A study on bridge management of local roads in Japan

Masayuki KURIHARA

ABSTRACT

In Japan, almost all the portion of the road network is managed by local government except the trunk highways managed by national government. The budget for road management is not enough for the expenditure required for new investments, maintenance and operations. In particular, the local governments are facing the shortage of the budget for the maintenance of their road assets and the sustainable road transport.
This paper overviews the financial condition of the road assets, activities of road management. Then it verifies the issues of the above, and makes a suggestion to the solution of it.

1. INTRODUCTION

There is a 1,177,000km road network with 625,000 bridges in Japan. While specially important trunk roads such as expressways and national highways are managed by the national government or the organizations related to the government, the other roads are managed by prefectural governments and municipal governments. Relatively, the former shares heavy traffic and the latter have a large amount of road facilities.
The budget for road network management is planned and allocated to each road administration authorities by the long-range plans and the allocation systems in accordance with national road strategies. However, the budget for road management is not enough for the expenditure required for new investments, maintenance and operations. In particular, the local governments are facing the shortage of the budget for the maintenance of their road assets and the sustainable road transport.

2. OUTLINE OF THE ROAD NETWORK OF JAPAN

2.1 ROAD NETWORK AND TRAFFIC

Table 2-1 shows the length of the road network managed by national government, and that managed by local governments in both countries. The table also shows the actual traffic volume of each road network.
The length of National Highways, roads managed by national government, Ministry of Land, Infrastructure and Transport (MLIT), is about 22,000 km and that of Local Roads, roads managed by local governments, is about 1,143,000 km.

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[1] Senior Researcher, Economic Research Division, National Institute for Land and Infrastructure Management

The actual traffic volume of the roads in Japan is about 204 billion vehicle-kms. The traffic shared by National Highways is about 20% and that shared by Local Roads is about 70% in Japan (The remaining 10% is shared by Expressways).
So national highways support heavy traffic in comparison with local roads.

Table 2-1 Road Network System and Traffic

Road Type	Length (km)		Traffic Volume (vehicle-km)	
Expressways	6,851	0.6 %	220 million	10.8 %
National Highways (Class-A)	21,828	1.9 %	390 million	19.1 %
National Highways (Class-B)	32,028	2.7 %	265 million	13.0 %
Prefectural Roads	128,409	10.9 %	634 million	31.1 %
Municipal Roads	982,521	83.9 %	530 million	26.0 %
Total	1,171,647	100 %	2,040 million	100 %

Source: Ministry of Land, Infrastructure and Transport(Japan)

There are roads managed by the national government and that managed by the prefectural governments as roads called 'National Highways' in Japan. The latter national highways (Class-B) are classified into local roads in this paper. Expressways in Japan are toll roads managed by public corporations separated from the national government. Therefore, they are classified as roads different from national highways in this paper.
Table 2-2 shows them by grouping the road types on two categories, national highways and local roads excluding expressways in Japan.

Table 2-2 Road Network System in Japan

Road Type	Length of Roads		Bridges			Control Authorities
			Number	Length		
Expressways	6,851 km	0.6 %	6,896	935.6 km	8.4 %	Public Corporations
National Highways (Class-A)	21,828 km	1.9 %	19,846	1,145.7 km	10.3 %	National Government (MLIT)
National Highways (Class-B)	32,028 km	2.7 %	29,666	942.1 km	8.5 %	Prefectural Governments
Prefectural Roads (Regional)	57,574 km	4.9 %	47,035	1,205.2 km	10.8 %	
Prefectural Roads (General)	70,835 km	6.0 %	52,525	1,497.3 km	13.5 %	
Municipal Roads	982,521 km	83.9 %	516,577	5,392.7 km	48.5 %	Municipal Governments
Total	1,171,647 km	100 %	665,647	9,620.9 km	100 %	

Source: Road Statistics Annual Report 2002 (Japan)

In Japan, MLIT manages national highways, makes the decision of the principles about road networks including local roads, distributes subsidies and performs the technical instructions to the local governments.
There are many local governments who manage the local roads in Japan ,47 prefectural

governments and about 3,000 municipal governments. (In Japan, many municipalities are merging together. So number of municipalities is decreasing year by year.) In addition, there are some public corporations, and local road corporations who manage expressways and toll roads. (Length of toll roads other than expressway is about 1,400km and included in the length of roads other than expressway shown in Table 2-2.)

2.2 EXPENDITURE FOR ROAD NETWORK

Table2-3 shows the expenditure for the construction (including upgrading, improvement and other capital investments) and maintenance of the road network spent by each road administrator.

Table2-3 Expenditure for Road Network

Road Type	Expenditure (JPY Million)			Percentage of Maintenance
	Construction	Maintenance	Total	
National Highways (Class-A)	2,243,649	703,267	2,946,916	23.9 %
National Highways (Class-B)	810,094	178,153	988,247	18.0 %
Prefectural Roads (Regional)	1,539,165	256,564	1,795,729	14.3 %
Prefectural Roads (General)	1,170,479	213,491	1,383,970	15.4 %
Municipal Roads	2,806,508	583,297	3,389,805	17.2 %
Total	8,569,896	1,934,772	10,504,668	18.4 %

Source Road Statistics Annual Report 2002 (Japan)

The expenditure for maintenance of roads is about 24% on National Highways and only about 14-18% on local roads (roads managed by local governments including class-B national highways). That is, large amount of money are provided to construction from maintenance in Japan.
Table 2-4 shows the amount of money outlaid for maintenance of roads.
In Japan, about JPY700 billion is outlaid for maintenance of national highways and about JPY 1,200 billion for local roads in total. The maintenance cost per km in Japan is about JPY 32.2 million for national highways and about JPY 1.1 million for local roads in average. The expenditures for bridge repair differ accordingly.

Table 2-4 Expenditure for Maintenance of Road and Bridge

Road Type	Road Maintenance (JPY Million)		Bridge Repair (JPY Million)	
	Expenditure	Cost per km	Expenditure	Cost per km
National Highways (Class-A)	703,267	32.2	49,015	49.3
National Highways (Class-B)	178,153	5.6	25,520	29.0
Prefectural Roads (Regional)	256,564	4.5	27,796	24.4
Prefectural Roads (General)	213,491	3.0	11,436	8.0
Municipal Roads	583,297	0.6	17,390	3.4
Total	1,934,772	1.7	131,157	13.6

Source: Road Statistics Annual Report 2002 (Japan)

The maintenance costs of road network including bridges in Japan are remarkably high especially in national highways compared with that of local roads.
Figure 2-1 shows the flow in which the revenue concerning the road network are collected to the funds for roads and distributed to road projects through local governments in Japan.
The specified revenues are distributed to the national and local governments. The money required for the above fund other than the specified revenues is funded by other sources of revenue of each government.
The local governments supplies other part of expenses for the projects by bonds (The local governments allowed borrowing money only for capital investments. The return fund of the bonds is to be assisted in later fiscal years by the Ministry of Public Management, Home Affairs, Post and Telecommunications.)

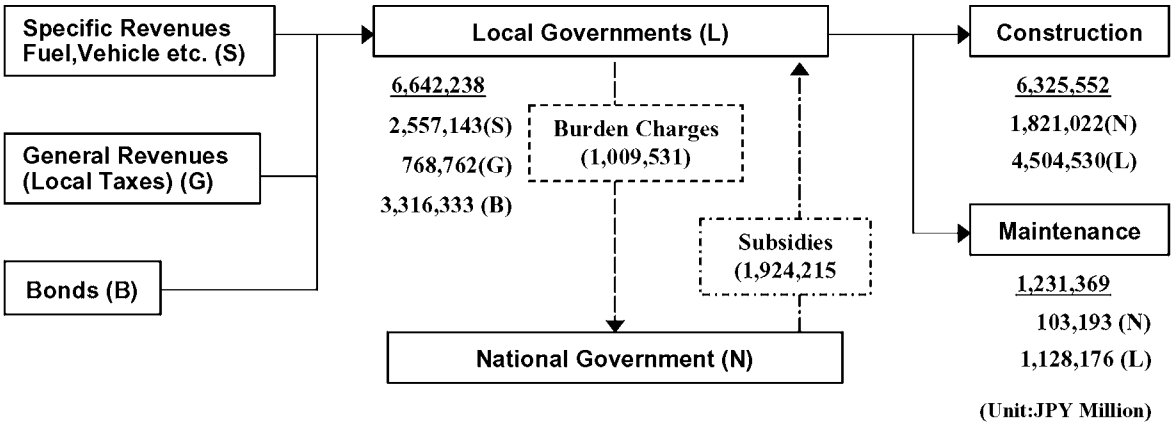


Figure 2-1 Flow of funds for local road projects in Japan

The national government (MLIT) gives subsidies to the projects undertaken by the local governments. The local governments pay some part of the expenditure to the projects undertaken by the national government. The rates of the subsidies and burden charges are shown in Table 2-5.

Table 2-5 Subsidies and Burden Charges Ratios for Road Projects in Japan

	National Projects (Class-A National Highways)		Local Projects (Class-B National Highways and Local Roads)	
	Construction	Maintenance	Construction	Repairs [2]
National Government [1]	2/3	5.5/10	1/2	1/2
Local Government	1/3	4.5/10	1/2	1/2

1) Higher rates are applied in Hokkaido, Okinawa and other specified districts.
2) Only large-scale repair works are to be assisted.

Source:MLIT

3. ROAD ASSET MANAGEMENT IN JAPAN

In Japan, the level of activities concerning road asset-management is behind. So, in this section, the situation of asset management of road control authorities (national government, prefectural governments and municipal governments) is outlined, then the condition of the local governments who has especially the problem is surveyed.

3. 1 Overview

Table 3-1 shows the situation of asset-management of road control authorities in Japan.
The national government comparatively well maintains its road facilities since it has abundant funds and personnel for maintenance. However, it has not established the asset strategy yet. Moreover, it needs to save and reduce the expenses by applying asset management.
Most of the prefectural governments do not have asset strategy and do not carry out preventive maintenance. They repair their facilities after their breakage or failure. Now they are trying to commence asset management of road facilities.
Most of the municipal governments carry out neither preventive maintenance nor minimum maintenance and repair since they have few funds and personnel for maintenance. They do not understand the necessity of asset-management and asset strategy yet.

Table 3-1 Situation of Road Asset Management in Japan

	National Government	Prefectural Governments	Municipal Governments
Execution of Maintenance	A (Fair)	B (Reactive)	C+ (Poor)
Asset Inventory	A (Fair)	B- (Poor)	C (Very Poor)
Maintenance Planning (Short Term)	A (Planned)	B (Reactive)	C (None)
Financial Planning (Long Term)	A- (Planned B- /Reactive)	B- (Reactive)	C (None)
Asset Strategy	B (Poor)	C (Very Poor)	C (None)

3.2 Activities for Road Management of Local Governments

Table 3-2 shows the result of the questionnaire survey which was conducted on the Japanese local government by the Asset Management Sub-committee of the Japan Society of Civil Engineers in 2004.
Many local governments do not determine their budget for maintenance regarding maintenance plan or result of inspection. Most of them do not perform the scheduled inspection and do not have long term maintenance plan.

Table 3-2 Road Management Activities of Local Governments (Japan)

Question	Types of local governments	Answers				
		Yes		No		Total
Do you determine the budget of maintenance based on plans or inspection results?	Prefectures	9	(25%)	27	(75%)	36
	Large Cities [1)]	8	(34%)	15	(65%)	23
	Small Cities [2)]	3	(14%)	18	(86%)	21
Do you inspect your facilities periodically?	Prefectures	18	(50%)	18	(50%)	36
	Large Cities	10	(43%)	13	(57%)	23
	Small Cities	7	(33%)	14	(67%)	21
Do you have any long-term maintenance plan? or are you beginning to make it?	Prefectures	30	(83%)	6	(17%)	36
	Large Cities	9	(39%)	14	(61%)	23
	Small Cities	6	(29%)	15	(71%)	21

1)Large Cities: Cities with Population of 200,000 or more
2)Small Cities: Cities with Population of around 50,000
Source: Asset Management Sub-committee JSCE 2004

Table 3-3 shows the result of the interview survey with the local government's staff about the consciousness to maintenance and management of roads. The which interview was held alongside the above-mentioned questionnaire.
According to their answers, the necessity for management is not well understood to the councillors, residents, and the staff of government. Furthermore, they do not have enough technology, methods, nor skilled personnel to perform the asset management.

Table 3-3 Local Governments' Recognition to Road Management

Question	Answers	Respondents
What do you think is (are) required about the management of road facilities?	Preventive maintenance should be introduced. Maintenance and management should be thought as more important by staff of governments.	5
	The necessity for maintenance and management should be recognized more by residents and councillors.	2
	The standard of maintenance level should be defined. Qualification and authorization system for inspection engineers should be established.	1
	The technical development for maintenance and management methods is required. The technology and the information on maintenance and management should be shared with other authorities.	3
	Skilled people of inspection and maintenance activities are more required.	4
	Total	15

Source: Asset Management Sub-committee JSCE 2004

3.3 Issues of Local Road Asset Management

From the above-mentioned results of the survey and the argument in Chapter 3, the issues of the road asset management of the Japanese local government is summarized as follows.

(1) Financial Issues

In Japan, since the level of road network has been low, road funds have been concentrated on construction of new roads and improvement of existing roads. The local governments and residents have been considered neither the deterioration of facilities, nor the necessity for maintenance. Therefore the local governments have not been able to fund enough to carry out sufficient maintenance.

(2) Issues of Asset Strategy

The local governments do not have asset strategy. Therefore, they cannot create the alternatives, whether a facility is replaced or maintained for example, based on the viewpoint of life cycle cost or environmental load. They cannot explain to residents and councillors who alternative will be the optimal selection.

(3) Technical Issues

Most of the local governments do not perform periodic inspection of facilities and do not collect and save the data of the condition of facilities including inspection results. They do not have technology for prediction of deterioration or estimate of repair and maintenance expense. Therefore, they cannot make up their asset-management plan.

(4) Issues of Finance System

The optimal selection may distort for the system of finances or subsidies.

For example, in case only replacement of facilities is financially assisted, the alternatives of using the existing facilities will be rejected, even if it is advantageous at life cycle cost.

Fortunately, above issues are being solved.

The system of subsidies has changed. While there ware only subsidies to capital investment before, now there some subsidies for repair works.

The local government's independency has come to be respected by the policy of decentralization. For example, the subsidies with interference of national governmental are being reduced and the funds which the local governments can use by their decision are being increased.

Residents and councillors have come to pay attention on the activities of national and governments. Therefore, it is strongly requested that the governments perform optimal selection in asset management.

4. New System for Infrastructure Management

In this chapter, a new management framework is introduced as a solution to technical issues of asset management.

4. 1 Framework of Asset Management

There are essentially two aspects in managing infrastructure. One is understanding of the conditions of each structure, on which basis the required repair and maintenance programs are implemented. The other is drawing up of plans and allocate budgets for repairing and maintaining in the most desirable way, the overall infrastructure such as the road networks and systems including the individual structures.

Generally, the organizations charged with the management of infrastructure are divided into local field management offices responsible for the first aspect of asset management noted above, and the ministries or agencies charged with the latter task of managing the overall systems.

In terms of budgets, the important aspect of the first scope of asset management is securing the budget funding needed to maintain and manage the asset under the charge of the field offices. The budget and funding responsibility of the latter includes determining the equitable allocation of funds, with an eye on balancing between management of the entire asset inventory under the charge of the ministries and agencies and implementing other policies such as new investment projects.

Different information content is required for each of the two aspects of asset management. Whereas to the former, detailed information on individual structures along with degree of deterioration of parts and members is important, the latter needs to know if structural conditions are improving or deteriorating as a whole, or if there is any imbalance between regions. Nor would it be considered reasonable or simple to provide data analyses on the degree of deterioration of each structure or member for the purposes of determining overall budget appropriations.

It is in this context that this paper suggests considering asset management from two different perspectives, i.e., macroscopic and microscopic perspectives, to provide management that is suitable for each level. The final goal is to create a new system that enhances the overall management by linking both types of managements (Figure 4-1).

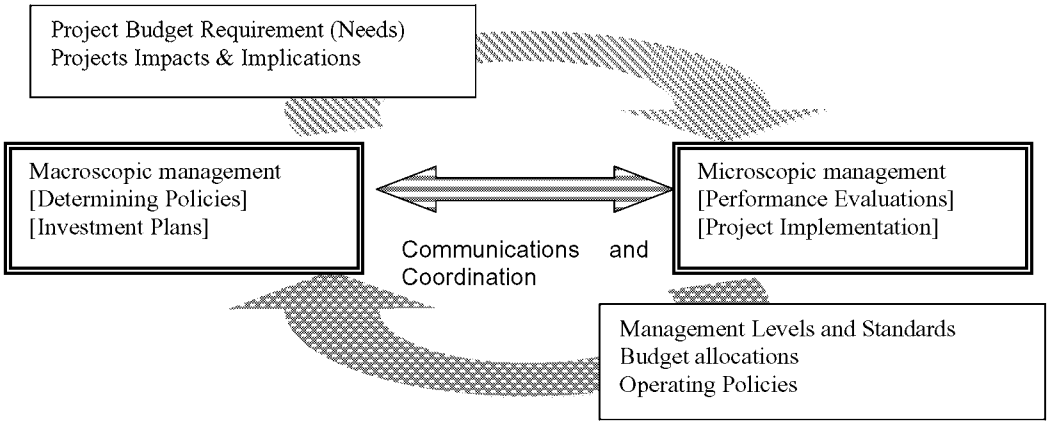


Figure 4-1 Framework of Macro-Microscopic Management

4. 2 Microscopic Management

Microscopic management is primarily the responsibility of organizations such as the local field management offices charged with maintenance and management of each structure.
For each individual structure, the concerns of microscopic management are with appropriate maintenance and management to provide for proper structural functions in the face of deterioration and damage due to aging.
Defining what constitutes "appropriate" maintenance and management requires an understanding of the conditions of deterioration of the structure, securing funding in line with the identified conditions, and implementing maintenance and repair within the allocated budget and other restrictions.
Microscopic management process is to be conducted with two types of indicators, indicator of the health and safety of individual structures (Health Index) and indicator of the level of deterioration or damage (Damage Degree) of the parts and members of the structure, and deterioration scenarios.

[Health Index]
The health index indicator reflects the safety of individual structures. It generally refers to how weakened structural functions may have become due to deterioration by aging or other factors.
The indicator is expressed either as a percentage against a perfect score of 100 where no deterioration is noted, or as one of five different levels of deterioration.
Structures integrate both parts and members. Therefore, it is assumed that accumulated damage (damage degree) for each parts and members impacts the overall health index of the structure as a whole. With this assumption, the more damage to components and materials, the lower the health index. That is the logic behind calculating the health index.

$$\text{Health Index} = (AX+BY+CZ+\ldots) / (A+B+C+\ldots)$$

Here, X, Y, Z… equals a numerical value marking degree of damage of components and material as 'degree of damage (major) numerical value (minor)'.
A, B, C… Weight coefficient of each parts and members

[Damage Degree]
The damage degree is a quantitative indicator defined for each type of damage affecting parts and members. Depending on the severity and extent, the damage degree can be expressed in levels as shown in Table 4-1. The damage degree is used as a basis for evaluating the health of each parts and members that has suffered damage, and for calculating the health index for the entire structure.
The damage degree as defined here is similar to the definition in the guidelines now in use for bridge inspections in Japan.

Table 4-1 Damage Degree for Road Bridges

Damage Degree	Meaning of the Damage Degree
V(OK)	No problem, not shown below
IV	Points requiring attention, damages to similar structures, environmental factors (damage caused by salt), heavy traffic volume, aged.
III	Identified as Damages, subject to preventive maintenance measures.
II	Survey for Repairs required
I	Danger, urgent repair required.

[Deterioration Scenarios]

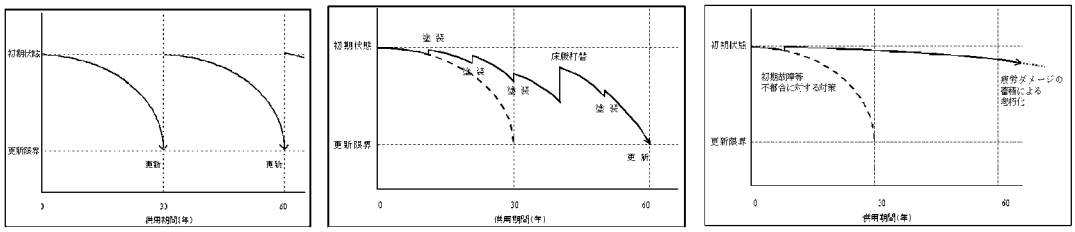
In managing structures, it is required to consider that the health index is subject to changes due to aging. Therefore, the following deterioration scenarios have been prepared.

The progress of damage to each parts and members will determine the health index. However, there is no clear understanding of the mechanisms of damage. To predict deterioration patterns, scenarios is to be prepared for a structural unit. Following are three scenarios based on expected maintenance patterns and length of usable life (Figure 4-2).

- Non Maintenance scenario: to be left without maintenance and repair (30 years usable life)
- Repair when broken scenario: repaired when damage becomes severe (60 years usable life)
- Trouble-shooting scenario: preventive measures applied, dysfunctions completely fixed in early stages, and lifespan extended by new technology. (120 years usable life)

These scenarios enable to predict the usable life of each structure as well as estimate costs for maintenance and repair over the mid- and long-term.

The scenarios introduced above were prepared based on a survey on conditions for bridge replacements (conducted in 1997 by the Public Works Research Institute and the Road Bureau, Ministry of Construction). The survey revealed that bridges were often replaced at points when they reached either 30 or 60 years of life. As more data from inspections and surveys is accumulated, scenarios will be constantly adjusted to make our predictions more precise.



[Non-maintenance scenario] [Repair when broken scenario] [Trouble-shooting scenario]

Figure 4-2 Scenarios of deterioration patterns.

The damage degree is used to ascertain the conditions of deterioration of each parts and members, and consequently, for the selection of repair method. Maintenance and repair are carried out as allowed within the allocated budget in compliance with a set of certain rules. The results of maintenance and repair are supposed to be reflected in changes in the damage degree, and further, in an enhanced health index.

4. 3 Macroscopic Management

Macroscopic management involves organizations at the ministerial and agency level responsible for maintenance and management of the overall asset inventory, drawing up plans for maintenance and management, and budget appropriation.
Macroscopic management is conducted using by indicators that reflect the health of the overall asset, calculated by the health index of individual structures. In some cases, indicators express the health index of structural stock by routes or regions. The weighted average value of the safety of individual structures is a usable indicator.
What is required in macroscopic management is to set middle to long term goals based on awareness of the health index of the complete asset inventory, to enhance or maintain the health index of the overall asset, and to make decisions such as whether or not to prioritize routes and regions with lower ratings in allocating budgets.

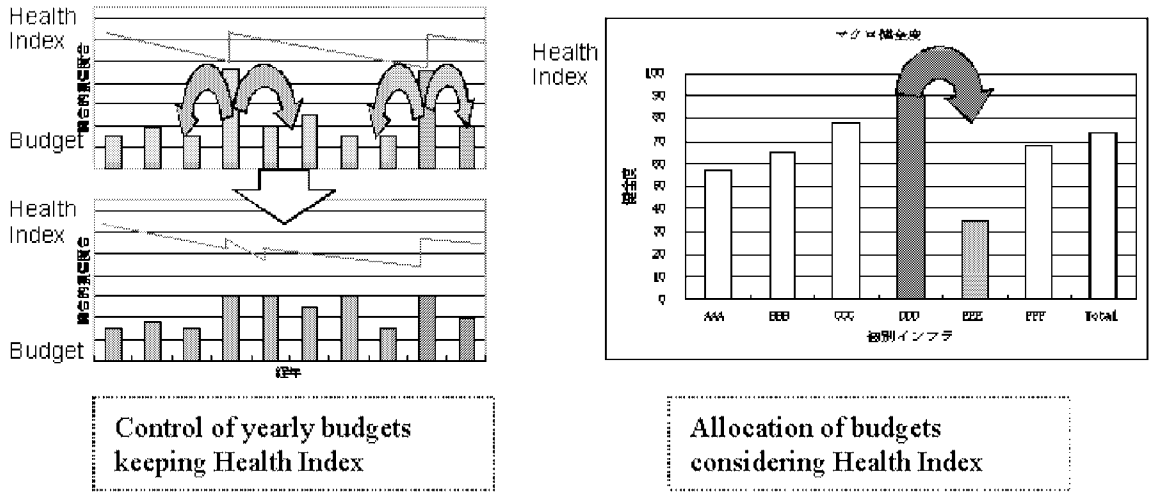


Figure 4-3 Macroscopic management

The combined system of macroscopic and microscopic management introduced in this report is based on some assumptions made for civil engineering structures but in the absence of clear information on the mechanism of deterioration and damage.
The management system of the above could be applied for buildings and structures other than bridges since they consist of steel, concrete and foundation structures.

5. CONCLUSION

This paper has outlined the road network, the budget and the expenditure for road network , and the situation of the maintenance of road networks of Japan, then it has suggested new framework of asset management including macroscopic and microscopic management. This management framework is currently being verified using simulations based on actual data from highway bridges.
The following measures are required for the improvement of the management system and road asset management in Japan.

(1) Technical Issues
- Showing of the methods for repair for damages and cost.
In evaluating life cycle costs and repair plans, it is necessary to understand which repair methods are appropriate for particular damage of parts and menbers, cost for repair and effect on recovery. So they should be shown in simple to understand manners.
- Methods for calculation of health index.
The exact method for calculation of the health index has not been established. Therefore, a provisional methods based on the current findings is to be used in the initial stages. The methods should be improved in the future by learning from results of ongoing researches.
- Transferring and sharing of asset management technology
Most of the local governments do not have enough technology for asset management. So the technology and the information on asset management should be transferred and shared with other authorities.

(2) Financial and Adminstrative Issues
- Establishment of asset strategy
The local governments need to change the importance of their policy from construction to maintenance. For this purpose, they should establish their asset strategy and commence the asset-management of their roads in earnest.
- Reduction of maintenance and management cost
Most of the local governments are facing the financial deficit for maintenance and management. Therefore, they should consider the measures to reduce the cost, such as outsourcing, partnership with residents and so on.
- Modification of Finance System
The finance systems, such as subsidies and bond system with which use of the existing institution becomes financially disadvantageous for the local governments, should be modified.

References:
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[2] PWRI: Survey on situations of replacement of existing bridges (Nov. 1997)
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