The Asset Management on the Road Pavement

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ABSTRACT: This paper reports a maintenance management method and the best operation and maintenance techniques for the public facilities such as road pavement.

On the major roads, this paper proposes an approach to create a thorough scenario for surface management without damage on the roadbeds, and conduct the classification on the road sections to early, routine and long-term deterioration sections by analyzing pavement surface characteristics survey data of the past fiscal years, and make a basic guideline for improving the quality of pavement by executing different maintenance management techniques for different road sections.

As for the community roads, the specific maintenance index LMI is created and set their pavement life to 44 years. The earlier detection of road sections needed to repair and the thoroughness repair at the early stage are the necessary measures to co-operate with the enterprises who occupies the roads in order to renew the road pavement space.

KEY WORDS: Asset management, MCI, LMI, pavement surface characteristics survey.

1 OPENING REMARKS

In fiscal 2005, the Nagoya City Greenification and Public Works Bureau began formulating the “Fundamental Policy on Plans for Optimal Maintenance of Public Facilities” as its asset management policy. To perform maintenance and renewal more efficiently and appropriately than in the past, management will be based on optimal maintenance plans created for each facility. This document is a report of the results of studies carried out from fiscal years 2007 to 2008 regarding ideas on future maintenance and optimal maintenance methods for the main structure of pavement and all of the facilities they comprise (hereafter referred to as “target facilities”).

2 METHODOLOGY OF THE STUDY

The study process of the asset management on the road pavement is as follows.

A process 1. The studies were carried out after a target maintenance policy was decided upon, in order to develop a direction for pavement maintenance for the City of Nagoya to aim for from a long-term perspective. A process 2. The current condition of pavement and actually generated deterioration are grasped correctly. A process 3. Cautions are required to set up a deterioration prediction formula. That is, it is investigating and analyzing by what kind of mechanism the causality of an accrual of deterioration and the performance of base course being influenced.

Below, the method is described about the major roads and the community roads.

3 UNDERSTANDING THE CURRENT CONDITION OF TARGET FACILITIES

Efforts were made between 2004 and 2007 to inspect and analyze the target facilities. Following the results of these studies, a goal was set to decide on mindset, goals, procedures, and methods, and develop a feasible plan for optimal maintenance of pavement for shifting to an optimal maintenance method from the ones currently in use.

The current situation (quantity and quality) of pavement (major roads and community roads) was made clear in the aspects of maintenance, repair, inspection status, and cost of maintenance. Issues resulting from continued use of current management methods were sampled and summarized. Also, in 2006 and 2007, the City computerized its checklists (20,591 checklists for pavement on community roads) and organized the data.

3.1 Understanding the current condition of pavement

Definitions were set for “major roads” and “community roads” for understanding the current situation.

Major roads are defined as national routes, principal and normal prefectural highways, and principal and normal city streets with a minimum width of 14 meters.
Community roads are defined as normal city streets less than 14 meters wide.

(1) Maintenance condition of pavement

①Pavement on major roads

The pavement rate for major roads was more than 99% in 1980, 12 years before the pavement of all of the city’s roads was completed including community roads.

②Pavement on community roads

In 1975, the pavement rate was 48.7%, lagging behind other cities comparatively. As a result of efforts to improve the percentage of paved roads through the use of inexpensive soil pavement beginning in 1976, the pavement ratio reached roughly 90% by 1981. Since then, the roads have been upgraded to a pavement composition that can stand up to full-scale traffic loads.

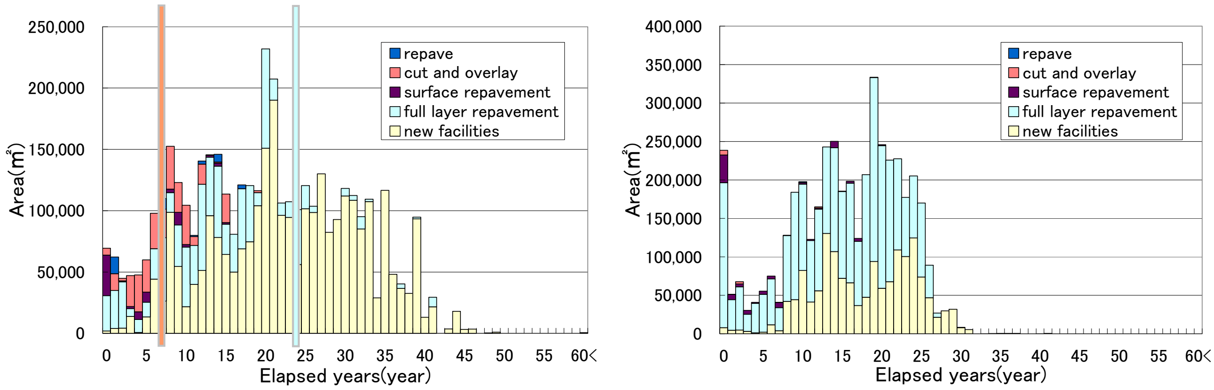
(2) Repair condition

①Pavement on major roads

Utilizing repair records from the Road Information Management System operated by the City, focus was given to areas which had been repaired more than once. The method used for the most recent repair and the time period from two repairs ago to the most recent repair were sought and divided into 5 construction types including new facilities and were aggregated with area (in m^2) as the base.

The type of construction carried out two repairs ago helps us understand the pavement’s useful life. Chiefly, we can see that some repair work is being carried out after 7 years for

overlay-type repairs, and after 24 years in the case of new facilities (see figure 1).
②Pavement on community roads
Regarding the state of repair of community road pavement as seen from records, it is clear that many roads have one layer of asphalt because of the amount of traffic, and reconstruction is more prevalent than the overlay repair method.(see figure 1)



[major roads] [community roads]

Figure1: Pavement Renewal Cycle – Pavement useful life since last repair

(3) Maintenance methods
[Regular maintenance]
①Pavement on major roads
Specialized measurement vehicles were used to carry out pavement surface characteristics survey inspections from 1987 to 2004, and light was shed on pavement surface conditions through the application of MCI (It is an index showing the deterioration degree of a pavement road surface. It is calculated from a cracking ratio, a rut depth and a flatness, is evaluated in ten steps, and let five or more be good.), a standard evaluation method throughout Japan.
②Pavement on community roads
Also, an inspection of 106 km (1,800 city blocks) was conducted in 2005 after items for inspection were decided upon. LMI (It is calculated from a cracking ratio, and a patching ratio.), an evaluative index of community road pavement, was updated.
[Routine checks]
①Major road pavement: 1 patrol inspection per week under direct management
(One 2-person group from each of the 16 public works offices, 3.5 hrs / day)
②Community road pavement: 1 patrol inspection per month under direct management
(One 2-person group from each of the 16 public works offices, 3.5 hrs / day)

(4)Maintenance costs
The following is the percentage of decline from the peak as seen in the results of a study of the transition of initial budget.
○Overall: The budget peaked in 1993, and in 2006 the budget was 25.1% of the peak period.

3.2 Sampling of issues faced if current pavement maintenance methods are continued

(1) Summary of major roads
Understanding of future maintenance levels and of the degree of soundness of pavement was obtained by future projection with the current budget scale in the case that the same maintenance methods as usual are continued. The current condition of major roads was

organized as follows based on these results and those displayed in section 3.1 Understanding the current condition of pavement.

i. The current records show that roads will be due for repairs 24 years after full layer repavement and 7 years (see figure 1) after overlay.

ii. Early deterioration disposition was shown as a result of the long-term estimation by MCI.

iii. By surface evaluation, although a short-term plan is good, it is not suitable for long range planning.

The issues were summarized in the following two points from the above data and form the basis of our established goal.

■Issues for major roads

Issue: If MCI (surface marker) is used by itself, full layer repavement will be the repair method employed uniformly across all areas where deterioration has progressed. Because of this, there is a possibility of overinvestment in the course of studying maintenance plans. It is necessary to focus on pavement as a marker of pavement soundness and inspect the relation between MCI prediction formulae and base course useful life.

■Goal at present

In addition to surface markers, we must find new maintenance methods and shift to a new maintenance plan.

(2) Summary of community roads

The degree of pavement soundness was made clear by organizing the current deterioration levels from the results of inspections carried out between 2006 and 2007 and repair history from the City-operated "Road Information Management System." The current situation of community roads is ordered below based on these results and those shown in section 3.1 Understanding the current situation of pavement.

i. According to a general overview of the results of a small-area (2% of the whole community roads) inspection conducted in 2005, with an LMI of around 5 for repair standards, 8.65% or 450 km of all community roads require repairs.

ii. Assuming it takes 14.5 billion yen to repair 450 km of road and repair rates remain unchanged from year to year, 222 years will be required in order to repair all community roads according to the existing budget scale.

iii. The most recent inspection was carried out over 23% of the community roads. Regarding inspections of pavement on community roads from 2008, it has been expressed that due to the amount of time required, it will be difficult to continue conducting inspections on a yearly basis.

The issues were summarized in the following two points from the above data and form the basis of our established goal.

■Issues for community roads

Issue 1:It is necessary to raise our awareness of overall trends and increase the precision of budget calculation by validating the accuracy of the existing LMI from the most recent inspection results

Issue 2:In addition to clarifying the distribution of soundness of community roads and the useful life of pavement without a complete inspection, it is necessary to decide on the amount of necessary repairs and an inspection cycle.

■Goal at present

We must find new methods for a vast amount of maintenance and shift to a new maintenance plan.

4 MAINTENANCE PLAN FOR MAJOR ROAD PAVEMENT

Asset management goals for major road pavement were set as follows.

Asset management goals and policies for main road pavement

①Shift evaluation of pavement soundness from top layer (MCI) to pavement body (MCI + base course)

②Thoroughly manage top layer (asphalt-concrete layer), maintain soundness under base course (measures to increase base course longevity)

③Raise to the standard group areas that are already severely damaged or easily damaged (with a deterioration rate of 1.5 times or higher)

④Set forth maintenance goals based on ① and ②, continue the operation of ③, and shift toward thorough management of top layer

"Thorough top-layer management without causing damage to the base course!"

(1) Pavement surface grouping

Nagoya's specialized surface aspect prediction formulae and survey data from past fiscal years were plotted on a graph by number of years passed and grouped into ranges of "long-term deterioration," "routine deterioration," and "early deterioration" according to differences in deterioration rates. To obtain uniform sample numbers, long-term deterioration was defined as a deterioration rate 1/3 to 2/3 that of standard interval of deterioration, and early deterioration was defined as 1.5 to 3 times the standard interval.

Also, emphasis was placed on the relation between regional features and understanding of the deterioration condition of the entire city, so the data was included in each group after being divided into categories of "harbor areas," "commercial areas," "residential areas," and "other."(see figure 2)

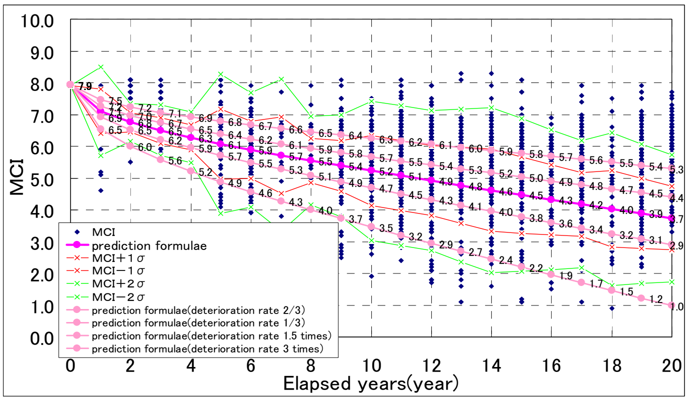


Figure2: Grouping according to deterioration rate

(2) Results of pavement structure survey

①Survey

A non-destructive FWD (falling weight deflectometer) survey was adopted. 28 areas where the asphalt pavement had not been repaired after pavement placement or repavement were selected based on history information in the Road Information Management System administrated by the City. Because the range of years passed is wide, the shift in traffic volume over the past 20 years was given focus and it was decided that the survey and analysis would be carried out under the assumption of designed traffic volume at time of construction.

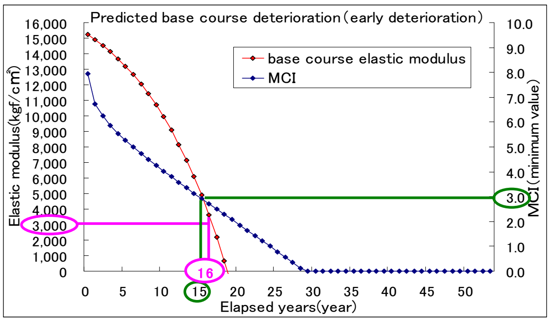


Figure3: Predicted base course deterioration (cracking ratio)

②Analysis

Multiple regression analysis using interactive variable selection method was used, and predictive formulae for base course deterioration was proposed for long-term, routine, and early deterioration with a focus on the elastic modulus of existing base courses. Figure 3 shows the early deterioration range.

③Summary of causal relationship between pavement body (base course) evaluation and MCI

i. A causal relationship resulting from differences in deterioration rate has been acknowledged between MCI and base course elastic modulus.

ii. The number of years it takes for a base course to reach dangerous levels is equal to its useful life. The long-term deterioration range has a lifespan of 52 years, while the routine deterioration range is 33 years. Base course lasts longer than the period of time required for MCI to decrease to 3.

iii. From figure 3, we can infer that facilities in the early deterioration range have a pavement useful life of 16 years, which is roughly the same number of years for the MCI of the early deterioration range to fall to 3.

iv. At present, it is necessary to have full-layer repavement repair candidate plans for areas dropping below an MCI of 3 or areas where only a short amount of time has passed between the most recent and previous repairs.

(3) Prediction of deterioration and future projection

In order to estimate future levels, it is necessary to create MCI deterioration curves for each repair construction method. Data were reanalyzed as Nagoya City's pavement formulae were for prediction by each pavement type and not by repair method. Keeping in mind that the pavement renewal cycle is 24 years as illustrated in figure 1**,** the degree 1 curve of the 20-year repavement system and the 8-year overlay system were averaged and taken as the MCI reduction coefficient.

The routine deterioration range was used as a base, and the quadratic curve showing that after full layer repavement the MCI of the base course will become 3 by 33 years later when the elastic modulus has become 3,000kgf/cm^2 was taken as fundamental, and it was combined with a degree 1 curve according to MCI up to roughly half this period, or 15 years. As for the overlay system construction, a degree 1 curve is still used on the assumption that it will be time for renewal when damage reaches the pavement body.

(4) Control levels and criteria for repair

The study of control levels advanced from the connection between pavement surface service levels for users and the scope of road managers' responsibility for flaws (risk). Adding in reference materials from within the country, the criterion for full layer repavement repair was set at an MCI of 3, and the criterion for overlay repair was set at an MCI of 4.

(5) Maintenance scenarios

Planned maintenance is the basis for the major road pavement scenarios. Survey data from past years indicates that there are a certain amount of locations that need full layer repavement, and it is necessary to take measures to bring areas from the early deterioration range to the level of the routine deterioration range. On that basis, a policy was set to curb long-term repair expenditures by utilizing MCI to the fullest extent and performing thorough surface management.

The 5 plans in table 1 were prepared from repair construction methods and cycle patterns. Repair expenses and control levels were estimated for each scenario for a period of 50 years, from 2008 to 2057. Keeping in mind the preservation of levels (average around MCI of 5.71) for target control levels, scenario 5-2 was adopted for formulating a maintenance plan.

Table1: Major road maintenance study scenarios (set target control levels)

Scenario Name	Provisions	Simulation Method
Scenario 1-2	Same method as used for last repair (repetition for areas that have two past records)	with control level restrictions
Scenario 2-2	Repetition of full layer repavement	
Scenario 3-2	Repetition of cut and overlay	
Scenario 4-2	Repetition of full layer repavement and cut and overlay	
Scenario 5-2	Repetition of cut and overlay *If shorter than term, area is deemed poor quality and full layer repavement is performed.	

(6) Introduction of asset management and an optimal maintenance plan

Following are long- and short-term plans summarized from the results of a study of maintenance scenarios.

①Long-term plan

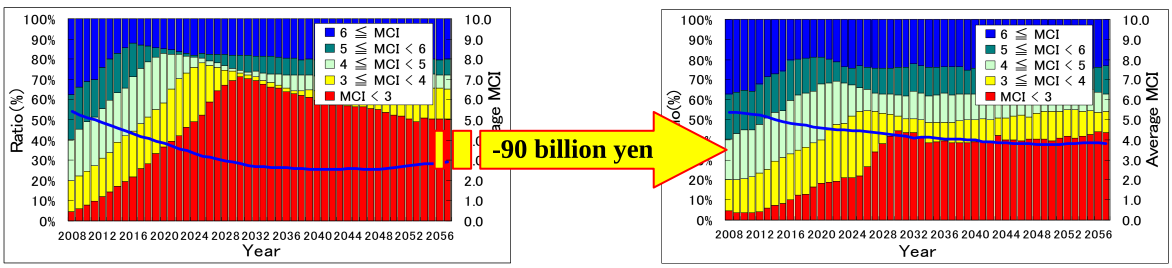
formulated from results of a 50-year projection conscious of bridging to the next generation average yearly budget 3.255 billion yen, average control level maintained at MCI=5.71

②Mid-term plan (10 years)

carry out full layer repavement in "poor quality" areas and improve the soundness of basecourse

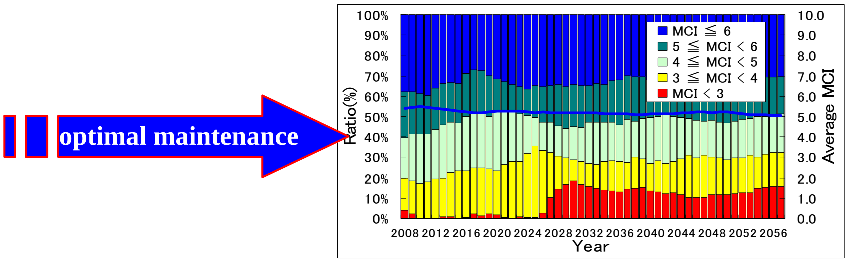
③Short-term plan (5 years at first)

select areas subject to repairs based on the mid- and long-term plans. However, the long term plan's yearly budget of 3.255 billion yen comparatively exceeds the fiscal 2008 budget by 1.4 billion yen. Figure 4 shows a shift from the conventional maintenance methods to the introduction of asset management and the process of operation cost calculation over 50 years of compressed budget increases. At the present time, this is our optimal maintenance plan for main road pavement.



i. Conventional management (255 billion yen, 5.1 billion yen/year)

ii. Introduction of asset management (165 billion yen, 3.3 billion yen/year)



iii. setting limit for yearly budget
increase at 550 million yen (117.2 billion yen, 2.3 billion yen/year)

Figure4: Optimal maintenance plan for major road pavement

5 MAINTENANCE PLAN FOR COMMUNITY ROAD PAVEMENT

Asset management objectives for community road pavement were set as follows.

Asset management goals and policies for community road pavement
①Gain an understanding of urgency of repairs and residents' demands from grouping according to number of years passed and regional features.
②Collaborate with enterprises which occupy roads for unified pavement management (shift to seamlessly executed pavement restoration)
[Collaboration with restoration work]
③Early detection and repair of damaged areas (to narrow down targets, survey, and maintain)
"Promptly locate and repair trouble areas and raise our accountability with residents!"

LMI is the index for community road pavement in Nagoya, proposed at a maintenance plan working group in 2005. Reanalysis of the results of 17,638 items (1,072.78 km) surveyed up to the end of December 2007 allowed us to confirm that a survey of cracking and patching could be used to help understand the current condition of community road pavement.

［LMI］
○When patching rate is less than 15%
$LMI=10-0.1\times H$ (1)
○When patching rate is 15% or more
$LMI=10-0.1\times H-2.7$ (2)
* H: cracking rate (%)

(1) Review of LMI
For basic analysis, the effects of the cracking rate and patching rate were offset. Table 2 shows that the patching rate stays mostly constant with no connection to repair decision period, but the cracking rate changes proportionately to the overall rate of deterioration. From this, the patched area from within 1, 3, and 5 years averages to a value of 27.4%, and the LMI formula was updated as shown below.

Table2: Deterioration rate by repair decision

	Average rate of deterioration (%)		
	Total area	Cracking	Patching
within 1 year	68.9	44.2	26.8
within 3 year	61.3	33.1	28.7
within 5 year	47.8	21.5	26.7

(2) Repair decision
Through deciding the relation between when a repair will be performed (degree of urgency) and which measures to take, a trial of LMI repair criteria was conducted. Regarding the range where the values for the number of intervals for each LMI rank and the number of intervals for each repair decision periods sorted by length are roughly the same, repair measure criteria were set as follows: repavement (renewal) necessary (LMI less than 3); repair necessary (LMI between 3.0 and 4.5); and observation necessary (LMI between 4.5 and 6.0).

(3) Calculation of useful life
In order to achieve integrated maintenance and renewal of road spaces, it is necessary to have a target, from a long-term perspective, for the useful life of pavement up to when pavement renewal occurs. LMI is the optimal index for understanding the current condition of community roads. However, as it is not suited to future projections, a study was carried out focusing on the differences between the two equations.

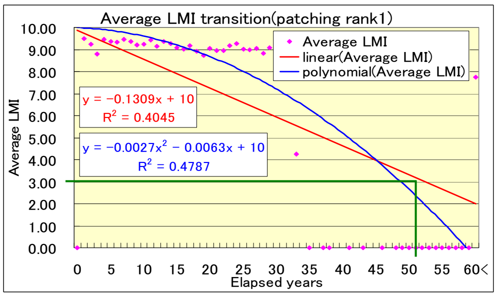


Figure5: Average LMI transition

A useful life of 52 years is achieved with the regression analysis of LMI formula 1, shown in figure 5. Additionally, a study to determine the number of years before more than 50% of areas are determined to have at least rank 2 cracking (15%) resulted in a pavement useful life of 36 years, as shown in figure 6. As survey data for all community road pavement is not available, the target pavement useful life was decided from a combination of both results, arriving at a useful life of 44 years.

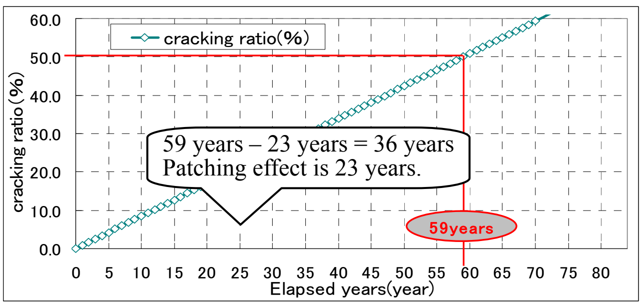


Figure6: Years for 50% to experience rank 2 cracking according to cracking ratio

(4) Survey subjects and decision on a cycle
As mentioned before, the renewal decision for community road pavement comes at an LMI of 3, and for assessing survey timing, it was decided that it was enough if the period when LMI reaches around 4 could be estimated.

Regarding the current state of pavement which has fixed patching, according to a regression analysis of LMI formula 2, areas where roughly 26 to 29 or more years have passed were subject to a survey. Also, the preparation period for repair measures was set to within an LMI of 1, and conducting roughly one survey per five years was found to be reasonable.

(5) Maintenance scenario

Breakdown repair-style maintenance is the basis for the community road pavement scenario. With this maintenance method, regular surveys are conducted and deterioration is allowed to progress. Measures are put into effect near the end of the accelerated phase.

This scenario is the core of the plan, and it was researched from the perspectives of a.) drafting a feasible maintenance plan based on a maintenance policy which makes clear the distribution of soundness and useful life of community roads without conducting a survey of the whole city, and b.) cost reduction. The relation between cracking rate, patching rate, and repair method (3.24 billion yen/year) as seen in figure 7 was taken as the optimal scenario in the aspects of pavement useful life, efficacy of repairs, and budget measures.

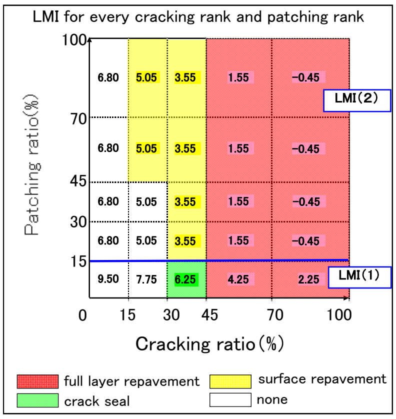


Figure7: Community road pavement scenario

(6) Introduction of asset management and an optimal maintenance plan

The budget for the scenario shown in figure 7 underwent verification. From a long-term viewpoint, plan 1 is the least expensive, but it is unlikely that the pavement will have a useful life of 200 years. At a maximum of 76 years, plan 3, where the repair gap between full layer repavement is supplemented by overlay repair, is a realistic plan with minimal expenses.

Table3: Verification of budget for optimal scenario (200 year period LCC)

Repair Plan	Repair cycle	The number of repair times	Annual cost (billion yen)
Plan1	Repetition of surface repavement	6	2.775
Plan2	Repetition of full layer repavement	5	3.680
Plan3	Repetition of surface repavement and full layer repavement	6	3.277
Plan4	Repetition of two times surface repavement and full layer repavement	6	3.038
Plan5	Repetition of surface repavement and two times full layer repavement	5	3.478

The yearly expenses of plan 3 total 3.277 billion yen, which roughly conforms to the 3.24 billion yen amount in the optimal scenario. The budget verification from a long-term perspective was approved.

Plans ranging from long-term to short-term from the results of a maintenance scenario study are summarized below.

①Long-term plan: formulated from a 50-year projection from the perspective of cost

reduction and budget measures. Average yearly budget of 3.24 billion yen, renewal standard of LMI 3.0. Unified pavement management through collaboration with road occupying enterprises is also an important policy.
②Mid-term plan (10 years): Inspect areas for which at least 26 years have passed, once every 5 years and draft a repair plan for the next 5 years.
③Short-term plan (5 years, at first): Select areas to be repaired based on the mid- and long-term plans

6 SUMMARY

■Major roads
If the early deterioration part of base course is coped with by specifying by the grouping, it is manageable in MCI henceforth.

■Community roads
It is manageable at the cracking ratio, and the patching ratio.

7 FUTURE ISSUES

We have formulated a maintenance plan for pavement (major roads and community roads), but the following studies will need to continue in order for the plan to be realized.
○Restructuring organization corresponding to the optimal maintenance plan
○Inspection plan for major road pavement
○Accountability
○Utilize the energy of private enterprises
○Participation from residents (establishment of partnership with local residents)

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