ROAD PAVEMENT MANAGEMENT ACCOUNTING SYSTEM APPLICATION

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Abstract: In this paper, a Pavement Management Accounting System application (in brief, PMAS application) is presented to control the life cycle costs of road pavement. The aim of the PMAS application is to provide the decision makers with the planning information regarding repair strategies and the accounting information on the asset values for the efficient asset management of road pavement. By comparing alternative accounting schemes, the authors conclude that the maintenance accounting is the best accounting scheme for the efficient asset management of road pavement. The PMAS for the asset management is constructed by applying the maintenance accounting scheme. The validity of the PMAS presented in this paper is investigated through case studies conducted for Mie Prefecture in Japan.

Key Words : *dynamic optimization, steady-state strategy, life cycle cost ,pavement management systemt*

1. INTRODUCTION

Since 1970, a variety of studies have been made on the Pavement Management System (PMS), which is designed to reduce the life cycle costs of road pavement at the project level and/or network level[1)-3)]. There are many uncertainties with regard to pavement depreciation, making it impossible to forecast accurately when a future repair will become necessary. It may be desirable to design state-dependent repair rules, i.e., to decide upon repair times while casually making observations of road pavement at the service level. In view of the uncertainties of pavement depreciation, the optimal maintenance model was presented using the Markov decision process[4)-8)]. Likewise, the optimal maintenance model with continuous-state was presented by use of financial engineering techniques[9)].

Recent studies on the asset management system of road pavement have aimed at reducing life cycle costs. Ideally, road pavement repair should occur when the expected life cycle cost is at a minimum. However, not only is a road manager often unable to secure a sufficient annual budget to execute optimum repair planning for all the road pavement under his supervision, but he also frequently cannot avoid limiting repair work within a certain year to only those road sections of the highest priority, postponing other necessary repairs until a later time. As the budget for public works changes significantly depending on economic policy or financial status, the budget for repair also changes. As is the case with most infrastructure in the case of road pavement, when a necessary repair is deferred temporarily, the effects do not immediately appear. When the budget of public works is fixed at a certain amount and expenses are increased for the repair field, the amount that can be invested in new projects is reduced. Accordingly, a preference for executing new business projects may uniformly reduce or delay the dispersal of the budget resources necessary for maintenance. Deferred repair work must be performed at a certain point in time; otherwise, there develop a backlog of sections to be repaired and an overall degradation in the service level of the infrastructure.

For road pavement management, it is important both to assess whether repairs are being continuously executed which maintain the functions of road pavement, and to construct a management accounting system, which automatically adjusts the budget to maintain an appropriate service level[10)]. In this paper, a Pavement Management Accounting System (PMAS) is presented for the road managers of local governments who wish to execute rational repair by referring to asset management

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information regarding road pavement. The PMAS is comprised of the following: 1) Pavement Management Accounting (PMA), to record changes in the asset price of road pavement and assets (or debts) during the fiscal year; and 2) a Maintenance Management System (MMS), to determine the repair strategies of road pavement with regard to the execution budget during the fiscal year. The results of repairs in a certain fiscal year are counted as increases in assets (or decreases in debt) in the corresponding year, and such information is used as a basic tool in managing the budget for repairs of road pavement in the following fiscal year.

2. MOTHODOLOGY OF THE RESEARCH

(1) The Roles and Structure of PMAS

Many road management agencies have tried to estimate the demand for road pavement repair. In many agencies, however, there is a lack of data concerning the estimation of road pavement deterioration. To forecast the demand for repair in the future, a method has been devised using time series data from the results of road pavement repairs in the past, while making assumptions about the useful life of road pavement referenced from information regarding such repairs. However, the disadvantage of using information about repair from the past is that the budget level for repair does not take into account the entire life cycle costs of the road pavement. Also, there is the disadvantage that it cannot be forecast clearly to what degree the service level of road pavement will be degraded in the future if resources for repair are insufficient.

It is necessary to manage appropriately accounting information in order to determine a budget for investment on repair that will be necessary at a certain point of time in the future, so that the service level of road pavement can be maintained over a long time. Although short period changes in budget for repair may be allowed, management accounting systems need to be fixed so that stable resources for investment on repair are available in the long term.

The PMAS presented in this paper is aimed at providing accounting information that will automatically procure the resources necessary for maintaining the service level of road pavement while assessing whether the repair is sufficiently realized for maintaining the service level of road pavement via the valuation of road pavement assets. In the construction of the PMAS, the budget for road pavement repair is an important policy

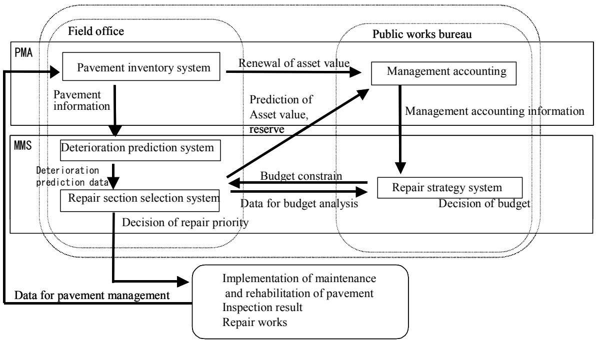

Fig.1 PMAS composition

parameter. It is especially important in acquiring a budget level at which the expected life cycle costs can be reduced as much as possible while maintaining the pavement service level of the entire road network. The MMS constructed in this paper determines road repair strategies to reduce expected life cycle costs as much as possible. Furthermore, the PMAS is presented for efficiently executing repair work management as well as repair budgeting management, to be documented at the PMA, describing road pavement management accounting information for each fiscal year.

Consider the repair work of a local government in charge of the asset management of road pavement. The entire configuration of the PMAS is as shown in **Fig. 1**. The PMAS is comprised of the following: 1) a PMA that is to record changes in assets (or debts) during the fiscal year and the changes in asset prices of road pavement; and 2) an MMS that is to devise the repair strategies of road pavement documented in the execution budget during the fiscal year. Furthermore, the PMA is comprised of the following: a) a pavement inventory system that is to record the status of road pavement in each road section; and b) management accounting that is to record the asset prices of road pavement and any changes thereto. The MMS is comprised of the following: a) a deterioration estimation system that estimates the deterioration process of road pavement; b) a repair section selection system to determine the priorities of the repair section based on the forecasted value of the deterioration level; and c) a repair strategy system of road pavement that provides basic information for review on the budget for repair in each fiscal year, including decisions on the budget for road pavement repair.

The pavement inventory system encompassed by the PMA is a database of management inventory regarding road pavement. The following are recorded regarding the pavement in each road section as part of the pavement inventory system: technical status, past repair history, past inspection history, pavement level measured during inspection (ratio of split, rutting amount, smoothness, etc.), service level, and traffic volume measured through traffic census. The road pavement service level is described as a Maintenance Criteria Index (MCI) value formulated by the Ministry of Construction of Japan. Furthermore, the information that is recorded in the pavement inventory system is amended sequentially whenever such information is acquired by actual inspection, new measurements of value including that of service level, or observation through repair work.

Meanwhile, the management accounting contained in the PMA is to describe the asset price of road pavement in the fiscal year, the result of the assessment of repair demand, and the road pavement's history. In management accounting, the road pavement service level and asset status in the corresponding fiscal year for each road section are recorded, and accounting information for individual sections is summed up for the entire road network. The functional obsolescence of road pavement is an uncertain process, and it is impossible to forecast clearly the level of deterioration at a certain point in the future. Thus, if a value measured by actual inspection is acquired, asset management information for each road section is added, referred to as a new MCI value. Most of the actual inspection of pavement is executed at specified time intervals, and up-to-date MCI values are not acquired in all fiscal years. In this case, it is necessary to estimate the MCI value and asset status in the corresponding fiscal year found in the past measured value information recorded for the pavement inventory. Meanwhile, the MMS sets the priorities for repairs while extracting the road section that requires repair within the corresponding year referenced at the PMA information. When the budget limit is given for the corresponding year, the repair target sections are selected and repair is executed in the corresponding year. The PMA is renewed, revised according to the results of repair.

(2) Management Accounting

Although the PMAS is aimed at contributing to the efficient asset management of road pavement, management accounting information is required to formulate repair planning for road pavement in the future as well as to assess the asset value of road pavement in the corresponding fiscal year attendant on new improvement of roads in the past. Accordingly, with the PMAS, it is necessary to conduct accounting on an accrual basis that is aimed at understanding clearly the demand for road pavement repair via the assessment of road pavement assets.

Road pavement has the following characteristics: 1) it is a public good comprising infrastructure for social and economical activities; 2) its service level, although lowered with long-term use, should be maintained through repairs; and 3) it requires appropriate management from planning to maintenance. The PMAS is aimed at a budget management to keep the service level of road pavement above a certain level by the road manager, and it should be able to recognize and assess the generation of costs corresponding to life cycle. Although there may by a variety of costs in response to the life cycle of a road facility, this paper will focus on the repair cost required to maintain the service function of road pavement at a given level from the standpoint of the operator of the road facility already being used.

For the valuation of assets of road pavement, taking into account the difference in concepts about depreciation, the following three types of accounting methods may be defined: 1) renewal accounting; 2) deferred maintenance accounting; and 3) depreciation accounting[11]. In renewal accounting, the expenses for asset use are decided with the amount spent on renewal. Also, depreciation of assets is not undertaken, supposing that the maintenance required for road pavement is always performed, and that therefore the initial service level is always maintained. Renewal accounting assumes that road pavement always retains its initial level, but in reality the service level of road pavement is lowered due to the transit of vehicles, and the initial service level may not remain intact. In renewal accounting, accounting information on the actual asset price of road pavement is not shown on the balance sheet. Shown only is accounting information related to deferred costs of the renewal costs that should have been spent in the past. Accordingly, in renewal accounting, accounting information on the asset price of road pavement during a fiscal year cannot be provided.

Deferred maintenance accounting is determined as the expected cost for asset use to maintain the corresponding asset system. In deferred maintenance accounting, total maintenance costs are calculated with regard to long-term asset management planning, at the same time allocating to each year the total amount of costs. By calculating appropriate repair time and repair costs with a technological review of all road sections, maintenance reserves brought forward from the previous account in each year are carried over to the category of expenses. In deferred maintenance accounting, a decrease in asset price due to aging of road pavement is shown in management accounting as deferred maintenance reserve and deferred insufficient maintenance reserve, so that the asset level in each fiscal year can be assessed.

Depreciation accounting is decided by the calculation of service provision capability at which expenses for asset use are spent. To accomplish depreciation, asset values are allocated with regard to a certain rule during durable years of road pavement. The depreciation cost that is appropriated as cost every term is not actually spent in the corresponding term. To recognize the cost that is not actually spent as a cost in accounting statements, the total of depreciation cost may be regarded as reserve for future repair. However, legal durable years of road pavement are often inconsistent with the physical and functional useful life of actual road pavement. When calculating depreciation cost using durable years in taxation, there is no assurance that the total of depreciation cost is consistent with the cost required for repair. In such a case, we may not acquire appropriate information on the propriety of maintenance cost, even though we directly compare the maintenance cost every year with the depreciation cost for acquisition cost. To secure accountability in financial accounting for the aging of assets, SFFAS No.6 regulates that deferred maintenance cost should be recorded in financial statements with footnotes[12)]. The purpose of the PMAS is to perform maintenance budget management of road pavement, and the useful life of road pavement should be set appropriately so that the depreciation cost to be generated every year is approximately consistent with maintenance cost acquired as a result of technological review. However, it cannot be decided how much maintenance cost is to be spent each fiscal year, only with the information on the total of depreciation cost. In case road pavement is managed for its assets using depreciation accounting, the asset value of desirable road pavement that should be maintained over a long-term period is necessarily defined separately.

If depreciation cost is appropriated using durable years for which technological review was made and if maintenance asset price and stock management level of road pavement in a fiscal year are recorded, the required management accounting information may be acquired, using any of the methods of renewal accounting, deferred maintenance accounting, or depreciation accounting. However, from the point of view of the easy accessibility of accounting information, deferred maintenance accounting seems to be the best.

3. CONSTRUCTION OF PMAS

(1) MCI Management Level

It is theoretically possible to forecast the deterioration process of pavement by examining the MCI inspection records of the past. In the existing inspection data, such data as different measuring points by year was not constructed, nor was data recorded with respect to estimating deterioration process to a high degree. Accordingly, deterioration process should be described with a simple deterioration model, where it is supposed that the measuring MCI value for a road section in year t is $z(t)$. The estimated value of MCI in year $t+\tau$ may be expressed as follows:

$$z(t+\tau) = z(t) - \psi\tau \qquad (1)$$

, where ψ is the average falling-off amount of MCI in the corresponding road section for one year. Real deterioration process is uncertain, and it is impossible to forecast the deterioration process that actually takes place. Equation (1) presents an expected value pass that is expressed by the expected value of MCI at each point in time. In this application example, ψ in every road section was presented with reference to the MCI value at the point of past repair and at the point of inspection immediately prior to repair. The annual MCI drop in road pavement managed by Mie Prefecture was on average 0.2 or so. Expected life cycle costs can be minimized by executing repair work at the point in time when the MCI value reaches some critical level (referred to as the MCI management level in this paper). Suppose that pavement is repaired at the initial point in time, $t=0$ and MCI value is returned to Z. Also suppose a rule stipulating that repair work is performed again when the MCI value of pavement reaches $z(\theta) = z^o$ after θ years have passed from the initial year. The repair cost which is required to recover MCI from z^o to Z is denoted by $F(z^o)$. Suppose the expected life cycle cost in the case the initial MCI value is Z is defined as $J(Z;z^o)$, then the expected life cycle cost $J(Z;z^o)$ may be expressed as follows using recurrent property:

$$J(Z;z^o) = \sum_{t=0}^{\theta(z^o)} \frac{c(z(t))\beta}{(1+\alpha)^t} + \frac{F(z^o)}{(1+\alpha)^{\theta(z^o)}} + \frac{J(Z;z^o)}{(1+\alpha)^{\theta(z^o)}} \qquad (2)$$

, where $c\left(z\left(t\right)\right)$ is user cost when MCI value is $z\left(t\right)$, β is annual average traffic volume, $\theta\left(z^{\circ}\right)$ is time interval (year) from the corresponding year to the year when the first repair is performed. That is, the first term on the right side expresses the present value of total user cost that is generated up to the repair point of the next time, the second term expresses the present value of repair costs at the next point in time, and the third term expresses the present value of expected life cycle costing that is generated by executing optimal repair the next time. Arranging the above equation for $J\left(Z;z^{o}\right)$ produces the following:

$$J\left(Z;z^{o}\right)=\left\{1-\frac{1}{\left(1+\alpha\right)^{\theta\left(z^{o}\right)}}\right\}^{-1}\times\left\{\sum_{t=0}^{\theta\left(z^{o}\right)}\frac{c\left(z\left(t\right)\right)\beta}{\left(1+\alpha\right)^{t}}+\frac{F\left(z^{o}\right)}{\left(1+\alpha\right)^{\theta\left(z^{o}\right)}}\right\} \tag{3}$$

In equation (3), expected life cycle cost changes according to MCI value z^{o} at the time when repair is performed. Using one-dimensional direct searching method allows calculation of MCI management level z^{o} that renders $J\left(Z;z^{o}\right)$ as the minimum. Suppose that z^{o}, creating the minimal expected life cycle costing, is considered the MCI management level, and is expressed as z^{*}. The MCI value measured at the present point in time $t=0$ is z, and the expected life cycle costing that is achieved in a case where the repair of pavement is performed at optimal timing referenced at MCI management level z^{*} hereafter may be expressed as follows:

$$J\left(z;z^{*}\right)=\sum_{t=0}^{\hat{\theta}\left(z^{*},z\right)}\frac{c\left(z\left(t\right)\right)\beta}{\left(1+\alpha\right)^{t}}+\frac{F\left(z^{*}\right)}{\left(1+\alpha\right)^{\hat{\theta}\left(z^{*},z\right)}}+\frac{J\left(Z;z^{*}\right)}{\left(1+\alpha\right)^{\hat{\theta}\left(z^{*},z\right)}} \tag{4}$$

$\hat{\theta}\left(z^{*},z\right)$ is average period which MCI becomes to its management level z^{*} from the year when MCI value is z.

(2) Cost-Benefit Rule

The benefit of repair work on a certain road section is defined as the difference between expected life-cycle costs in the case of repairs deferred until the following year, and expected life-cycle costs acquired in case optimal repair is performed using the MCI management level. Let us denote the expected life cycle cost in a case where repair is deferred for one year by $\tilde{J}\left(z\right)$, and the expected life cycle cost in a case where repair occurs at optimal timing year by $J\left(Z;z^{*}\right)$. Then, the benefit of repair work is defined as $\tilde{J}\left(z\right)-J\left(Z;z^{*}\right)$. Then, the cost-benefit ratio (B/C) of repair work on pavement in the corresponding year t can be expressed as follows:

$$\left(B/C\right)=\frac{\tilde{J}\left(z\right)-J\left(Z;z^{*}\right)}{F\left(z\right)} \tag{5}$$

$$\tilde{J}\left(z\right)=c\left(z\right)\beta+\frac{F\left(z\left(t+1\right)\right)}{\left(1+\alpha\right)}+\frac{J\left(Z;z^{*}\right)}{\left(1+\alpha\right)}$$

Using the cost-benefit ratio formulated above may determine the order in which maintenance should be carried out under a limited budget with the practical method outlined in the following sequence.

1) Determine the lowest MCI level $\underline{z}$ to repair.
2) Extract the section that reaches $\underline{z}$ as the highest priority section.
3) After calculating cost-benefit ratio (B/C) for all road sections, select the section of the highest (B/C) among sections where cost-benefit ratio is (B/C) > 1.
4) Determine the section where repair should be performed within the scope of budget constraints, referring to the priority decided by the steps listed above.

Thus, a desirable repair order of pavement may be calculated approximately in cases where budget constraint exists.

(3) Accounting for Road Pavement

It is necessary for pavement management to establish PMA which clearly express state of pavement service level on balance sheet, according to inspection, expensed repair cost and expected repair cost for maintaining pavement service level in fiscal year[15),16)]. There are three kind of accounting method 1) renewal accounting, 2) deferred maintenance repair accounting, 3) depreciation accounting. Among these accounting system, in deferred maintenance repair accounting, cost about asset use is estimated by technical study to maintain concerned assets[17)-19)]. The other accounting method cannot express accounting information based on technical study in balance sheet[26)-29)]. Therefore, this research use deferred maintenance repair accounting shown in **fig.2**. This figure shows trial balance which integrates balance sheet and profit-loss statement to express the balance between the flow and the stock[24)]. In this figure only the information which has relation to

Asset	Liabilities
Fixed asset S_2	Deferred lacked maintenance repair reserve B_2
Deferred maintenance repair reserve $\varDelta D_2$	Equities
	Revenue
Expenditure	
Deferred maintenance repair reserve transfer A_2	
Deferred additional maintenance repair reserve transfer E_2	

Fig.2 Trial balance of balances of deferred pavement management is described.

Deferred maintenance repair accounting calculates total repair cost base on a long term asset management plan, and allocates its total cost to every year. Repair cost of each road sections which is calculated in technical study is transferred into "Expenditure" as deferred maintenance repair reserve transfer A_2 Suppose that expensed repair cost of fiscal year is C_2, if $A_2 - C_2$>0, then the balance is recognized as "Liabilities", and transferred into deferred maintenance reserve D_2 , (or transferred into asset part as negative deferred maintenance repair reserve). When deferred maintenance repair reserve of the end of former period is $\overline{D}_2$, deferred maintenance repair reserve of the end of this period is revised as $D_2 = \overline{D}_2 - C_2 + A_2$. On the other side, if $A_2 - C_2$<0, deferred maintenance repair reserve decreases. Suppose the case in which repair of a road section is deferred and larger-scale repair becomes necessary than that of the optimal case. Then, deference between optimal repair cost and larger-scale repair cost is defined as additional repair cost. Additional repair cost of fiscal year is transferred into "Revenue" as deferred additional maintenance repair reserve transfer. When additional repair cost F_2 is expensed, $E_2 - F_2$ is transferred into "Liabilities" as deferred lacked maintenance repair reserve B_2. Lacked maintenance repair reserve is $\overline{B}_2$, deferred maintenance repair reserve of the end of this period is revised as $B_2 = \overline{B}_2 + E_2 - F_2$. Asset value of pavement S_2 is evaluated by historical value or current value. In deferred maintenance repair accounting, decrease of asset value due to pavement deterioration is expressed as reserve on balance sheet, and pavement asset value of every fiscal year can be evaluated.

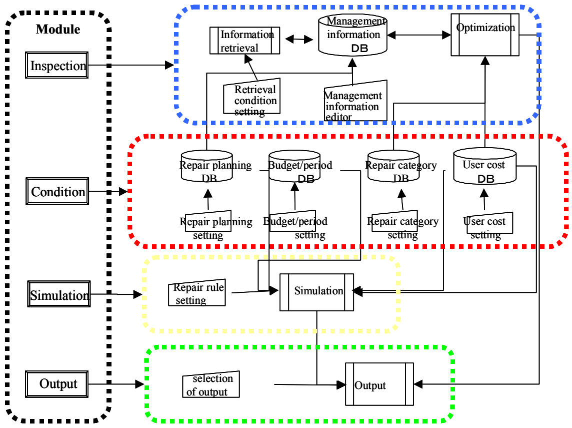

Fig.3 PMAS application

4. DESIGN OF APPLICATION SYSTEM

(1)Outline of Application System

This research designs an application system for road pavement, based on PMAS proposed above section (see **Fig.3**). The application system is constructed by "Visual Basic.Net" and "Microsoft Access", which are usually available on personal computers.

(2) Inspection Inventory Module

The road facilities in Mie Prefecture are divided into a total of 35,540 sections with one section as 100m. Information on road pavement for each road section is arranged in pavement inventory, and periodic inspection on surface status is executed, to measure the MCI index in each unit section. The latest available MCI data are surface condition examination results taken from 2000 to 2002, and the data for MCI values in each section at the time of March 2003, which was estimated referenced at the former. The inspection inventory module (see **fig.4**) plays a role as the database which stores management information such as specification data of each section, cost data of repair methods and MCI management level, which is also calculated in this module. The results of inspection are recorded in the database. This module has a search function that can extract management information such as specification data of each section and MCI management level, which is calculated by the methodology proposed in **3(1)**.

(3) Condition Setting Module

An object of the condition setting module (see **fig.5**), is to set and store the input data to use for a simulation in the application. The input data for simulation are repair category, the pavement repairing cost, a user cost and a year repair budget of fiscal year. These input data can be altered by a system user. The repair method that should be applied for each road section is specified by using

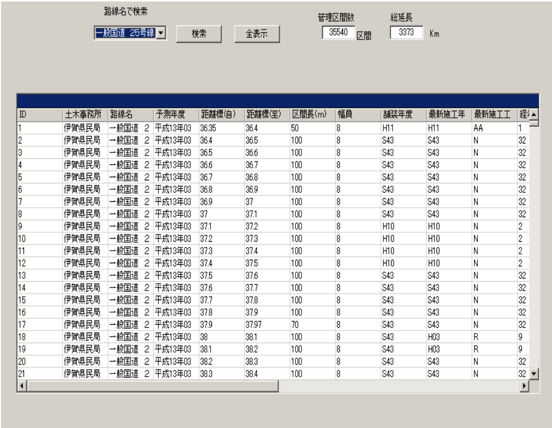

Fig.4 Inspection inventory module

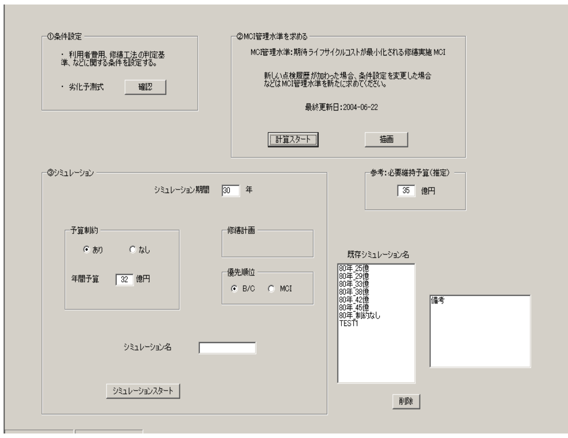

Fig.6 Simulation module

Fig.5 Condition setting module

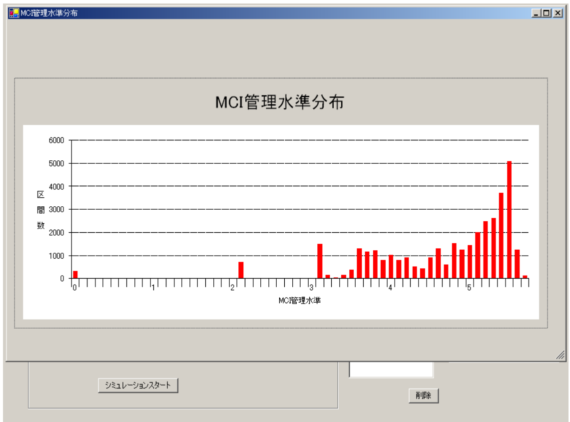

Fig.7 Output module

repair category (see **Table 1**in the M&R manual of Mie Prefecture. A pavement repair unit cost is shown in **Table 2**. In this application, a simulation is executed according to repair category and the pavement repair unit cost. User cost can be also specified by a system user. Repair budget of fiscal year is used in the repair investment simulation by the network level which is executed by the simulation module.

(4) Simulation Module

In the simulation module (see **Fig.6**), network level investment simulation is executed by two types of repair rules. One is the priority rule based on cost/benefit ratio, the other is the priority rule based on low MCI value. In the simulation module, repair activities for 100 years are simulated based on pavement deterioration and repair rules for some repair budget cases. According to these simulations, the relationship between repair budget scenario, life cycle cost and service level of road pavement can be analyzed. When annual repair budget is fixed for long period, this module can calculate repair budget which can decrease life cycle cost as low as possible and can maintain service level of total road network. In deferred maintenance repair accounting, this budget is equal to deferred maintenance repair reserve transfer. In this way, simulations under budget constrain are executed to calculate management accounting information by using management level z^* of each road section calculated in Inspection Inventory module.

(5) Output Module

This module (see **Fig.7**) makes figures of results of the inspection inventory module and the simulation module. From these figures, it is possible for road management agencies to specifically grasp the result of the M&R activities, the changes of service level and M&R investment demand in some budget scenarios.

5. AN EMPIRICAL STUDY

In this research, PMAS application is applied for the

Table 1 Repair category of Mie prefecture

classification	MCI devision	Repair works
1-1	3.5＜MCI 2.0＜MCI≦3.5 MCI≦2.0	Overlay Cut overlay replacement
1-2	3.5＜MCI 3.0＜MCI≦3.5 MCI≦3.0	Overlay Cut overlay replacement
2-1	3.0＜MCI 2.0＜MCI≦4.0 MCI≦2.0	Overlay Cut overlay replacement
2-2	3.5＜MCI 3.0＜MCI≦3.5 MCI≦3.0	Overlay Cut overlay replacement

management problem of road pavement in Mie Prefecture. First, annual MCI decline quantity is calculated in the inspection inventory module. As a result, it was proved that the average annual MCI decline quantity was about 0.2. Second, repair category (**Table 1**), the pavement repair unit cost (**Table 2**), and user cost (**Fig.8**) are input in condition setting module.

MCI management level of each road pavement section calculated by the way proposed in **3.(1)**. **Fig.9** shows distribution of MCI management level of each road section in whole road network.

Fig.10 shows the result of repair cost of each year, under the scenario to implement a repair as the MCI value of each road section reaches MCI management level. In this case, over 20.0 billion yen is expensed in first year. This is because a lot of section where the MCI value of present state falls below the MCI management level. The service level recovers to optimal level. Then, the condition of the pavement is maintained with 4.3 billion yen per a year.

When repeating repair at the MCI management level, life cycle cast can be minimized, repair cost in each year fluctuates. For mid-and-long term budget analysis, it is desirable to seek the budget which decreases life cycle cost as much as possible under the constant budget constraint. **Fig.11** shows relationship between annual budget and the life cycle cost. This figure shows that 4.6 billion yen per a year gives minimum lifecycle cost. **Fig.12** shows 100 year transition of average MCI values under the budget constraint which is 4.3 billion yen per a year and 4.4 billion yen per a year. When budget constraint is 4.4 billion yen per a year, average MCI value is maintained for 100 years. But when budget

Table 2 Unit repair cost

Repair works	Traffic division	Unit cost (yen/m^2)
Overlay	L	3,300
	A	3,300
	B	3,300
	C	3,750
	D	3,750
Cut overlay	L	4,500
	A	4,500
	B	4,500
	C	4,950
	D	4,950
Replacement	L	8,700
	A	11,250
	B	15,300
	C	19,800
	D	19,800
Replacement (Low cost re-pavement)	L	6,900
	A	9,000

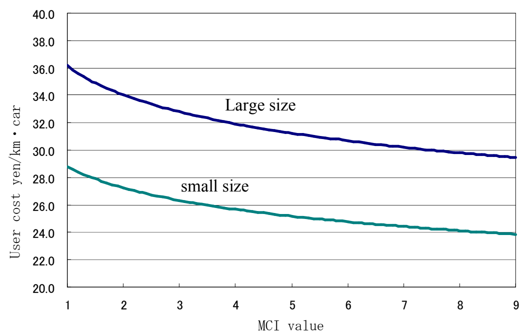

Fig.8 User cost

constraint is 4.3 billion yen per a year, average MCI value is not maintained. Therefore, 4.4 billion yen is the minimum budget which can maintain pavement service level. Based on above technical study result, management accounting information is calculated. **Fig.13** shows transition of the sum of deferred maintenance repair reserve and deferred additional maintenance repair reserve (call this sum "total deferred maintenance repair reverse"). Average MCI value is also plotted in the figure. As shown in this figure, total deferred maintenance repair reserve decreases until 2026, because both deferred maintenance repair reverse and deferred additional maintenance repair reverse is expensed every year. After 2027, total deferred maintenance repair reverse maintains 29.6 billion yen for long term. In the steady state, total deferred maintenance repair reserve is defined as stock management level in the case that annual repair cost is equivalent to normal

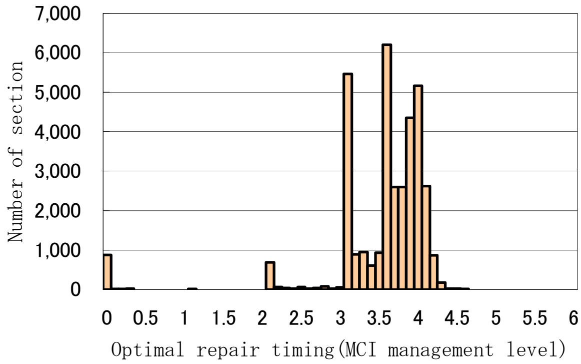

Fig.9 Distribution of MCI management level

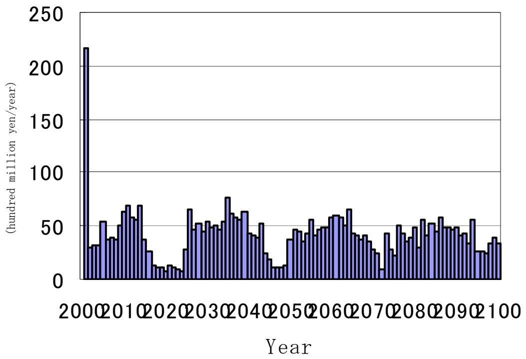

Fig.10 Transition of repair cost in optimal case

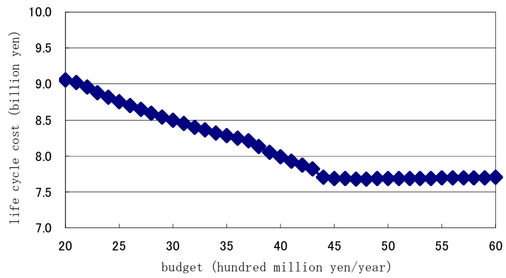

Fig.11 Budget and life cycle cost

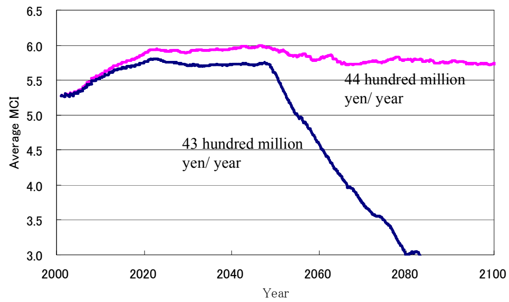

Fig.12 Transition of average MCI for 2 budget cases

deferred maintenance repair reserve. Stock management level is 29.6 billion yen, and average MCI value is maintained about 6.7. Long term average MCI value is defined as average MCI management level, then average MCI management level is 6.7 in this case, and average MCI value is 5.7 in 2002, is lower than average MCI management level. The budget manager can make budget control of road pavement efficiently based on such information. According to the result, the annual repair sections are selected at the same time. **Fig.14** shows a selected repair section list. The field manager can select repair sections according to this information.

6. CONCLUSION

In this paper, it developed the PMAS application for efficient road pavement management and it verified the availability to the road pavement managed by Mie Prefecture. It found that this application could become a very influential tool more from the pavement management in the on-site level to resulting in higher rank budget control as a result of the verification.

Some problems that should be resolved in order to improve the reliability of the PMAS application still remain. First, it is required to develop such a system as the deterioration model can be automatically generated from the inspection data of the road pavement. Mie Prefecture divides road facilities over 3,372.66km of total length into 35,540 sections (the basic section of which is 100 meters) and manages them. When estimating in the deterioration using the latest inspection data, the latest inspection data are added and the deterioration forecast is estimated again. It is tiresome to do these works manually, and lots of time must be spared only by that process. Therefore, it is needed that this work be automated. Second, deterioration process in this application is deterministic, but it is very difficult to predict future condition state of road pavement, due to uncertainty of pavement deterioration. When deterioration process is stochastic by considering uncertainty, there is possibility to take a lot of time for network level calculation. Therefore, the application system which can execute efficient calculation must be developed. Third, it is necessary to design application system which is easier to handle and enables to share management information between every level of system users. Fourth, the database system in this application is

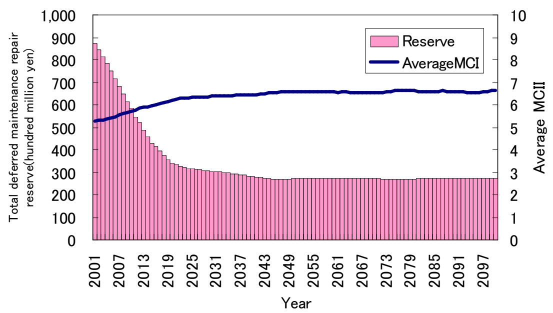

Fig.13 Transition of total deferred maintenance repair reserve

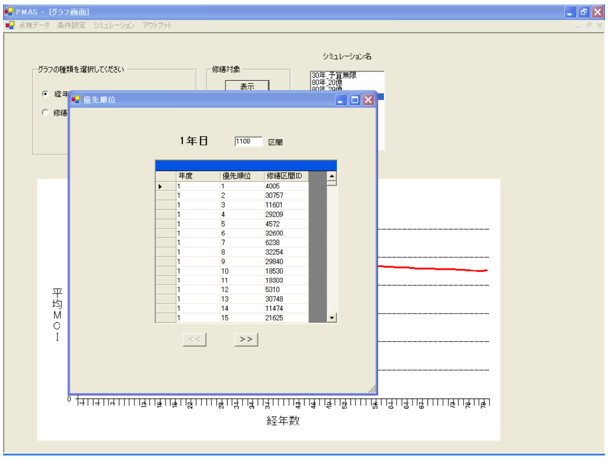

Fig.14 Repair priority

regarded as electronic inventory system. The information on the circumstance and underground facilities in surrounding area must be considered for road pavement management. GIS is efficient tool for such broad road management.

REFERRENCE

1) Hass, R., Hudson, W.R. and Zaniewski, J.P.: *Modern Pavement Management*, Krieger Publishing Company, 1994.

2) Hudson, W.R., Hass, R. and Uddin, W.: *Infrastructure Management: Integrating Design, Construction, Maintenance, Rehabilitation and Renovation*, McGraw-Hill, 1997.

3) Herabat, P., Amekudzi, A., and Sirirangsi, P.: Application of cost approach for pavement valuation and asset management, Transportation Research Record 1812, TRB, National Research Council, Washington, D.C., pp.219-227, 2002.

4) Howard, R.A.: *Dynamic* Programming *and Markov Processes*, John Wiley & Sons, New York, 1960.

5) Butt, A.A., Feighan, K.J. and Shahin, M.Y.:Pavement performance prediction model using the Markov Process, Transportation Research Record 1123, TRB, National Research Council, Washington, D.C., pp.12-19, 1987.

6) Carnahan, J.V., Davis, W.J., Shahin, M.Y., Keane, P.L., and Wu, M.I.: Optimal maintenance decisions for pavement management, *ASCE Journal of Transportation Engineering*, Vol. 113, pp. 554-572, 1987.

7) White, D.J.: *Markov Decision Processes*, John Wiley & Sons, New York, 1993.

8) Solberg, J.:*Rewards on Markov Chains*, Course handout, Purdue University, West Lafayette, Indiana, 2002.

9) Kurino, M., Kobayashi, K. and Watanabe, H: Optimal repairing rules under uncertainty, *Journal of Infrastructure Planning and Management*, No.667/IV-50, pp.1-14, 2001.

10) Federal Highway Administration and the American Association (FHWA): Primer: GASB 34, Rep. No. FHWA-IF-00-010, Washington D.C., 2000

11) Ingram, R.W. and Baldwin, B.A.: *Financial Accounting Information for Decision, 4E*, South-Western College Publishing, 2001

12) Federal Accounting Standards Advisory Board (FASAB): *Accounting for Property, Plant, and Equipment*, SFFAS (Statement of Federal Financial Accounting Standards) No.6, para.77-84, 1996