PERFORMANCE AND ECONOMIC ANALYSIS FOR RUT-RESISTANT PAVEMENT BY USING HDM

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ABSTRACT

In 1998, rut-resistant pavement was adopted, in Korea, to prevent plastic deformation. This paper is an investigation of the relationship between the optimal maintenance strategy and the economic level using the guidelines set out in the HDM-4 (Highway Development & Management-4). Also the pavement deterioration models incorporated in the HDM-4 have been calibrated and adapted to local conditions on the national highways in Korea.

Observed data, such as rut-depth and roughness was used to develop the deterioration forecast models. In this paper the performance and economic efficiency were used to investigate the differences between rut-resistant pavement and conventional Hot-Mix Asphalt (HMA) on the national highways in Korea. Based on the calibration results on the HDM-4, an economic evaluation, including agency cost and user cost, was performed for 22 road sections.

The results show that, for most road sections, rut-resistant pavement performs as well as, or better than, conventional HMA. Furthermore, it was confirmed that the application of HDM-4 is a useful tool for the pavement management system in Korea.

1. INTRODUCTION

For the maintenance of social infrastructures such as roads, it is often necessary to consider the network in the objective region as well as the objective area. The concept of maintenance is approached on the overall introduction to social infrastructure, not limited to pavement only. Since such a concept is based on the life cycle cost, a reliable analysis on diverse factors including initial construction cost, maintenance and demolition cost is required ([1], [2]). Recent studies on maintenance have been focused on preventive maintenance (PM) by small scale maintenance. Preventive maintenance involves the application of common methods prior to the time when the development of road damage is accelerated. This methodology is being studied as a major method for reducing the cost of road maintenance ([3]).

Since preventive maintenance is carried out prior to the damage occurrence of roads, this methodology may not be acceptable for policy makers. Presenting an objective basis based on reliable economic analysis is an important factor in the decision of road maintenance policy.

Therefore, this paper aims to suggest an efficient maintenance policy of pavement for the national roads in Korea using the HDM (Highway Development & Management)-4 and considering the future traffic demand and the uncertainty of degrading process of pavement.

2. PAVEMENT MANAGEMENT SYSTEM AND HDM

2.1. PMS and Life Cycle Cost Analysis

In Korea, the Pavement Management System (PMS) for the national roads has been constructed and in operation for the efficient use of the road management budget and optimal road maintenance since the late 1980s. Presently, the system collects pavement-related data (longitudinal roughness, rut-depth, crack) using Automatic Road ANalyzer (ARAN) for about 3,000km of national roads, deciding the pavement status rating for homogeneous section considering traffic volume and maintenance history, for use as basic data for maintenance.

According to the case study on economic analysis described below, it was discovered that no national standard or indicator is available, when compared with the foreign countries where studies and standards are provided for the economic analysis on road and transportation business on national basis. Therefore, studies on establishing a standard decision which can integrate standards and can be used commonly are urgently required.

Generally, the life cycle of a construction project has consisted of planning, designing, procurement, construction, maintenance (operation), and demolition. Each of these phases incurs cost. The total sum of the cost incurred through the life cycle is Life Cycle Cost (LCC), and the Life Cycle Cost Analysis (LCCA) is the method and procedure for calculating the total cost.

The agency cost is for the periodic inspection and maintenance of the structure in order to maintain the functionality of the structure and improve user convenience and safety. This cost includes overlaying, partial repairing, and surface treating costs.

The user cost is the cost paid by the users throughout the life cycle of the project, including the vehicle operating costs, user delay costs, and crash costs. User cost can also be classified into the cost for general utilization of the road and the road use cost during the operation of work.

This paper aims at suggesting an efficient pavement maintenance policy minimizing the expected LCC considering traffic demand in future and the uncertainty in the degradation process of the pavement. Also, an objective analysis was attempted on the long-term performance and economy, on the basis of the on-site pavement data and the availability of the HDM-4 which is being used worldwide.

2.2. Outline and Applicability of HDM-4 Model

The HDM-4, which was developed by the World Bank, is a microscopic model that consists of diverse supplementary models. This model was devised to provide a variety of information about PMS operation including the selection of optimal maintenance policy and budgeting on the basis of road performance and economic evaluation. Many countries are conducting studies and applying the HDM-4 ([4], [5]).

Since it is a microscopic model, the HDM-4 requires somewhat large or difficult to obtain data, which are time series serviceability data for the compensation of road deterioration model (RDM) and various unit costs which are the major indicators for the evaluation of traffic volume and economy. These data are converted to modifying coefficients within HDM-4, and applied as variables that describe the deterioration process ([6]). However, as the data varies by country (even locally) according to the traffic environment, climate, vehicle characteristics, and design standards of pavement compatibility is not supported. Therefore, calibration (localization) process is required to apply the HDM-4 locally.

3. PREDICTION OF LONG-TERM SERVICEABILITY

3.1. Outline of the Methodology and Data

In this chapter, in order to evaluate the long-term serviceability and economy of pavement, calculation method of correction coefficient, for the prediction of deterioration process on the basis of the data on the conditions of the actual pavement, is described.

Also, the information on the initial status of pavement is very important for the prediction of serviceability. This initial value, which is the value immediately after the maintenance work, is important for determining the slope (correction coefficient) of the trend of the road deterioration in the prediction of the HDM-4 (KICT, 2003). In fact, the initial conditions immediately after pavement is influenced by the road conditions just before the maintenance work. That is, maintenance work cannot return the initial pavement conditions. Since data in this area is not available in Korea, the default values of Rut-depth 2.0mm, IRI 2.0m/km, and Crack 0.0% in HDM-4 were used in this study.

Since the correction coefficient is calculated by considering the influence of the traffic volume, traffic data is essential. After correcting the pavement deterioration model, the serviceability and economy are evaluated by applying the analysis options (period, maintenance alternatives, analysis module, etc.) according to the purpose of the analysis.
In Korea, the SMA (Stone Mastic Asphalt) was first introduced in1998, on Suwon National Road #39, in order to set up countermeasures against rutting on national roads. After the test pavement by Korea Highway Cooperation in 1995, in order to devise application method of rut-resistant asphalt method preventing rutting, one section, where rutting has occurred, in each Local National Territory Administration was selected and tested with the SMA and PMA (Polymer Modified Asphalt).

Service year of pavement was considered as the major variable for selecting the objective section. Data collection was conducted from August to September, 2005. The first survey was conducted focusing on the longitudinal roughness in 160 sections. In the second survey, data on cracking and rutting in 22 sections_were investigated considering the compatibility with the data from the first survey and past data.

For measuring the rutting, sample section (1 km) was divided by 200m sections. Measuring points were 6 including the beginning and ending points. Rutting depths at 5 points in traversing direction, for each point, were measured. Rutting values were calculated by the difference between the maximum and minimum rutting depths which were measured using a rutbar.

On the other hand, traffic volume is an important factor for the damage of pavement. Especially, number and ratio of heavy vehicles are important. Data on the time series traffic characteristics in the respective section was obtained from the annual census data surveyed by MOCT (Ministry of Construction and Transportation). In this study, the 11 types of vehicle in the statistics annual report was converted to 7 types of vehicle in order to use the vehicle type classification system by 7 types in the HDM-4.

3.2. Estimation of Deterioration and Coefficient Correction using HDM-4

HDM-4 enables the creation of an optimal plan by predicting the deterioration process according to the maintenance plan and calculating the agency cost and user cost accordingly. Major correction factors include; correction for vehicle-related data (vehicle characteristics, operational characteristics, cost characteristics, etc.) and road deterioration model using performance data and pavement characteristics.

Correction of the Road Deterioration and Work Effect model is an important part of using HDM-4. The factors which influence the serviceability of pavement are 1) pavement type and design level: raw materials and PG rating, 2) strength of pavement: Structural Number (SN) and bending (deformation) resistance of pavement, 3) traffic volume, ratio of heavy vehicles and ESALF (Equivalent Single Axles Load Factor), 4) climate, and 5) service period.

For correction, time series serviceability data of the road pavement is required and the traffic data in the objective section has to be acquired for the analysis period. The correction items in HDM-4 are crack, ravelling, pothole, edge break, IRI, and environmental influence. Presently, cracking, rutting, and longitudinal roughness are under investigation in Korea. Other values were found out to be not so important for the serviceability of pavement by prior studies ([7], [8]).

Ravelling, pothole, and edge break were decided in accordance with the methodology of Level 1 presented in the HDM-4 (almost same as the default values). K_{ge} and K_f which are connected with climate were selected using the data of Korea Meteorological Administration.

Cracking is one of most important distresses in bituminous pavements. Fatigue and ageing have been identified as the principal factors which contribute to various defeats of a bituminous pavement layer. Accordingly, correction for crack has to be conducted in the initial phase. This is because cracks influence the structural strength (SN) which influences the calculation of rutting, and the rut-depth influences the longitudinal roughness.

The crack correction coefficient can be divided into the related with the beginning of the crack K_{ci} and K_{cp} for the increment (slope) after the crack. In HDM-4, crack is considered to be occurred when the crack exceeds 0.5% that expressed as a percentage of the carriageway area. Since no data is available for the beginning time of crack, K_{ci} is recommended to be 1.0 (default) ([7]).

Correction coefficients related with rutting are related with the structural deterioration (durability) of pavement and related with the progress of rutting. It is known that the initial density and surface wear have almost no sensitivity ([9]).

The roughness model consists of several components of roughness (cracking, disintegration, deformation and maintenance). The total incremental roughness is the sum of these components.

1) 1st Step: Select 20 or more pavement segments (minimum 10 per pavement type), 1km length, uniformly distributed in matrix of age group (young, medium, old), and annual traffic loading (light, medium, heavy), for each pavement type.
2) 2nd Step: The incremental values should be determined preferably by linear regression between the first and last applicable survey, and mean values by arithmetic average.

$$MORI = \frac{SUM(ORI_1 : ORI_n)}{n} \quad (1)$$

where, ORI_i is longitudinal roughness observed in *i*-th year (or last year of observation).
3) 3rd Step: predict unadjusted roughness increment (ΔPRI_t).
4) 4th Step: calculate the difference between the observed and measured values of the incremental roughness for each calibration section.

$$RESR_i = \Delta(PRIj_t - \Delta ORIj_t) \quad (2)$$

Here, determine the correlation and slope (b) without an interception between $RESR_i$ and MORI. If the correlation and the determination of 'b' are significant, than determine the adjustment factor, K_{gp} , as follows ([7]);

$$K_{gp} = 1 + b \quad (3)$$

In HDM-4, the longitudinal roughness is described as an integrated index which is calculated by considering all the serviceability indexes, and is closely related to the economical evaluation. Correction of road deterioration model can be considered to be complete when the calculation of all the correction coefficients to IRI is completed.

Correction of longitudinal roughness must be done after the calculation of the correction coefficients for crack and rutting. The reason can be understood by considering the equation (4) which represents the influence among each correction coefficient.

$$\Delta RI = K_{gp}[\Delta RI_S + \Delta RI_c + \Delta RI_r + \Delta RI_t] + \Delta RI_e \quad (4)$$
$$\Delta RI_e = K_{gm} m RI_a \quad (5)$$

where, K_{gp} is longitudinal roughness correction coefficient, K_{gm} is an environmental influence correction coefficient, m is the environmental coefficient, ΔRI_s is a change in IRI by structural change, ΔRI_c is change in IRI by crack, ΔRI_r is change in IRI by rutting, ΔRI_t is change in IRI by pothole, ΔRI_e is change in IRI by environment and RI_a is roughness(m/km, IRI) in the initial year.

Table 1 shows list of correction indexes by serviceability index in the 22 road sections calculated with the Fitting methodology suggested in this paper.

Table 1. Correction Coefficient of rutting and IRI

Section	K_{ci}		K_{cp}		K_{rst}		K_{rpd}		K_{gp}	
	HMA	Rut-resistant	HMA	Rut-resistant	HMA	Rut-resistant	HMA	Rut-resistant	HMA	Rut-resistant
T1-55	1.55	2.00	1.00	1.00	1.00	1.00	9.67	3.50	1.23	1.75
T1-53	0.90	1.00	2.94	0.85	1.00	1.00	9.01	1.86	1.05	1.50
T1-50	1.00	2.12	2.13	1.00	1.00	1.00	6.48	2.15	0.18	1.71
T1-48	1.00	1.00	2.00	1.69	1.00	1.00	5.22	1.03	0.46	0.65
T1-13	2.78	1.00	0.10	0.90	1.00	1.00	12.20	3.96	0.44	0.66
T1-10	0.45	1.00	4.00	1.23	1.00	1.00	20.00	0.54	0.46	2.78
T2-21	1.00	2.31	0.42	1.00	1.00	1.00	6.48	0.23	1.03	11.00

T2-18	2.70	0.50	1.00	2.95	1.00	1.00	5.74	2.18	2.03	2.49
T2-12	1.00	2.00	4.64	1.00	1.00	1.00	10.42	4.50	0.98	2.07
T2-10	1.65	1.00	0.95	0.79	1.00	1.00	3.41	0.51	0.02	0.94
T3-49	1.00	2.00	0.97	1.00	1.00	1.00	12.15	0.28	0.41	7.00
T3-41	1.00	2.00	0.85	1.00	1.00	1.00	4.68	0.33	0.40	6.57
T3-39	0.50	1.00	0.80	0.71	1.00	1.00	13.70	0.17	0.82	3.64
T3-35	2.00	3.00	1.00	1.00	1.00	1.00	4.95	0.68	0.23	2.50
T3-26	1.00	1.00	1.00	0.90	1.00	1.00	11.40	2.03	0.45	1.53
T3-2	1.00	1.00	1.63	1.23	1.00	1.00	3.23	0.34	0.01	1.20
T4-18	1.00	1.00	0.78	1.88	1.00	1.00	15.20	0.95	1.04	1.00
T4-15	0.50	1.00	0.35	0.15	1.00	1.00	14.15	1.22	0.75	0.10
T4-11	1.00	2.00	0.67	1.00	15.18	1.00	20.00	0.74	1.05	2.54
T4-9	1.00	1.00	0.58	0.80	1.00	1.00	5.05	1.74	1.69	0.96
T4-6	0.50	1.00	0.30	1.04	1.00	1.00	19.41	1.45	1.18	2.35
T4-2m	1.00	1.00	0.30	1.04	1.00	1.00	12.54	0.63	0.53	0.09

4. ECONOMIC EVALUATION OF PAVEMENTS

4.1. Outline of Economic Evaluation

The agency cost in this study is limited to the management and maintenance cost and the user cost is the sum of VOC (Vehicle Operating Cost) and the travelling time cost. VOC is calculated with purchasing cost, fuel cost, tire replacement costs, engine oil, part consumption and indirect expenses which are incurred by vehicle operation. As the basic concept for economic analysis, two cases were compared for analysis. In a road section which was changed from conventional to rut-resistant asphalt to suppress rutting, 1) the case of operating the road with the rut-resistant asphalt as present condition and 2) the case of operating in conventional pavement.

The standards of maintenance were set up individually for crack, rutting, and longitudinal roughness, applying maintenance method suitable for the type of damage. Costs are applied with the actual construction unit cost.

One of the most important factors in the economical analysis is the maintenance management standard. In this study, in order to find out economic indexes by pavement under various standards, analyses were conducted by increasing the IRI from 3.0m/km to 4.5m/km by 0.5m/km. Therefore, maintenance work will be carried out when the management standard of IRI or rutting (25.0mm) is reached according to the progress of the deterioration of the pavement surface.

The economic aspect can be evaluated with the serviceability estimation model by pavement which was estimated in the previous chapter. Long-term serviceability can be estimated by calculating correction coefficient from the actual pavement condition data (rutting, IRI, crack), and the economy of the rut-resistant asphalt was calculated with the result.

4.2. Results of Economic Evaluation

According to the economic analysis with the long-term serviceability of conventional and rut-resistant asphalts, for the case of 25mm rutting and 4.0 IRI, if agency cost only is considered, rut-resistant asphalt was more economical in all the sections except 4 sections than conventional pavement. If the total cost is considered, though the value varies as shown in the case of IRI 4.5, rut-resistant asphalt was more economical in 12 sections of the 22 sections.

However, it should be noted that, if the standard of maintenance is set at IRI level 3.0, that is, if the quality of pavement becomes better, the agency cost of rut-resistant asphalt increases in more sections (7 sections), and considering the total cost, rut-resistant asphalt is more economical in 16 sections of the 22 sections.

Table 2. Economic evaluation criteria

Item		Criteria		
Term of Analysis		40 years		
Maintenance	Cutting 50mm and Overlay 50mm	. Longitudinal Roughness 3.0~4.0m/km . Plastic deformation 25.0mm		
	Patching	. Wide structural cracking 10%		
	Crack Sealing	. Transverse thermal cracks 15 & Wide structural cracking 10%		
Cost (Won/m^2)	Cutting 50mm and overlay 50mm	Classification	Financial Cost	Economic Cost
		Ordinary	14,539	13,085
		SMA	17,681	15,913
		CRM	19,201	17,281
		PMA	17,123	15,410
		PBS	16,484	14,836
	Ordinary Maintenance	Patching	21,207	19,086
		Crack Seal	14,771	164,12
Social discount rate (%)		4.64%		

As was known by the site survey, above results can be understood that, rut-resistant asphalt is superior to conventional pavement in the aspect of rutting. In case of conventional pavement, maintenance is mostly carried out when the rutting reaches management standard. On the other hand, rut-resistant asphalt maintenance is mostly carried out when the IRI level reaches the management standard.

From the results of economic analysis, in all cases, except for rutting 25mm or IRI 4.5, rut-resistant asphalt is more economical. These results are a sum of the total costs for all 22 sections. If only the management cost is considered, rut-resistant asphalt is more economical than conventional pavement in all cases. Though the difference in the benefit according to the maintenance management standard, when rutting 25.0mm or IRI 4.0 was selected as the management standard in all the sections, $4.5 million for 40 years in the agency cost could be saved by rut-resistant asphalt. The total cost, including the user cost, $1.1 million for 40 years of relative benefit could be obtained.

Because rut-resistant paved sections were operated under the non-optimal condition, total benefit was too small in existing maintenance rule. It is a fact that road user cost is sharply increased in particular condition.

When rutting 25.0mm or IRI 3.5 was set up as the management standard, $4 million for 40 years relative benefit could be obtained for the management cost, and $13 million for 40 years relative benefit could be obtained in the total cost, proving that rut-resistant asphalt is more economical. It was discovered that this strategy is more economical than existing standard. However, this result does not include the socio-environmental costs, traffic jam cost by construction work, bypassing cost, and accident costs, and therefore, it is for the minimum economic analysis.

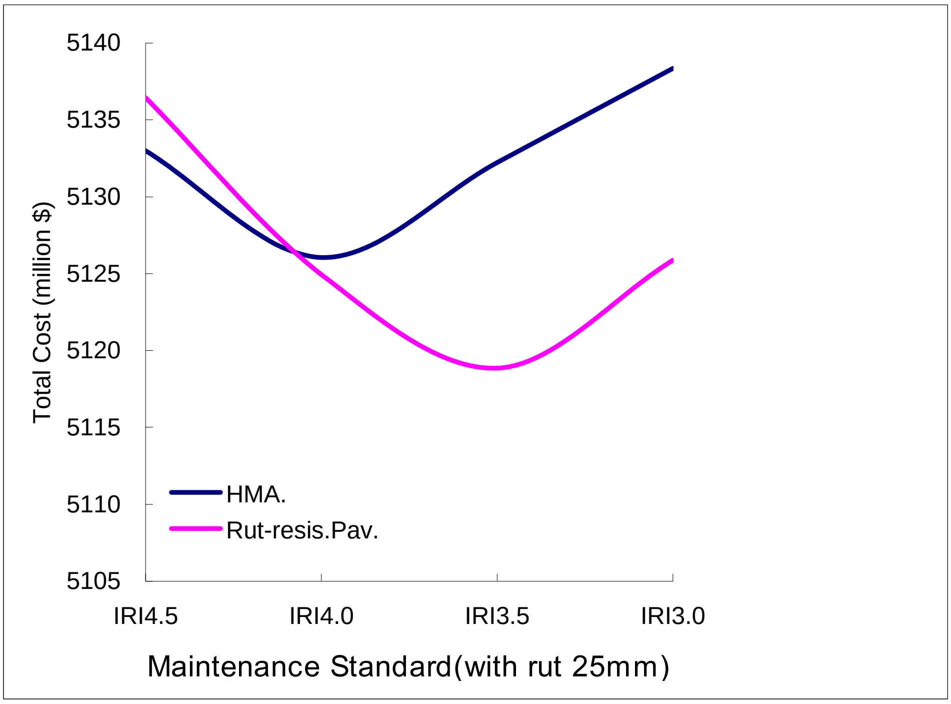

Fig. 1. Total cost according to the standard level (22 sections for 40 years)

Fig. 1 shows the trend of the total cost by management standard classified by conventional and rut-resistant asphalts. It shows that the optimal management standards of conventional and rut-resistant asphalts differ from each other.

The optimal maintenance standard minimizing the total cost is IRI 4.0m/km for conventional pavement and IRI 3.5m/km for rut-resistant asphalt. This can be analyzed that, as the speed of deterioration of rut-resistant asphalt is slower than that of the conventional pavement, the user cost greatly increases according to the lower standard of IRI.

In other words, since rut-resistant asphalt has a longer period of worse pavement quality than conventional pavement, the user costs exceed those of conventional pavement.

5. OPTIMAL MAINTENANCE TIMING AND BUDGET LEVEL

5.1. Decision of Optimal Maintenance Timing

The key factor in the pavement management system is the timing (or road condition) of maintenance, which can be represented by deciding budget level suitable for the optimal maintenance or preparation of optimal maintenance program. In HDM-4, decision of optimal maintenance timing and maintenance work program can be made by year and section according to the budget level using Program Analysis.

By setting up diverse maintenance plans for each section, agency and user costs operated and spent according to the maintenance standard for the analysis period can be obtained. On the basis of this result, NPV/Cost Ratio can be calculated for each maintenance plan, and in HDM-4, the priority order of maintenance is decided on the basis of the results. Here, the benefit is the reduction of user cost against Base Alternative (usually, the minimum standard is applied), and the cost is assumed to be the management cost. In this paper, the optimal maintenance times with reference to the individual section and network are presented.

When diverse alternative plans are decided for each road section, optimal alternative is selected by considering the management and user costs of each alternative. For maintenance alternative plans, multiple standards were set up through sensitivity type alternative considering the alternative applied in the economic analysis and the empirical service level. The selected alternative was based on the rutting and IRI which are the maintenance standard of PMS in Korea and the IRI which is the integral serviceability index in HDM-4.

The optimal alternative, when budget is not constrained, may vary according to the progress of deterioration by pavement types. When the deterioration speed is slow, as the period in high serviceability is long, better standard will be selected. If the deterioration speed is faster, the influence will be reduced even though relatively higher level is selected.

On account of space considerations, let me summarize the optimum maintenance timing in the condition of UDMS (Unconstrained optimal pavement Design and Maintenance).

The standard is a result of the unconstrained optimal maintenance program and if the budget level changes, the optimal time changes accordingly. If the results of conventional and rut-resistant asphalts are reviewed, the IRI was found to be optimal at 3.5m/km in most cases and for rutting, 25mm is adapted at more sections. That is why this research suggests the optimal maintenance level be 25mm of rutting and 3.5m/km of IRI.

The network-based optimal maintenance time is the time when the cost is lowest as a result of economic analysis by applying the identical maintenance standard to each section. Therefore it is rather different from the method of applying the optimal alternative for each section. This analysis enables us to find the identical optimal time by network or pavement and analyze the difference of the maintenance times by serviceability property (the deterioration rate).

The total costs, including the section length (102.71km in total), were compared and the comparison was conducted through 4 alternatives from 3.0m/km of IRI to 4.5m/km of IRI with the rutting at 25mm.

The conclusion of the economic analysis is as follows. Firstly, the optimum maintenance time of conventional pavement and rut-resistant asphalt is different. Here, the optimum maintenance time is the maintenance level where the total cost is lowest in the LCC analysis. That is, the IRI is optimal at 4.0m/km in case of conventional pavement and at 3.5m/km in case of rut-resistant asphalt respectively.

In addition, if the IRI of the standard level is 4.5m/km, rut-resistant asphalt proved less economical in the total cost in comparison with conventional pavement, but in other standard levels, rut-resistant asphalt was always more economically efficient than conventional pavement.

As explained in the previous chapter, it was discovered that the further from the optimal maintenance time in either direction, regardless of conventional or rut-resistant asphalt, the more the total cost is increases. This is because if the pavement quality is better (to the right) than at the optimal maintenance time, the agency cost greatly increases and if the pavement quality is worse than at the optimal maintenance time (to the left), the user's cost increases.

5.2. Performance according to Budget Level

Budget optimization is a methodology considering the administrator's position. If the budget for road maintenance is unlimited, the road will always be able to maintain the optimum level with necessary maintenance available at any time. However, it is realistically almost impossible to have enough budgets to maintain the optimal pavement state. With practical aspect taken into consideration, therefore, the budget optimization based on economic efficiency and a corresponding maintenance program can be said to be absolutely important in PMS operation.

The planning procedure of the budget optimization and a corresponding maintenance program is as follows.
1) selection of an alternative of the optimum maintenance of each section, 2) calculation of agency cost and user costs by applying the alternative of the optimum maintenance, 3) calculation of NPV/Cost ratios by maintenance operation, 4) decision of priority of maintenance operations, 5) decision of the budget at a feasible(or actual) level, 6) decision of the optimum maintenance time and work type according to the decided budget level, 7) decision of feasible operations(according to the priority), 8) making the program of the selected maintenance operations(program by year and section is also possible).

In this paper, the average longitudinal roughness by budget level in comparison with the required cost in optimum maintenance with the budget not allotted and NPV by pavement have been compared.

Table 3. IRI and NPV of HMA by budget level

HMA	60%	70%	80%	90%	100%
Budget (million $)	12.711	14.830	16.948	19.067	21.186
Average of IRI(m/km)	3.44	3.25	3.08	2.92	2.82
NPV (million $)	6.937	9.540	10.909	11.650	11.962

Table 4. IRI and NPV of rut-resistant pavement by budget level

Rut-resistant	60%	70%	80%	90%	100%
Budget (million $)	12.334	14.390	16.446	18.502	20.558
Average of IRI(m/km)	3.28	3.06	2.86	2.80	2.70
NPV (million $)	7.301	10.206	11.256	11.905	12.135

Tables 3 and 4 are a summary of the results of comparison of longitudinal roughness and NPV by budget level of pavement

The comparison shows that rut-resistant asphalt costs less than conventional pavement despite its high unit price when the required budget is 100% given. This is deemed to result from the difference of the standard level. Rut-resistant asphalt has also proven superior in the average longitudinal roughness and NPV by budget level.

It was indirectly found that the delayed maintenance due to an insufficient budget could result in a larger amount of budget through the analysis of the serviceability level and budget in this chapter.

6. CONCLUSTION AND FUTURE TASKS

This paper presented a way to build a decision-making supporting system for pavement maintenance by suggesting the optimum maintenance time and optimum budget level for efficient pavement maintenance and management. For the analysis, this research assessed the serviceability by alternative of conventional pavement and rut-resistant asphalt on the basis of the data on the pavement state (rutting, IRI, cracks) of 22 sections and past records of traffic volume. Furthermore, a method for calculating the correction coefficients was also suggested in order to apply the HDM-4, which is used worldwide for pavement management, to Korea.

As a result of the analysis of serviceability for 40 years, rut-resistant asphalt was found to have higher resistance against rutting and cracking than conventional pavement. IRI proved more or less different according to the interval. Despite some difference of benefits according to the maintenance and standard level, rut-resistant asphalt proved in general more economically efficient.

Furthermore, because there are differences between the optimum standard levels of conventional pavement and rut-resistant asphalt, the IRI of the optimum maintenance standard level was found to be 4.0m/km in case of conventional pavement and 3.5m/km in case of rut-resistant asphalt respectively. This is deemed to be because of the cost increase due to the traffic volume with rut-resistant asphalt deteriorating more slowly than conventional pavement and therefore the pavement quality being low. In other words, this paper showed that the serviceability of pavement is determined by a variety of factors including the traffic load, pavement quality and climate and so on and the economic efficiency is sensitive to the serviceability level and traffic volume.

The optimum maintenance time for efficient maintenance showed similar results for each type of pavement. Because the optimum maintenance time is determined by the pavement performance, traffic volume and deterioration rate at the same time rather than by the type of pavement, the pavement with high durability (against rutting and roughness) should be applied to the area where there is a lot of traffic and the optimum maintenance time must be found with the deterioration rate taken into account. In this regard, it is suggested that the optimum maintenance time should be when the IRI is 3.5m/km and rutting is 25mm in this paper.

With respect to the maintainable serviceability level according to the budget level, the more insufficient the budget is, in other words, the lower the budget level is, the more a base alternative the optimum maintenance method selectable at each section is, with the average serviceability gradually decreasing. It was also found that a higher serviceability level can be maintained with lower cost when compared with conventional pavement if the budget is restricted.

The most urgent research subject in the future is accumulation of analysis cases by increasing additional data on the long-term serviceability of pavements and it was determined that it is necessary to enhance the reliability of correction and application of HDM-4.

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