Bridge Management System in Osaka City

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ABSTRACT: In Osaka City, most of managed bridges were built intensively at the beginning of the Showa era (period of the first urban planning program), when the urban infrastructure was improved drastically, and also during the period of high economic growth (when the world exposition was held). It is expected these aging bridges will simultaneously require intensive repair and renewal work in the near future. To maintain the service standard for users within a limited budget, it is necessary to equalize renewal times and minimize the cost of repair and renewal work. Therefore, it is essential to develop a comprehensive bridge management system to establish an optimal maintenance and management plan based on prediction of bridge deterioration and minimization of life cycle cost.

1 PRESENT SITUATION OF BRIDGES IN OSAKA CITY

1.1 *The number of managed bridges and their characteristics*

As of April 2004, there are 867 road bridges in Osaka City. Among them, 755 bridges are managed as certified roads by Osaka City. The total length is 46.5 km with area of 706,000 m^2. (See Table 1, Present situation of bridges.) One of the characteristics of bridges in Osaka is that there are many steel bridges. Approximately 90% of the whole bridge area is steel. One of the reasons for this is a limited girder height of bridges in Osaka due to overhead crossing of bridges that laterally cross rivers or are located in urban areas. Another reason is a measure being taken to alleviate deal load against constructions on soft ground and underground facilities such as subways. The second characteristic is that bridge area is considerably large as compared to the number of bridges. This is because there are many large-scale bridges with wide width and long length, such as successive elevated bridges and bridges for harbor area.

1.2 *Trends of the number of Bridges Managed by Osaka City and bridge areas*

The Figure 1 shows the trends of the number of bridges managed by Osaka City and bridge area. When the city was municipalized in 1889, there were 196 bridges. During the first expanding period of the city in 1897, there were 395 bridges. After that, from the end of the Meiji era to the Taisho era, there were 400 to 500 bridges. During the second expanding period of the city in 1925 (Taisho 14), the number of bridges increased rapidly to

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1,629. Then the number decreased to 1,200 or so due to reclamation of waterways. However, it increased again to 1,470 bridges because of the third expanding period of the city in 1955. After the war, the Japanese economy entered the high growth period, and waterways were reclaimed because of improvements of the sewage system in Osaka City. Consequently, the number of bridges decreased to less than 800. Around the same time, Japan started constructing elevated bridges and large-scale bridges. In line with this, the number of bridges decreased, however, the average bridge length and bridge area have increased up to the present date.

Table 1. Present situation of bridges
As of April 1, 2004

		Number of bridges (unit: bridge)	Total bridge length (unit: m)	Total bridge area (unit: m^2)
Management of Osaka City (Certified roads)	Steel bridge	502	40,224	624,452
	Concrete bridge	248	5,647	80,655
	Stone bridge	4	11	23
	Wooden bridge	1	614	1,117
	Sub total	755	46,496	706,247
Management of Osaka City (other than certified roads)		63	7,003	112,350
Management of Osaka Prefecture or adjacent local governments		20	1,131	17,308
Management of the nation		29	7,732	198,989
Total		867	62,362	1,034,894

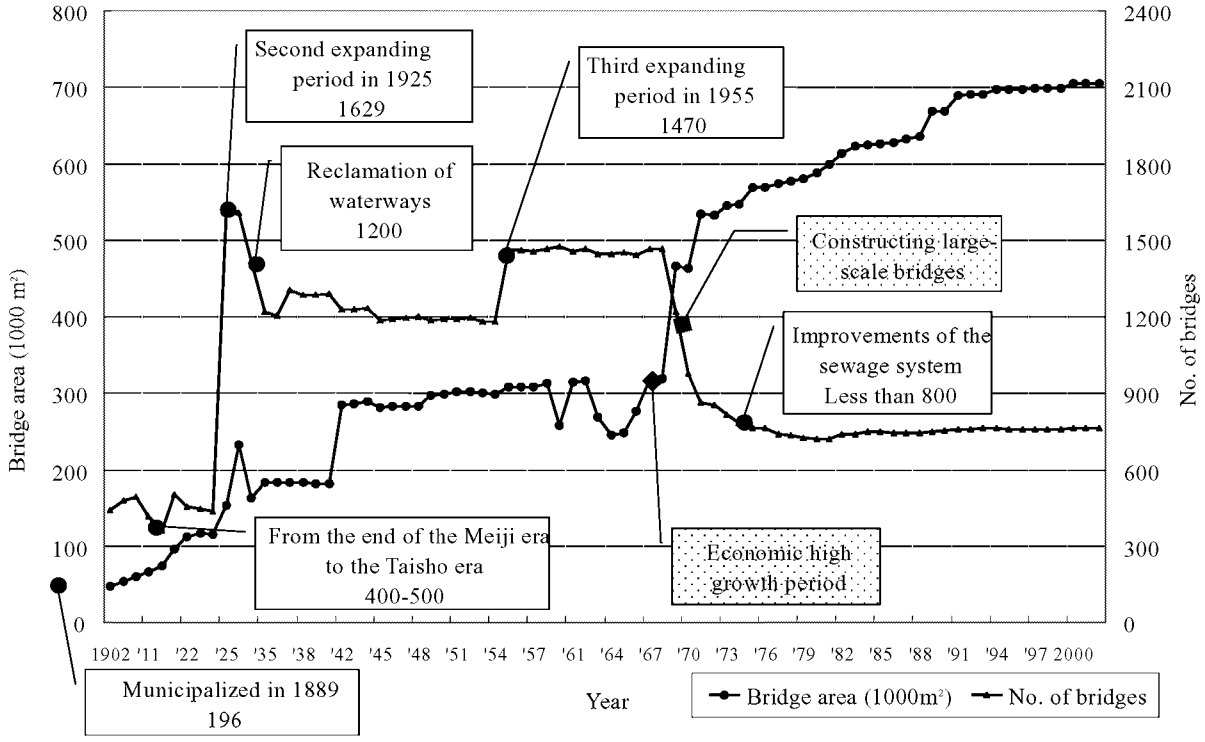

Figure 1. Trends of the number of bridges and bridge area

1.3 *Year of bridge construction and bridge's age*

Figure 2 shows years of construction and ages of bridges managed by Osaka City. According to this figure, there are two peaks for construction years: one in prewar times and another in postwar times. In particular, the number of bridges built is the highest in 1970 (Showa 45) when Senri Expo was held. The average bridge age is approximately 30 years.

The oldest existing bridge in Osaka is the Honmachi Bridge built in 1913 (Taisho 2). The bridge has been used for transportation for approximately 90 years. (See Figs 3, 4) However, there is no urgent need for reconstruction at this point so that it is possible that the bridge will be used for over 100 years. Factors for this longevity are daily maintenance and a large-scale repair implemented in 1983 (Showa 58). Replacement of damaged members and reinforcement of RC floor slabs have been conducted for other aging bridges also. Proper management after some years is probably a factor that lengthens the life of a bridge.

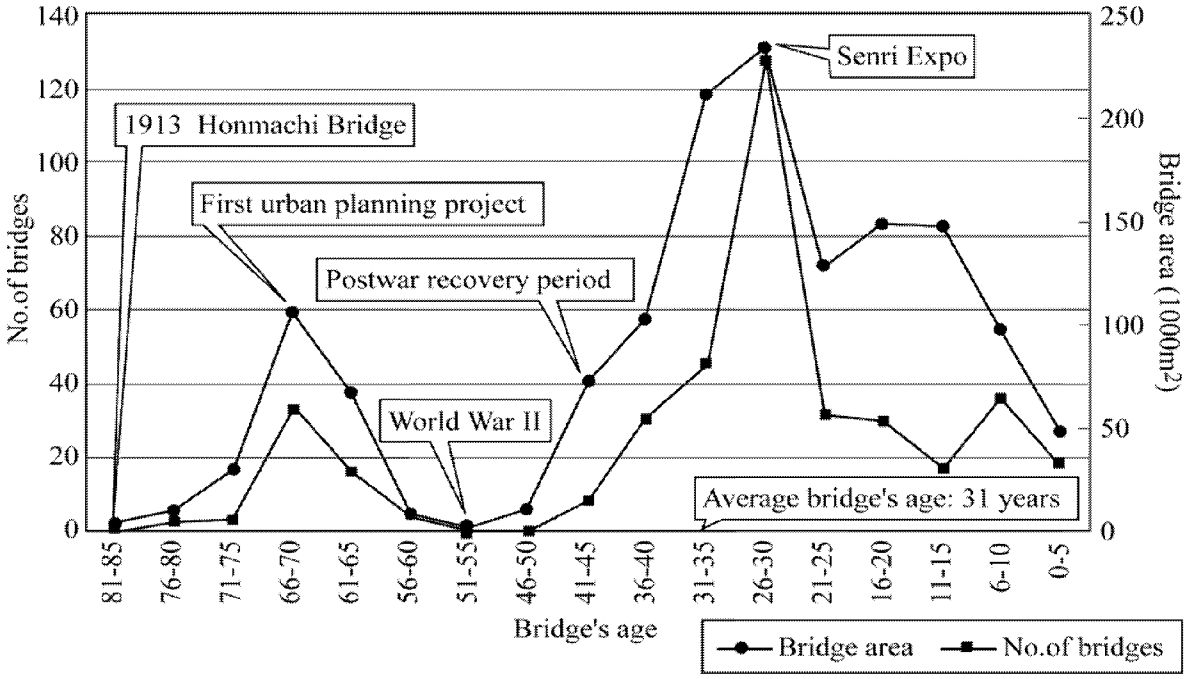

Figure 2. Relationship between bridge age, the number of bridges, and bridge area

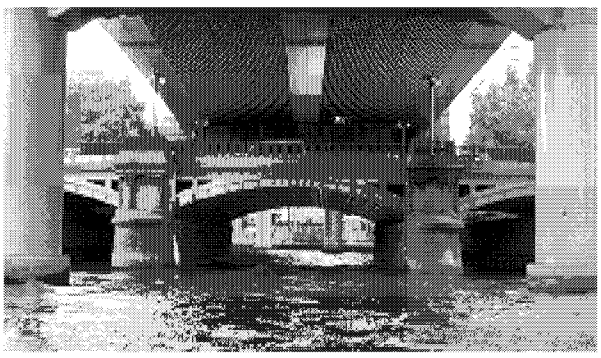

Figure 3. Side of Honmachi Bridge

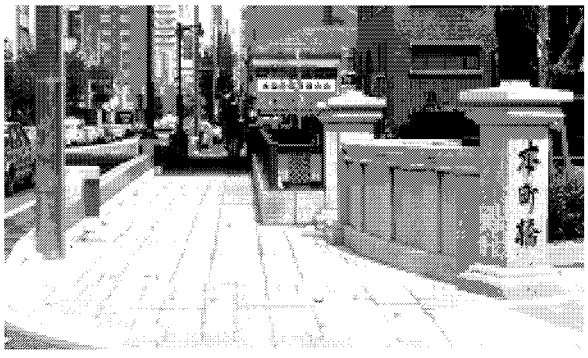

Figure 4. Bridge face of Honmachi Bridge

1.4 *Distribution of managed bridge's ages*

The Table 2 shows the number of bridges in Osaka by date. Bridges built during the first urban planning project, which is the first construction peak, account for approximately 10% of all bridges. When combining these bridges and bridges built before the first urban planning project, approximately 13% of all bridges are 70 years old or older as of today. These bridges will be 100 years old or so in 30 years. Additionally, bridges that will be 70 years old or older 30 years from today will account for approximately 32% of all the bridges. The bridges built during the Japan Exposition year, which is the second construction peak, will be also as old as 68 years old in 30 years. As a result, in the future we will face a situation where a wave of aging bridges will surge one after another. In preparation for such a situation, an urgent issue in addressing aging bridges is development of a maintenance and management system to minimize life cycle cost through life extension (lengthening and leveling of life cycle) and a lower cost for maintenance and repair.

Table 2. List of the numbers of bridges in Osaka by date••road bridges•

	Date	Years used	Number of bridges		Other
Bridges that are 50 years old or older	1912 (Taisho 1) - 1925 (Taisho 14)	91-78	17	2.3%	Improvement through city electric project
	1926 (Showa 1) - 1930 (Showa 5)	77-73	24	3.2%	First urban planning project
	1931 (Showa 6) - 1935 (Showa 10)	72-68	54	7.2%	
	1936 (Showa 11) - 1940 (Showa 15)	67-63	19	2.5%	
	1941 (Showa 16) - 1945 (Showa 20)	62-58	2	0.3%	Wartime and postwar recovery
	1946 (Showa 21) - 1950 (Showa 25)	57-53	2	0.3%	
	1951 (Showa 26) - 1955 (Showa 30)	52-48	25	3.3%	High water prevention project
	1956 (Showa 31) - 1960 (Showa 35)	47-43	28	3.7%	
	1961 (Showa 36) - 1965 (Showa 40)	42-38	67	8.9%	1964, Tokyo Olympic
	1966 (Showa 41) - 1970 (Showa 45)	37-33	159	21.0%	1970, Japan World Exposition
	1971 (Showa 46) - 1975 (Showa 50)	32-28	71	9.4%	1973, oil crisis
	1976 (Showa 51) - 1980 (Showa 55)	27-23	65	8.6%	
	1981 (Showa 55) - 1985 (Showa 60)	22-18	90	11.9%	
	1986 (Showa 61) - 1990 (Heisei 2)	17-13	76	10.0%	1990, Osaka Flower Expo
	1991 (Heisei 3) - 1995 (Heisei 7)	12-8	37	4.9%	1995, Kobe earthquake
	1996 (Heisei 8) - 2000 (Heisei 12)	7-3	16	2.1%	
	2001 (Heisei 13) -	2-	3	0.4%	
	Total		755	100.0%	

2 BRIDGE PROJECT IN OSAKA CITY

2.1 *Present situation and budget of bridge project*

We will show budgetary situation trends and budget scale of each bridge project in Osaka City. Bridge projects in Osaka City can be divided into the following four groups.

(1) New construction : New construction or reconstruction of bridges
(2) Improvement : Widening, changing stairs to slopes, surrounding improvement
(3) Quakeproof : Pier reinforcement, prevention for bridge fall, series of girder
(4) Repair : Regular repair, repair and reinforcement measures, steel bridge recoating

Figure 5 shows the trend of project cost in the last 10 years. A project cost for 2003 was approximately five billion yen, with a breakdown of 1.9 billion yen for new construction, 1.3 billion yen for improvement and quakeproof work, and 1.8 billion yen for repair work.

Although necessity for repair and reinforcement is increasing, the budget for such work is decreasing, allowing only a minimum level of maintenance work.

Next, Table 3 shows bridges that were reconstructed during the last 20 years and reasons for such reconstruction. Traditionally, main reasons for reconstruction of bridges are to raise bridge girders and or to expand span length along with river improvements, and to expand width along with road improvements. There have been few cases where bridges have to be reconstructed due to structural malfunction. There are six cases of reconstruction of old bridges in 20 years. Such reconstruction takes place at a rate of one bridge in approximately three years.

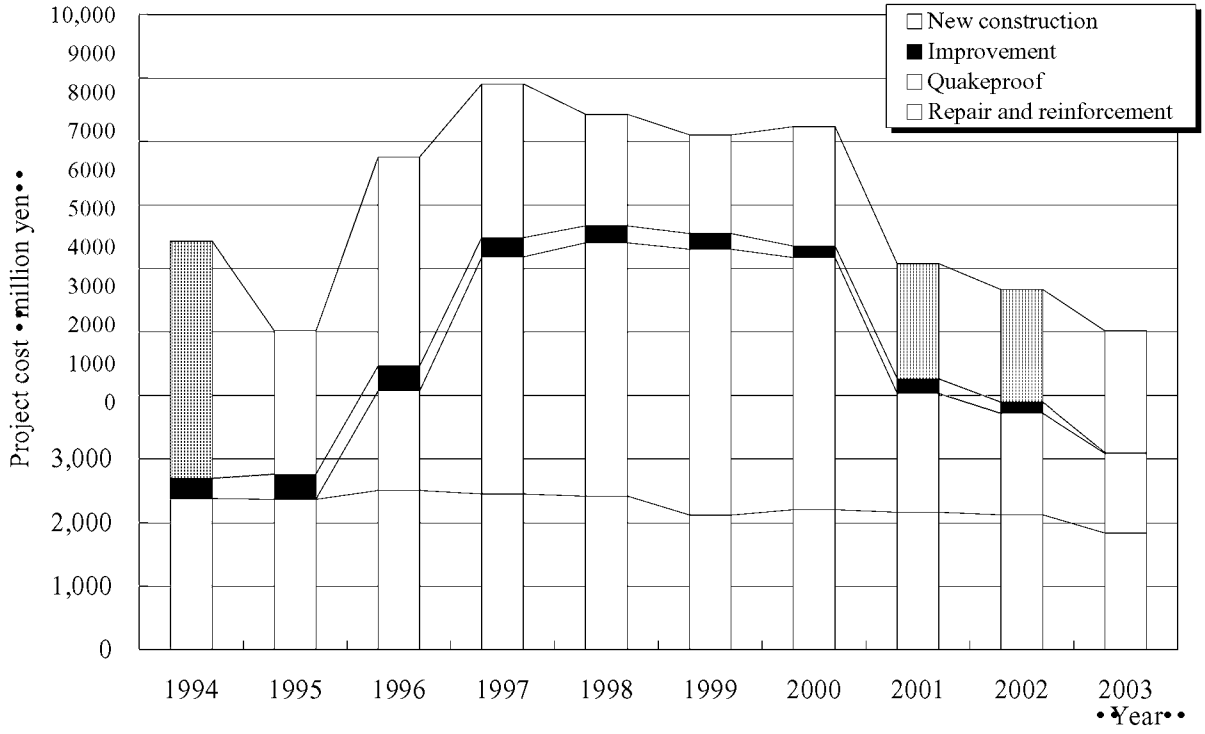

Figure 5. Trend of bridge project cost

Table 3. List of reconstruction in the last 20 years in Osaka City

	Bridge name	Style	Year of construction	Major reason for reconstruction	Year of reconstruction completed	Years in service
1	Ebisubashi	Arch	1925 (Taisho 14)	Aging	Under construction	79
2	Iwamatsubashi	Plate girder	1922 (Taisho 11)	Road improvement	1997(Heisei 9)	75
3	Hanatenobashi	Plate girder	1930 (Showa 5)	Road improvement	2003(Heisei 15)	73
4	Onkijimabashi	Plate girder	1926 (Taisho 15)	Highway project	1998(Heisei 10)	72
5	Imabashi	Plate girder	1924 (Taisho 13)	Aging	1994(Heisei 6)	70
6	Takatsuharabashi	Plate girder	1927 (Showa 2)	Subway	1997(Heisei 9)	70
7	Kamiyamatobashi	Plate girder	1925 (Taisho 14)	Aging	1994(Heisei 6)	69
8	Kasugadebashi	Plate girder	1935 (Showa 10)	Aging	Under construction	66

	Bridge name	Style	Year of construction	Major reason for reconstruction	Year of reconstruction completed	Years in service
9	Ukishimabashi	Plate girder	1925 (Taisho 14)	Aging	1990(Heisei 2)	65
10	Hakurakubashi	Plate girder	1940 (Showa 15)	Road improvement	Under construction	61
11	Gokurakubashi	Plate girder	1932 (Showa 7)	River improvement	1992(Heisei 4)	60
12	Shimoyamatobashi	Plate girder	1928 (Showa 3)	Landscaping	1987(Showa 62)	59
13	Nishifukubashi	Plate girder	1936 (Showa 11)	Aging	1995(Heisei 7)	59
14	Meijibashi	Plate girder	1930 (Showa 5)	Road improvement	1988(Showa 63)	58
15	Emonbashi	Plate girder	1929 (Showa 4)	River improvement	1984(Showa 59)	55
16	Furudutsumibashi	Plate girder	1939 (Showa 14)	River improvement	1992(Heisei 4)	53
17	Sigitabashi	Plate girder	1934 (Showa 9)	River improvement	1986(Showa 61)	52
18	Sendannokibashi	Plate girder	1935 (Showa 10)	Landscaping	1985(Showa 60)	50
19	Nakasumirebashi	Plate girder	1956 (Showa 31)	River improvement	1996(Heisei 8)	40
20	Minamiimafukubashi	Plate girder	1964 (Showa 39)	River improvement	1999(Heisei 11)	35
21	Imafukukitabashi	Plate girder	1968 (Showa 43)	River improvement	2003(Heisei 15)	35
22	Shinmorikobashi	Plate girder	1975 (Showa 50)	River improvement	1995(Heisei 7)	20

3 STUDY TOWARD BRIDGE MANAGEMENT SYSTEM IN OSAKA CITY

3.1 *Necessity of BMS*

Aging of bridges managed by Osaka City is advancing. Traffic control due to deficiency of load bearing capacity of old bridges and a sudden increase in traffic restriction due to reconstruction and/or reinforcement of bridges can seriously influence social and economic activities. Therefore, in order to avoid such situations and to maintain proper municipal services for citizens into the future, it is necessary to try to prolong lives of old bridges and to promote the level of facility renewal. Additionally, concentration of reconstruction must be avoided since public investment will be restrained according to prediction of social conditions in the future. It is imperative that reconstruction should take place in order from bridges with a low level of soundness and load bearing capacity among old bridges. Also, adequate maintenance and reinforcement must be taken to promote measures to prolong lives of existing bridges. Besides these points, it is necessary to develop a maintenance and repair plan based on consideration for the following characteristics of bridges managed by Osaka City. Such characteristics can be roughly divided into three groups.

i) Approximately 90 of all managed bridges are steel bridges
ii) In urban areas, there are large-scale, elevated bridges that can seriously impact economic activities.
iii) There are two main construction periods: in the beginning of the Showa era and during the high economic growth period. Times for reconstruction, reinforcement and repair will be concentrated.

3.2 *Future approaches of BMS*

Traditionally, measures such as repair, reinforcement, and reconstruction and their priorities have been determined based on bridges' conditions observed by experienced workers and people in charge of bridge construction. However, in order to deal with the enormous amount of required work in the future, we need an alternative approach to comprehensive decisions made by people in charge. We need a system to develop quantitative and com-

prehensive plans. Such a system should enable us to grasp damage content and degree of damage; predict load bearing capacity in case damage expands; make economic comparison for reconstruction; examine social impact caused by reconstruction and cultural values of bridges; and classify the weight of these factors to tally up their points for evaluation. It is important to deal with bridge issues effectively through such a system.

As for establishment of the system, it is necessary to clarify principles of maintenance and management. In particular, bridges are the symbol of Osaka, as it has been said "there are 808 bridges in Osaka." The bridges also support the urban transportation system and create urban landscape at the same time. They are urban facilities that are close and familiar to the citizens. We believe that, as we work on establishment of a management system, it is imperative to fully discuss a desirable way of bridge maintenance and management that is unique to Osaka City so we can preserve these valuable and historical bridges. We will list issues that should be addressed in the future in order to establish a system.

(1) Improvement of inspection system
We have been implementing daily and regular inspection in order to ensure road function and to prevent damage to third person. In the future, it will be necessary to examine inspection items needed, frequency and method of inspection as well as current inspection method, in order to collect data necessary for prediction of deterioration and determination of countermeasures and timing.

(2) Database
Osaka City has been utilizing Osaka City Bridges Administration System (OBAS) since August 1998. The system helps prompt and effective retrieval of data from enormous amount of administrative information by making a database of information necessary for bridge management. This system consists of "the main body system" that deals with property data inherent to bridges and "the record system" that deals with bridge inspection, damage, and construction data. A main purpose of this system is to compile and store data. In the future, it will be necessary to add a function to this system as a bridge management subsystem, which can actively support decision-making concerning investment in maintenance and repair.

(3) Prediction of deterioration process, minimization of lifecycle cost, model for selection of parts
Based on prediction of a deterioration process and a maintenance and management plan to minimize lifecycle cost, it is important to study models necessary for selection of repair and maintenance parts in a way that would be the most cost effective.

(4) Public relations to the citizens
Establishment of a bridge maintenance and management system is an urgent issue in order to constantly keep the service standard for the citizens. However, first of all, PR activities for the citizens about conditions of bridges in Osaka Cities are needed. It is also necessary to gain the citizens' understanding on a desirable way of bridge maintenance and management in the future through provision of information and public comments for the citizens.

3.3 *Experience toward BMS building*

The city has been advancing examination of the above issues since September 2003 through a committee (Committee to Examine the Bridge Management System in Osaka City, chairperson: Eiichi Watanabe, the professor of Kyoto University) composed of people of learning and experience, with a view to building the BMS some time in 2005.

In 2003, the committee examined deterioration prediction, LCC computation, property assessment methods and other basic elements of BMS. This year, utilizing the results obtained in the year before, the following activities will be implemented on a trial basis in order to verify effectiveness: painting of steel bridges, which accounts for a major portion of maintenance costs; compilation of maintenance plans of floor slab; and BMS construction targeting a few representative bridges.

4 REMARK•

It used to be that a great emphasis was placed on bridge construction itself and technical investigation of newly constructed bridges. However, today, examination of measures to safely preserve existing bridges for a long time is required. The traditional way of bridge maintenance and management needs to undergo a drastic reform. As the bridge administrators, we must autonomously coordinate a series of processes to gain citizens' consensus and establish a bridge maintenance and management system to draw results that are quantitatively easy-to-understand.