCI(Highway Pavement Condition Index) especially developed for the Korean expressway is used in the prioritization of the PMS.

Sections to be surveyed each year are selected based on the request by the branch engineers as well as the programmed survey schedule.

Acknowledgement

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