Information Collection and Confirmation Survey on Road and Bridge Maintenance Management

Final Report (Summary)

January 2013

Japan International Cooperation Agency

Mitsubishi Research Institute, Inc.

EI
JR
12-250

Contents

Note: The objective of this survey is to provide a summary overview of the situation in each country, and the terminology used is not necessarily based on strict definitions

1. Outline of the Survey

1.1 Background and Objectives of the Survey

Problems of maintenance management of roads and bridges are not confined to developed countries where their development is almost complete, but they are also common issues in semi-developed countries and developing countries. In developing countries particularly, although road and bridge maintenance management systems and maintenance equipment have been introduced through funds and technical assistance from foreign donors, the condition of roads and bridges still continues to be poor.

Under these circumstances, JICA is implementing customized cooperation based on human resource development in developing countries, through technical cooperation projects, etc., in connection with road maintenance management, and it is considered that a certain level of evaluation has been obtained. On the other hand, other donors, in particular the World Bank, are attempting to optimize road maintenance management by formulating road maintenance management policies (road maintenance funds, commercialization of road management, performance-based maintenance contracts), and the introduction of maintenance management software (HDM-4, etc.). Although this has been somewhat effective, there are examples where this has not contributed to the formation of administrative know-how, and was not an effective and sustainable solution.

Based on the above, in this survey, information on the status of road maintenance management in developed countries (Japan, United States, United Kingdom, France, etc.), semi-developed countries (South Africa, Thailand, Malaysia, Brazil, Chile), and developing countries (Vietnam, Indonesia, Philippines, Laos, etc.), and the initiatives of other donors (World Bank, etc.) was collected and summarized as basic material for investigating the future cooperation policy of JICA.

[1] In this report, South Africa, Thailand, Malaysia, Brazil, and Chile, where local surveys have been carried out, are referred to for convenience as "semi-developed countries"

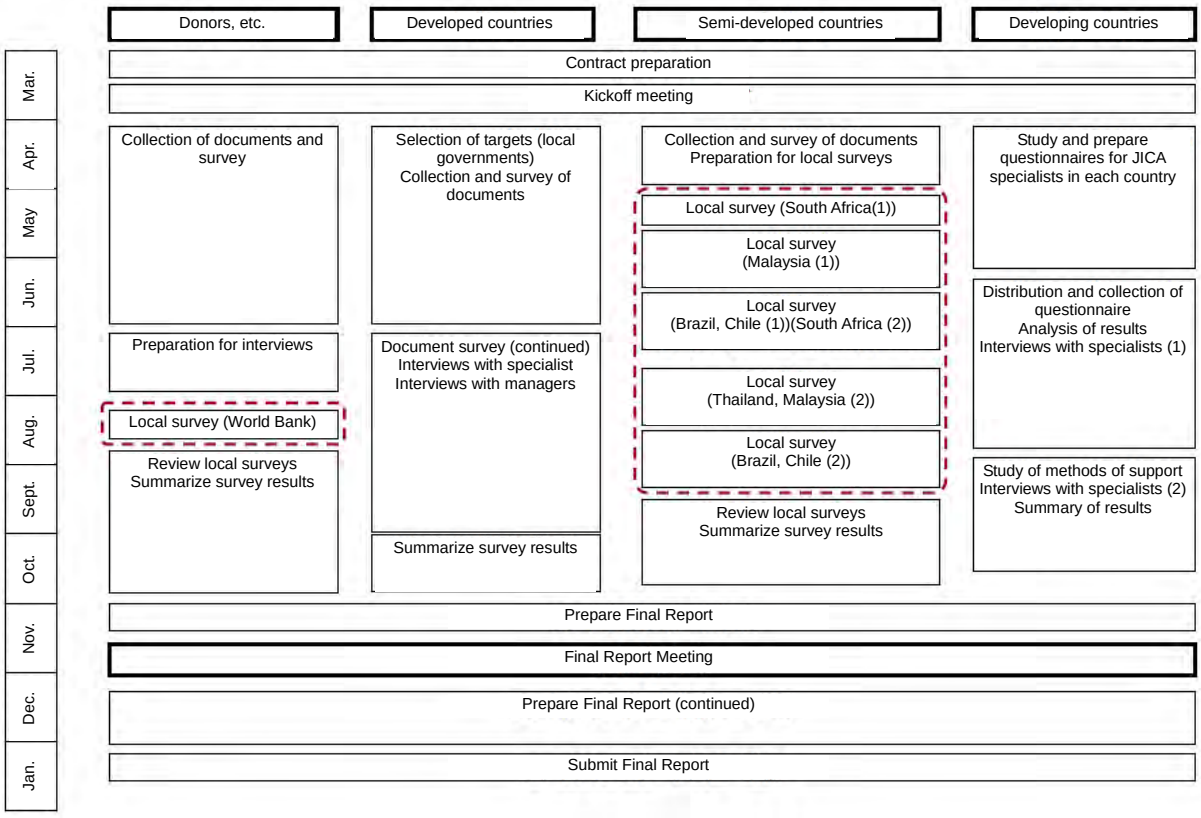
1.2 Survey Items and Survey Method

The items and the targets of this survey, and the survey methods were as follows.

Survey items	Target of survey	Survey method
Survey of global trends in the field of road maintenance management • Policies regarding system aspects and technical aspects of road asset management • Trends in the establishment of international standards	<u>Donors, etc.</u> PIARC, WB, ADB, IDB, etc. <u>Related agencies</u> ISO55000s, EN1504	Document survey (local interview survey with the World Bank) Document survey, domestic interview surveys
Basic information regarding road maintenance management Road maintenance management systems (pavements) Road maintenance management systems (bridges) Measuring equipment necessary for road and bridge maintenance management (pavements and bridges)	Developed countries Japan, United States, United Kingdom, France, Australia, Singapore, Sweden, etc.	Document survey (interview surveys in Japan)
	Semi-developed countries (five countries) South Africa, Thailand, Malaysia, Brazil, and Chile	Document survey, local interview surveys
	Developing countries (15 countries) Vietnam, Indonesia, Philippines, Laos, East Timor, Egypt, Ethiopia, Kenya, Mozambique, South Sudan, Uganda, Bolivia, etc.	Questionnaire and interview surveys with JICA specialists

1.3 Survey Schedule

The survey schedule was as follows.



1.4 Composition of Study Team and Allocation of Roles

The composition of the study team and the allocation of roles were as follows.

Role	Name	Affiliation
Project leader Road and bridge maintenance management	Naoki Takesue	Research Director, Social and Public Management Research Division, Mitsubishi Research Institute, Inc.,
Pavement maintenance management systems	Koji Tsunokawa	Mitsubishi Research Institute, Inc. (Assistance: Professor at Saitama University)
Bridge maintenance management systems	Osamu Otomo	Senior Researcher, Overseas Project Centre Mitsubishi Research Institute, Inc.
Road and bridge maintenance management measurement equipment	Kazuya Aoki	Mitsubishi Research Institute, Inc. (Assistance: Pasco Corp.)
Work survey and data processing (1)	Kei Owada	Researcher, Overseas Project Centre, Mitsubishi Research Institute, Inc.
Work survey and data processing (2)	Dinh Minh Fung	Researcher, Overseas Project Centre, Mitsubishi Research Institute, Inc.

JICA staffs were assigned for this project as follows.

Name	Affiliation
Yoshihiro Kakishita	Senior Advisor to the Director General Economic Infrastructure Department
Fusato Tanaka	Director Transportation and ICT Division 3, Transportation and ICT Group Economic Infrastructure Department
Ryoichi Kawabe	Transportation and ICT Division 3, Transportation and ICT Group Economic Infrastructure Department
Aya Shimada	Transportation and ICT Division 3, Transportation and ICT Group Economic Infrastructure Department
Moriyasu Furuki	Financing Facilitation and Procurement Supervision Department Visiting Advisor

2. Global Trends in Road and Bridge Maintenance Management

[Overview]

(Trends in the World Bank)

- The World Bank is having a major effect on the trends in developing countries regarding organizational and technical aspects of road and bridge maintenance management.

- The organizational aspects include the introduction of road maintenance funds, commercialization of road maintenance, performance-based road maintenance contracts (some cases with financial conditions), and the technical aspects include the introduction of pavement management systems (PMS) as represented by HDM-4 is being positively promoted.

- The advantages of performance-based maintenance management contracts are the use of private sector technical capabilities, and the implementation of medium- and long-term maintenance management using various know-hows, and the results are expected to produce cost reduction and innovation.

(Trends in establishment of international standards)

- International standards (ISO55000s: Asset Management) and local standards (EN:1504: Concrete Structures) relating to maintenance management are being established and used.

- It is anticipated that eventually the European countries and the USA will disseminate these international standards and local standards to semi-developed countries and developing countries, and there is a strong possibility that the standards will become the default standards.

2.1 Trends in the World Bank

2.1.1 Trends in Organizational Aspects

Trends in the organizational aspects include the introduction of road maintenance funds, commercialization of road management, and performance-based maintenance management contracts, and these have a major impact on trends in developing countries.

(1) Introduction of road maintenance funds

The World Bank has been investigating the introduction of road maintenance funds since the 1980s, but from the late 1990s they have established and implemented support for "second-generation road funds," mainly in various African countries. Specifically, around 1980, various countries reported problems due to road maintenance management not being properly performed, so funding policies for roads were changed to focus on maintenance management. In the 1995 Heggie Report, the establishment of road boards and the establishment of accountable “business-like” road public corporations that can provide financial management were proposed, and problem points regarding reliable and sufficient procurement of finance (methods of charging road users, general rules to guide costs and expenses, methods of management of residual revenue) were raised. Thereafter, the concept of "budget" in which roads are owned by the public, and their budget is covered by taxes such as fuel tax or vehicle registration tax, etc., paid by the public, the concept of "road funds" in which road users should bear the costs associated with roads, as well as the concept of "second-generation road funds" in which the

operation and management of roads is commercialized and road management has a commercial significance, have arisen.

(2) Commercialization of Road Management

Regarding commercialization of road management, in developed countries, operation has been carried out by independent or semi-independent public corporation organizations that are within the scope of influence of governments. However in developing countries also there is a trend towards commercialization of the existing road management organizations. Commercialization is considered to be a process far more effective and efficient road management, by commercialization of public sector asset and financial management, or its performance by the private sector, so that public sector operation is more "business-like." It is necessary to point out that commercialization does not necessarily mean privatization.

(3) Performance Based Maintenance Management

Performance-based maintenance management is a method in which, for example, performance such as "flatness," etc., are prescribed for maintenance management of the pavement, and it is in contrast to specification-based management methods such as the frequency of cleaning and inspection, locations of repair, methods, and so on. The advantage of performance-based maintenance management is that it can utilize the technical capabilities and creative ideas of the contractor, and as a result it is expected to result in reduced costs.

Regarding performance-based maintenance management, at the World Bank, the comprehensive term for performance-based contracts for long-term maintenance management of road networks is “Output and Performance-based Road, and three types of approach are envisaged to suit the level of the locality or country (network management type, DBMOT, unpaved roads type).

1) Network management type

Maintenance management of road networks that can be stably maintained without major investment such as refurbishment, etc., is contracted out to the private sector, the roadway network is maintained to a certain standard, and the aim is to minimize the lifecycle cost.

2) Design, Build, Maintain, Operate and Transfer (DBMOT)

This is a method in which the private sector is commissioned to upgrade a road network to a condition in which it can be maintained, by refurbishment using a large initial investment, and thereafter maintain the road network for a defined period of time (other name: CREMA).

3) Unpaved roads

Unpaved roads have particular conditions such as the road surface condition changes suddenly, there are particular risks such as effect of weather, etc., and the scale of investment is relatively small, so it is easy to involve small and medium-sized construction companies. Therefore unpaved roads have been defined as a separate type.

In addition to the above three types, there are other types such as public private partnership (PPP) for toll roads that require a large initial investment by the private sector, design and build methods, and so on.

2.1.2 Trends in Technical Aspects

The trends in technical aspects include the use of software systems such as PMS and BMS for effective maintenance management, and the introduction of preventive maintenance, etc. Among donors the World Bank has been pioneering in implementing these methods.

Specifically, the World Bank has supported the construction of core systems necessary for integrated management of road structure parameters, past inspection data, history of repairs, etc., measures and plans to reduce medium- and long-term costs. For example, HDM-4, which is the representative pavement management system (PMS), was derived from HDM-3 which was developed by the World Bank in the 1980s. Thereafter it was developed by the International Study of Highway Development and Management System (ISOHDM) which was established by four main sponsors: the World Bank, Asian development Bank, the British Department for International Development, and the Swedish National Road Administration. HDM-4 deals not only with technical aspects of pavement degradation and repair, but it can also provide optimum solutions including economic aspects such as user costs, etc. For the establishment of medium- and long-term road maintenance management plans, it is expected that it would provide a common language for both technical departments and administrative departments. Currently it has been introduced into more than 100 countries throughout the world as the core computer software for PMS.

There are several representative bridge management systems (BMS), such as PONTIS, BRIDGIT, etc. However as inspection criteria and evaluation manuals, etc., for bridges have been individually developed by each of developed countries and semi-developed countries, the current situation is that BMS are individually constructed. The reason that there is no system that has spread worldwide is because unlike pavements, bridges are complex structures made from many different members and materials. Also, the types of bridges are very diverse due to the forms and materials, so it is considered difficult to construct a system that is common for all of these.

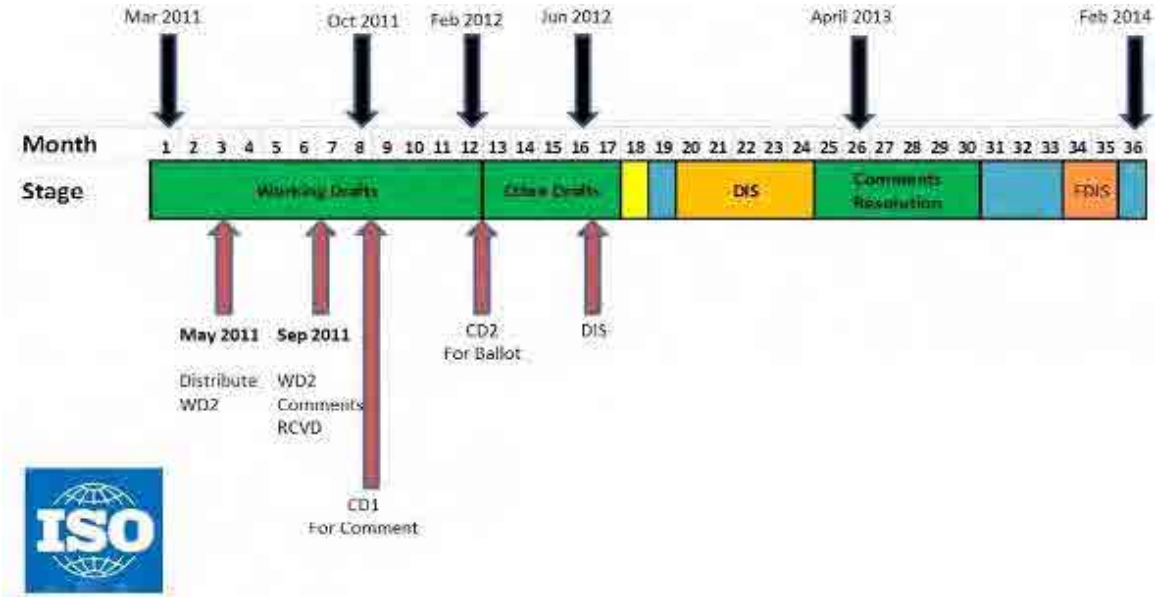
2.2 Trends in the Establishment of International Standards

2.2.1 ISO55000s

Currently, in ISO/PC251, steady work is in progress for the establishment of an international standard on asset management (ISO55000 series). PC251 is a project committee provided to develop asset management system standards. International standards have been established for the principles of asset management (ISO55000), the requirements of management systems using asset management (ISO55001), and guidelines for the application of management systems (ISO55002). The aim is that they will enable organizations that own or manage assets to implement asset management in accordance with international standards in compliance with requirements such as establishment of plans, operation, performance evaluation, and improvement, and not take asset management to be just the maintenance of facilities.

ISO55000 Asset management – Overview, principles and terminology ISO55001 Asset management – Management systems – Requirements ISO55002 Asset management – Management systems – Guidelines for the application of ISO55001

After holding a preliminary meeting in London, United Kingdom, in June 2010, to date there have been a total of four meetings, and preparation of a DIS (Draft International Standard) and FDIS (Final Draft International Standard) are in progress for official publication in February 2014.



Source: ISO/PC251 document

Fig. 2-1 Schedule for establishment and issuing ISO55000s

International standards include "de jure standards" whose framework is determined by ISO, etc., and "de facto standards" that are determined by the responsible organization in each country, and become fixed as a result of market competition. Unlike a product specification, the international standard for asset management prescribes a management framework, so it does not prescribe specific asset management technologies or software, etc., as these must not be directly restricted for governments or businesses. However, as in past examples, when the Europeans

take the initiative in the framework of an international standard, and take a lead in developing planning and evaluation tools and total management systems, they become the de facto standard, and there is a strong possibility that Japan will also be affected by this. If a de facto standard is established, technologies and systems not included in this standard are eliminated from the market.

2.2.2 EN1504

EN is an abbreviation for European Norm (European standard), which have been established as "local standards" to ensure smooth trade between members of the EU and to ensure uniform industrial standards. One of these standards is EN1504 (Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity), which has been established as the standard for products and systems for the protection and repair of concrete structures.

The feature of EN1504 is that one comprehensive package has been produced to prescribe "diagnosis, design, construction, and approval of repair materials" to deal with problems of degradation in areas of concrete that have been repaired. After it was issued in 2009, all products used in the repair and protection of concrete are required to obtain the CE mark of approval in accordance with EN1504.

The point of difference from the Japanese standard is that during the process from inspection to repair, the repair objectives are summarized, and the materials and methods used are prescribed. EN1504 is a European standard, but in the future it is envisaged that it will be developed by ISO to become an international standard. Also, the USA is developing similar standards (Vision 2020). If this becomes an international standard, Japan will also have to make similar arrangements regarding protection and repair materials for concrete, and this will require a lot of effort.

EN1504-1	Describes terms and definitions within the standard
EN1504-2	Provides specifications for surface protection products / systems for concrete
EN1504-3	Provides specifications for the structural and non-structural repair
EN1504-4	Provides specifications for structural bonding
EN1504-5	Provides specifications for concrete injection
EN1504-6	Provides specifications for anchoring of reinforcing bars
EN1504-7	Provides specifications for reinforcement corrosion protection
EN1504-8	Describes the quality control and evaluation of conformity for the manufacturing companies
EN1504-9	Defines the general principles for the use of products and systems, for the repair and protection of concrete
EN1504-10	Provides information on site application of products and quality control of the works

- CE mark
- Approval number of notifying organization
- Name of manufacturer or identification number
- Year the mark was assigned
- Certification number based on declaration of conformity
- Number of the related European Standard
- Explanation of product
- Additional information on special regulations

3. Basic Information on Road and Bridge Maintenance Management

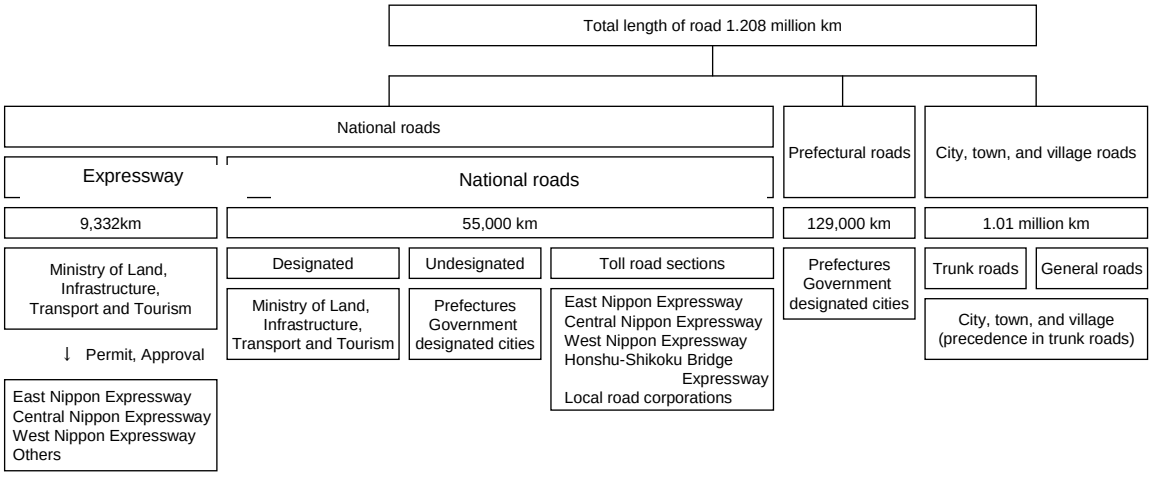
[Overview]

- Overall the road network is developed, and maintenance management is implemented either directly or using concessions, etc.
- The number of old and aging structures is increasing, so maintenance management is an important policy issue.
- There are vigorous initiatives in road maintenance management (in particular bridge maintenance management) at network level, particularly in USA.

3.1 Developed Countries

3.1.1 Japan

The total length of road in Japan is 1.208 million km, consisting of a total of 9,332 km of expressways and 1.194 million km of general roads (which includes 55,000 km of national roads, 129,000 km of prefectural roads, and 1.01 million km of city, town, and village roads). Construction and maintenance of national roads within designated areas is carried out by the Ministry of Land, Infrastructure, Transport and Tourism, but outside these areas it is carried out by a prefecture or government-designated city. The construction and maintenance of toll roads is carried out by expressway companies such as NEXCO, etc., and for prefectural roads it is carried out by the prefecture (or if it is within a government-designated city, by the city). However, construction and maintenance of city, town and village roads is carried out by the city, town, or village.



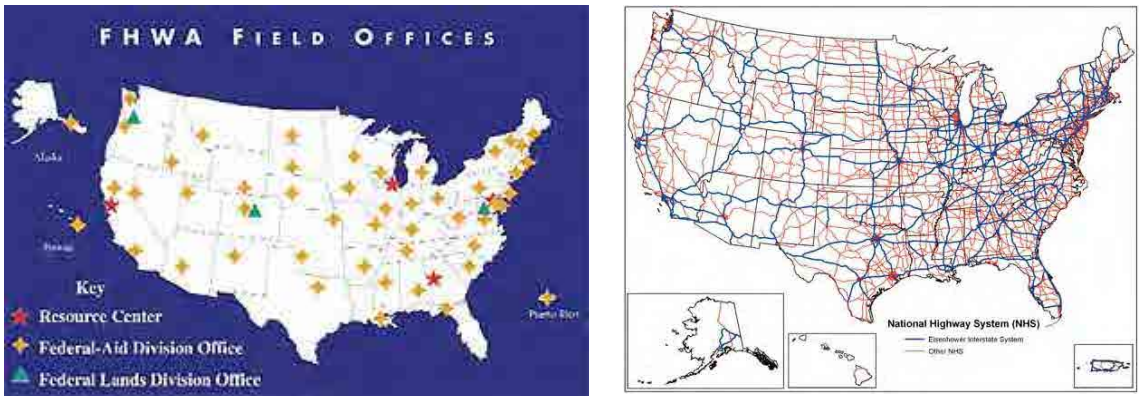
Source: Prepared by the Study Team

Fig. 3-1 Total road length and management organizations (Japan)

3.1.2 United States of America

The Federal Highway Administration (FHWA) is an organization of the Department of Transport. FHWA provides the necessary funding and technical support to each local

government for road construction, maintenance and development, provides local and natural environmental protection adjacent to expressways to ensure safe, convenient, and economical movement within the country. FHWA constructs an integrated transport system to vitalize the economy through road management. FHWA classifies the roads in the country into three hierarchies: arterial roads, collector roads, and local roads. Among the arterial roads is the national highway system (total length: about 260,000 km) whose roads are important for the country's economy, defence, and transport; interstate highways; the strategic highway network whose purpose is defence; intermodal connectors; and other principal arterial roads.

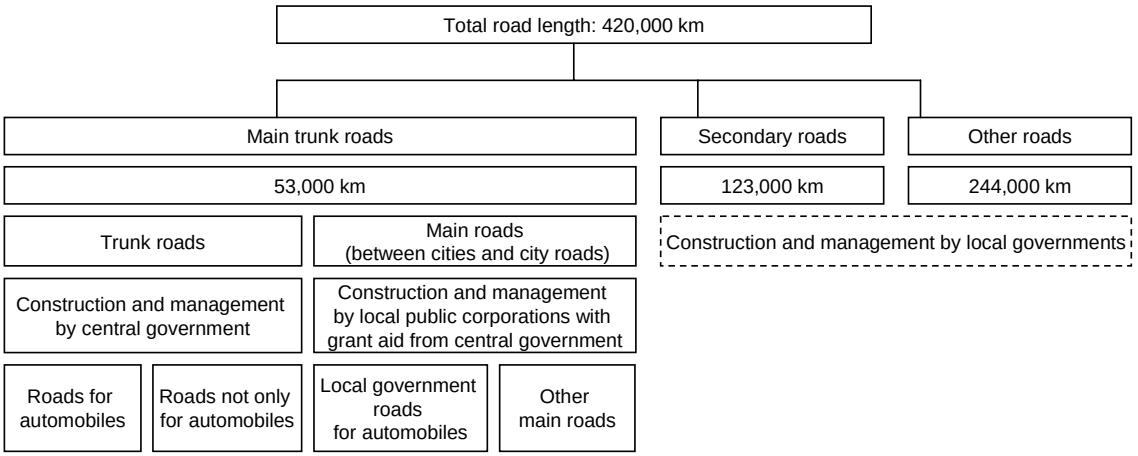


Source: FHWA

Fig. 3-2 National arterial road network and FHWA offices

3.1.3 United Kingdom

In 2009 the total length of road was 420,000 km, consisting of a total length of 53,000 km of main trunk roads, 123,000 km secondary roads, and 244,000 km of other roads. The Highways Agency (HA), which manages the roads in England, was established in 1994 as an agency affiliated to the Department for Transport with the objectives of managing traffic and reducing congestion, providing information to users, improving safety, improving the reliability of travel times, environmental conservation, etc. The HA has adopted Managing Agent Contracts (MAC) in which management and operation of roads is comprehensively contracted to private companies in 14 areas. However, over several years from 2012 they will be changing from MAC to Asset Support Contracts (ASC) which emphasizes more on quality management. ASC contractors will assume responsibility for road maintenance management within an area.



Source: Prepared by the Study Team

Fig. 3-3 Total road length and management organization (United Kingdom)

3.2 Semi-developed Countries

[Overview]

- Human resources at central and site office level is provided to a certain extent, and each country implements maintenance management using either direct management or concessions, etc.

- The following is a summary of the five semi-developed countries (South Africa, Thailand, Malaysia, Brazil, and Chile).

(South Africa)

- Because of apartheid, oil which is the raw material for asphalt could not be imported, so from the 1970s management methods based on preventative maintenance were implemented. However after the abolishment of apartheid, the maintenance cycle in many local governments has collapsed.
- In part advanced road asset management is currently implemented through a partnership of industry, government, and academia.
- National roads (toll roads) are managed by concessions, and other roads (national roads (non-toll roads), city roads, provincial roads, city town and village roads) are each managed by their administrators.

(Thailand)

- Both national roads and local roads are directly managed, but their management bureaus differ, national roads being managed by DOH, and local roads by DDR.
- Technical staffs with Ph.Ds in maintenance management are employed in key positions, and a maintenance management scheme with links to universities has been constructed.

(Malaysia)

- National roads and expressways are managed by concessions, provincial roads and local roads are each directly managed by provincial governments and local governments.
- Concessions are actively employed in a scheme in which road assets are owned by the nation and managed by the private sector, and contracts are specification based.

(Brazil)

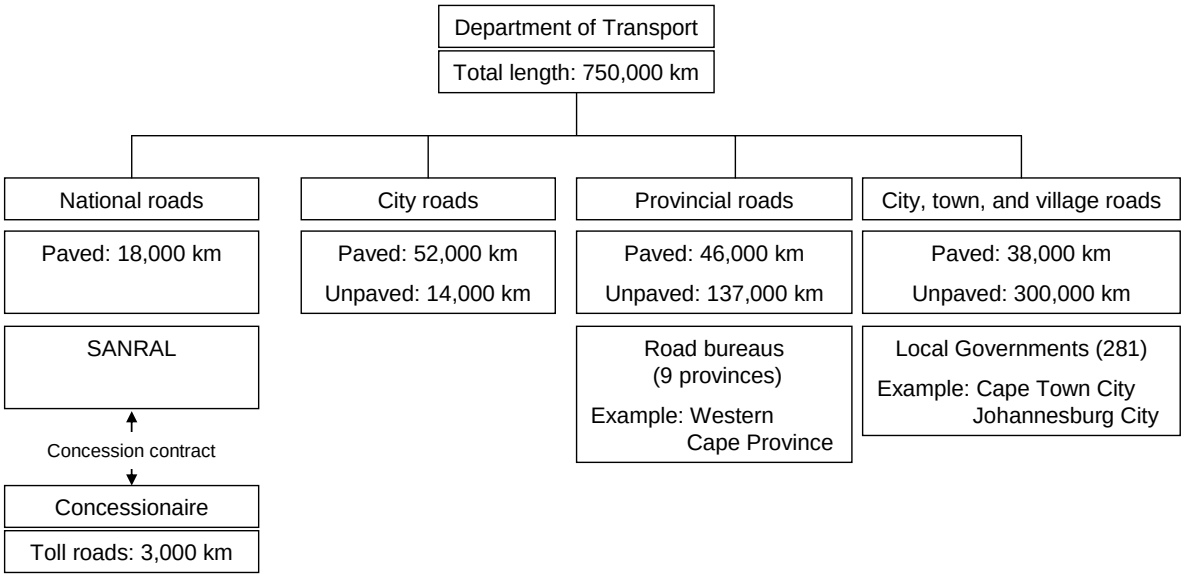
- Federal roads and provincial roads are a mixture of concessions and direct management, and there are also many different management agencies.
- Performance-based maintenance management contracts (CREMA type) are being tried on directly managed roads.

(Chile)

- Some national roads have been constructed and are managed by concessions; other national roads and local roads are directly managed.
- Concessions have been introduced on national roads with high traffic volumes, and at the present time no new concessions are planned.

3.2.1 South Africa

The total length of roads in South Africa is about 750,000 km, consisting of about 150,000 km of paved roads (national roads about 18,000 km, provincial roads about 46,000 km, city roads about 52,000 km, and urban roads about 38,000 km), and unpaved roads about 450,000 km (provincial roads about 137,000 km, city roads about 14,000 km, and urban roads about 300,000 km). The Department of Transportation manages the South African National Road Agency (SANRAL) which manages national roads, nine provincial road bureaus that manage provincial roads, and 281 local government road bureaus that manage urban roads. The national roads managed by SANRAL include about 3,000 km of toll road and 15,000 km of non-toll road, and management of toll roads is contracted to concessionaires.



Source: Prepared by the Study Team

Fig. 3-4 Total road length and management organization (South Africa)

There is a long history in South Africa of road asset management, including paving and bridges, and asset management systems have been positively utilized for paving and bridges. There are considered to be two reasons for this as follows.

- There were very few engineers, so young people were taken in and given authority, and a cooperative system among government, research institutes, universities, and industry was developed.

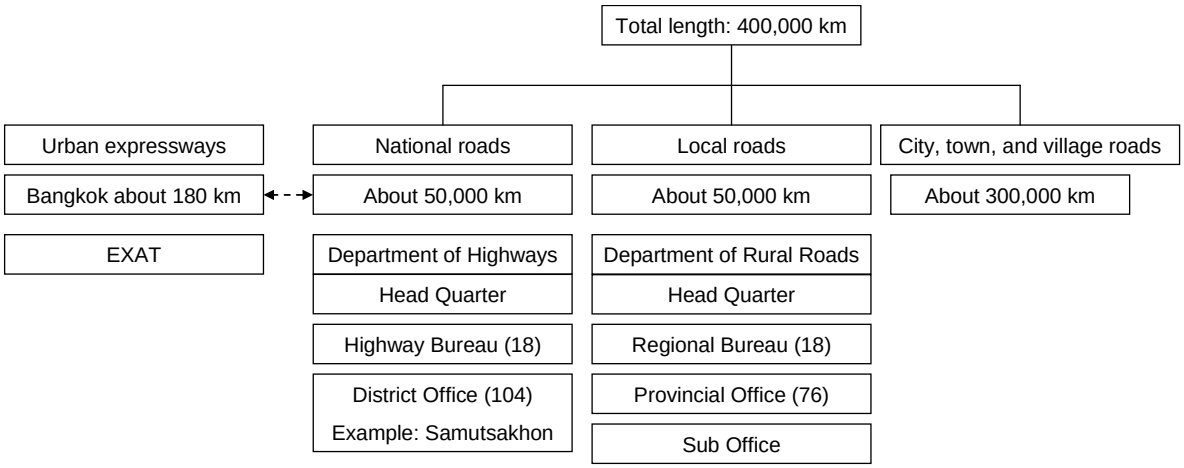
- In particular oil was not used for paving (and in addition the import of oil was not possible because of apartheid), so the thickness of the asphalt surface layer was small, therefore preventive measures are implemented for safety.

After BBEEE (a policy of empowerment for black people) in 1994, experienced engineers went overseas. In addition, as a result of division of local authorities, budgets were transferred from central government to provincial governments, but provincial governments were unable to allocate budget for road management, so road management was neglected, and the condition of roads degraded significantly. A scheme has presently been created in which the central government provides road maintenance grants specifically for use on road management to provinces that have introduced road condition surveys and asset management. Also, SANRAL, who manage national roads, has the concept that the most important thing for management of

roads is acquiring reliable data. Asset management software is just a tool, and even if the software is purchased, if there is no data it is not possible to start asset management.

3.2.2 Thailand

The total length of road in Thailand is about 400,000 km. National roads which are managed by the Department of Highways (DOH) are about 50,000 km, local roads which are managed by the Department of Rural Roads (DRR) are about 50,000 km, and city town and village roads which are managed by municipal government are about 300,000 km. National roads are managed under the hierarchy of Department of Highways (DOH) as headquarters, 18 local highway bureaus, and 104 district offices, with district offices provided at the rate of 1-2 per province. For local roads the Department of Rural Roads (DRR) is the headquarters, there are 18 regional bureaus and 76 provincial offices, and below the local offices the organization is expanded to include 376 suboffices. Also, the Expressway Authority of Thailand (EXAT) manages about 180 km of the 204 km of expressway in Bangkok, excluding the BTO (Build Transfer Operate) line.



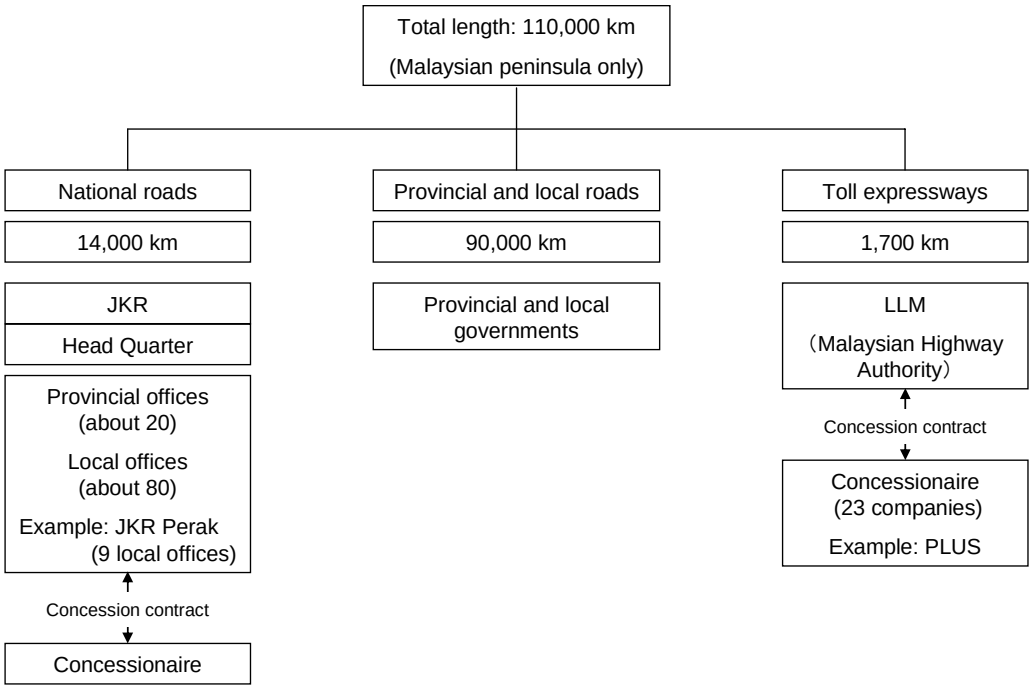
Source: Prepared by the Study Team

Fig. 3-5 Total road length and management organization (Thailand)

Budget for maintenance of pavements is classified as routine maintenance and special maintenance. The former is allocated to local offices based on workload which is determined by a function of the present quantity of road assets such as road length, number of lanes, age of the pavement, amount of traffic, number of lighting columns, etc. The latter is a budget for rehabilitation and periodic maintenance, and for each project the local office prepares a preliminary design and cost estimate and requests budget from the headquarters. The maintenance is either carried out directly or contracted externally, but rehabilitation is all contracted externally.

3.2.3 Malaysia

The total length of road in Malaysia (Malaysian peninsula only) is about 110,000 km, of which national roads are about 14,000 km, provincial and local roads about 90,000 km, and toll expressways 1,700 km. National roads are managed through a hierarchy of JKR (PWD: Public Works Department) as headquarters, about 20 provincial offices (JKR State), and about 80 local offices (JKR District). For expressways, the Malaysian Highway Authority (LLM) contracts the management of expressways to several concessionaires through concession contracts.



Source: Prepared by the Survey Team

Fig. 3-6 Total road length and management organization (Malaysia)

It is a characteristic of national roads in Malaysia that the work of maintenance management is carried out by the concessions. In December 2000, about 14,000 km of national roads (Malaysian peninsula only) was classified into three regions (northern region about 3,000 km, central region about 7,000 km, and southern region about 4,000 km), and the concessions for maintenance management work started. The concession period is 15 years (can be extended), and a review is carried out every five years.

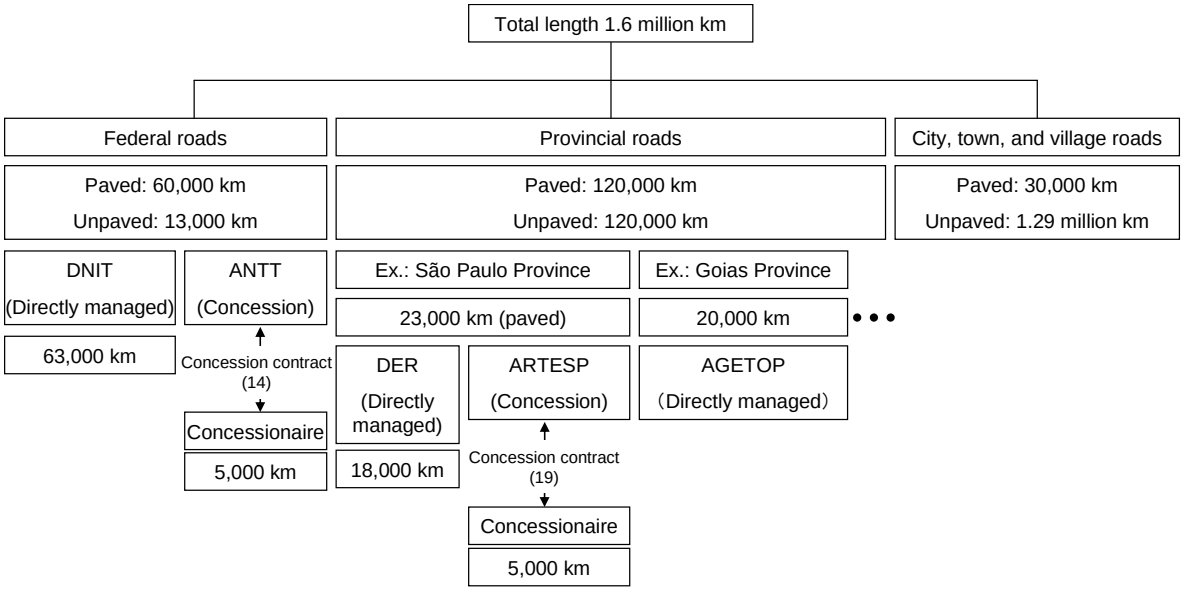
The nation owns the road assets, and concessionaires carry out the maintenance management service. Although it is referred to as privatization, the roles are divided as follows: the nation owns the road assets, and equipment is owned by private sector organizations who provide the maintenance management service. All the road maintenance management work apart from inspection and repair of bridges is contracted to the concessionaires, and repair work greater than a certain scale is carried out by JKR based on inspection results.

The concessionaire contracts are specification based (prescribing the number of times per week cleaning is carried out, etc.), not performance-based. Payments to the concessionaires are calculated by multiplying a specified amount of work by unit rates. The unit rate for routine maintenance is determined as a total amount of RM1550/km (the total for unit rates according to item such as management of road shoulders, cutting grass, etc.). However for periodic maintenance and emergency work, a schedule of rates (SOR: prepared by a committee) defined for each work is used.

3.2.4 Brazil

The total length of road in Brazil is about 1.6 million km, of which paved road is about 210,000 km (federal roads about 60,000 km, provincial roads about 120,000 km, and city roads about 30,000 km), and unpaved roads about 1.42 million km (federal roads about 13,000 km, provincial roads about 120,000 km, and city roads about 1.29 million km). The methods of maintenance are classified as either direct manage system or concession management system. For federal roads, maintenance is performed by DNIT in direct management system, and ANTT

in concession management system. For provincial roads maintenance is carried out by DER (São Paulo Province) and AGETOP (Goias Province) in direct management system, and ARTESP (São Paulo Province) in concession management system. Until 1994 the central, provincial, and city governments directly carried out development and management of roads. However in 1995 concessions was introduced to widen the existing roads and for rehabilitation, and maintenance management; at present there are about 4,900 km of federal road and about 11,000 km of provincial road managed by concessions.



Source: Prepared by the Survey Team

* Of the 55 roads subject to concession contract, there are 14 federal roads, 40 provincial roads (including 19 in São Paulo province), and 1 city road (Johannesburg City)

Fig. 3-7 Total length of road and organization of management (Brazil)

(Federal roads)

Federal roads are managed by two methods: the direct management system and the concession management system. In the direct management system the introduction of performance-based maintenance management contracts is in progress for pavements, and with assistance from the World Bank, the contract management system referred to as "CREMA" is being tested. The concession management system is being positively introduced with an upper limit of about 15% of the total length of about 60,000 km, mainly those roads with heavy traffic.

(Provincial roads)

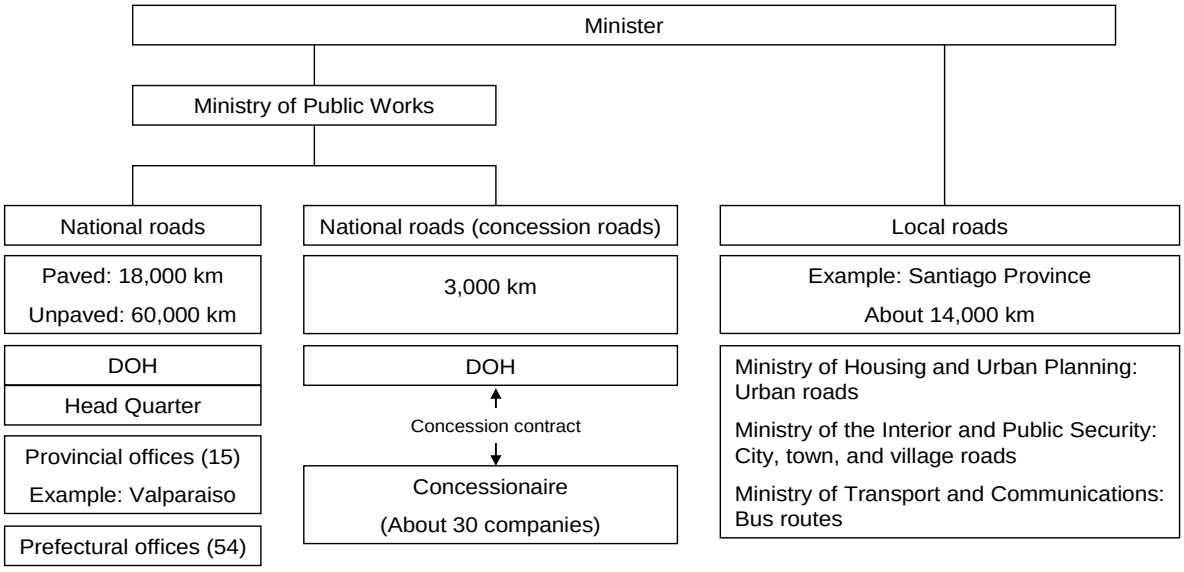
Provincial roads are managed by two methods: the direct management system and the concession management system, the same as for federal roads. In São Paulo Province, of a total of about 23,000 km of provincial road, about 5,000 km of road are subject to concession contracts, and about 18,000 km of road is directly managed by DER. Of the 40 concession contracts introduced for provincial roads in São Paulo Province, 19 or approximately half are under jurisdiction.

3.2.5 Chile

Roads in Chile include national roads managed by the central government and local roads managed by provinces. The total length of national road is about 78,000 km, of which paved road is approximately 18,000 km, of which about 3,000 km is concession road. There are three

types of local roads: urban roads under the jurisdiction of the Ministry of Housing and Urban Planning, city town and village roads under the jurisdiction of the Ministry of the Interior and Public Security, and bus routes under the jurisdiction of the Ministry of Transport and Communications. National roads are classified into paved, simple paved, and unpaved. There are three types of paved road: asphalt paving, concrete paving, and double bituminous surface treatment (DBST). Simple paved roads are dirt roads stabilized with salt, etc., single bituminous surface treatment roads (SBST roads), Otta Seal, etc. There are three types of paving for local roads: concrete paving, asphalt paving, and block paving.

The Roads Bureau, Ports Bureau, and Urban Development Bureau, and other bureaus are responsible to the Minister and Deputy Minister of the Ministry of Public Works, and the Roads Bureau has local development bureaus in 15 provinces. Also, an organization under the direct jurisdiction of the minister manages concession projects. This organization is separate from the Roads Bureau, has about 80 to 100 employees, and manages about 3,000 km of concession road that is managed by about 30 concession companies.



Source: Prepared by The Survey Team

Fig. 3-8 Total road length and management organization (Chile)

(National roads: concession management system)

The concession management system was introduced in 1995 to carry out maintenance management for 20 to 25 years, including construction of tunnels, improvement of existing roads, etc. At present there is a total length of about 3,000 km of concession road, each project has a total length of about 200 km, costing about US$150-US$300 million. Of approximately 6,800 bridges, 450 bridges are included on concession roads. Some cases include widening existing roads or providing new tunnels or bridges along existing roads. The concession period, which is a maximum of 35 years, and the prospective profit within that period are the two variables for determining the winning bid for concession projects. Concessionaires are responsible for management defects, so they have insurance in order to transfer responsibility for the risk of defects.

(National roads: direct management system)

Apart from concession roads, management of national roads (total length about 75,000 km) is carried out by head office, provincial offices (15), and prefectural offices (54). The role of the provincial offices is to confirm the data from inspections carried out by prefecturals, to determine the continuous maintenance needs of the prefecturals, to request budget from the

central government, to allocate maintenance and improvement budget to the prefecturals, to confirm the status of implementation, and to manage contracting of maintenance and improvement work to contractors.

3.3 Developing Countries

[Overview]

- In developing countries, the organizations responsible for maintenance management are both central and local organizations, the same as for semi-developed countries.
- Various methods are adopted for maintenance management work, such as direct management by central and local governments, commissioning public sectors, and combinations of these.
- The influence of the policies of the World Bank can be seen in most of these countries.
- The following four countries are typical examples.

(Vietnam)

- There are no offices directly under the Directorate of Roads for Vietnam (DRVN), but there are privatized maintenance management companies.
- Apart from the local management bureaus, the Provincial Department of Trade (PDOT) also carries out management of national roads.
- There are plans to privatize national road management organizations, and introduce road maintenance funds and performance-based contracts.

(Kenya)

- In addition to 47 directly managed local offices, there are also public corporations, etc., which are implementing organizations for road maintenance.
- Kenya has tried to introduce performance-based contracts using the World Bank model form, but they have not been established. Currently support is being provided for the introduction of performance-based contracts by JICA.

(Mozambique)

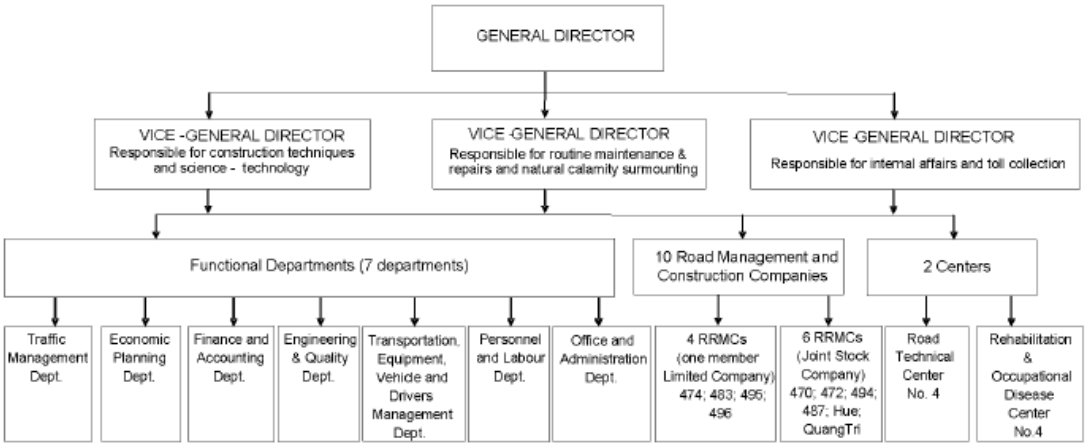
- A public corporation (ANE: an organization directly under the Minister of Public Works and Housing) manages more than 90% of the total road network.
- Performance-based contracts are being tried out as a pilot scheme on some roads.

(South Sudan)

- Construction companies carry out repairs within the scope of responsibility for defects.
- After completion of the warranty period, the road administrators carry out the repairs, but overall the technical level is insufficient.

3.3.1 Vietnam

The responsible organization is the Directorate of Roads for Vietnam (DRVN) of the Ministry of transport (MOT). The total length of road is 16,758 km (2009), and the number of bridges managed is about 4,300. There are four local management bureaus (RRMU) (RRMU2, 4, 5, 7). There are no offices directly under these, but there are privatized maintenance management companies. Apart from the local management bureaus, the Provincial Department of Trade (PDOT) also participates in management of national roads. The Provincial Department of Trade manages a total length of 8,839 km (2007), about 50% of the total.

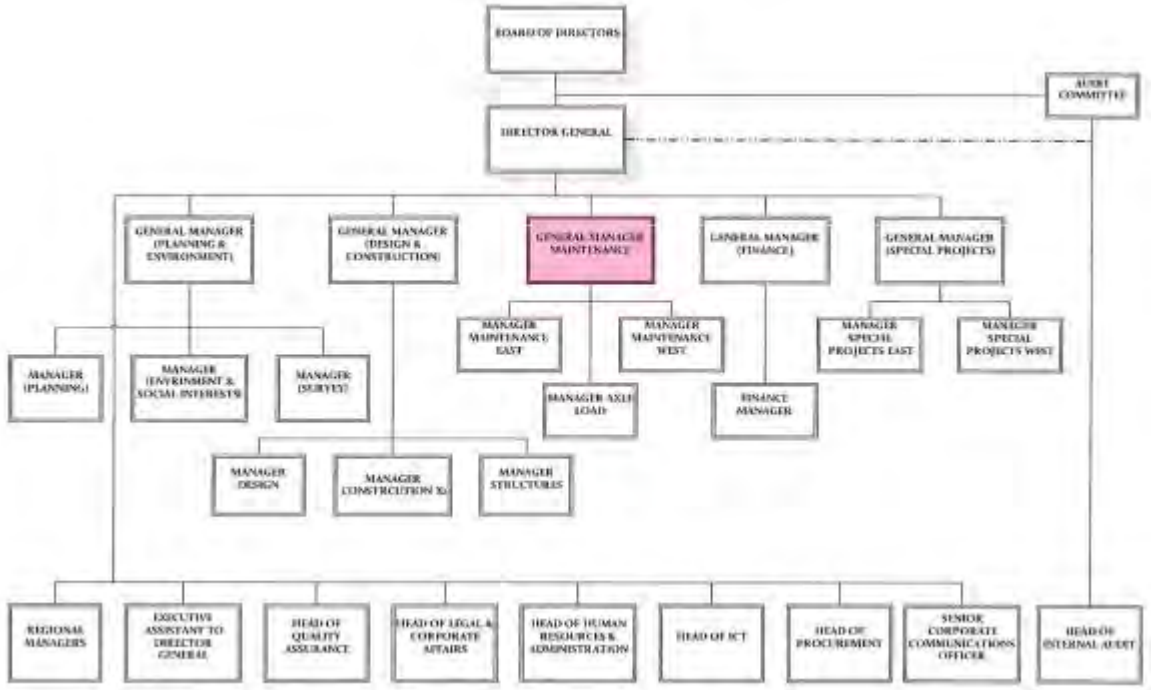


Source: JICA questionnaires to specialists

Fig. 3-9 Organization of road management (Vietnam)

3.3.2 Kenya

The responsible organization is the Ministry of Roads. The total length of road is 160,886 km, and the number of bridges is considered to be more than 1,000. (The actual number is not certain) Besides 47 local offices of the Ministry of Roads, implementing organization for road maintenance include the Kenya Roads Board (KRB), the Kenya National Highways Authority (KeNHA: see the diagram below), Kenya Rural Roads authority (KeRRA), Kenya Urban Roads Authority (KURA), and Kenya wildlife service (KWS).

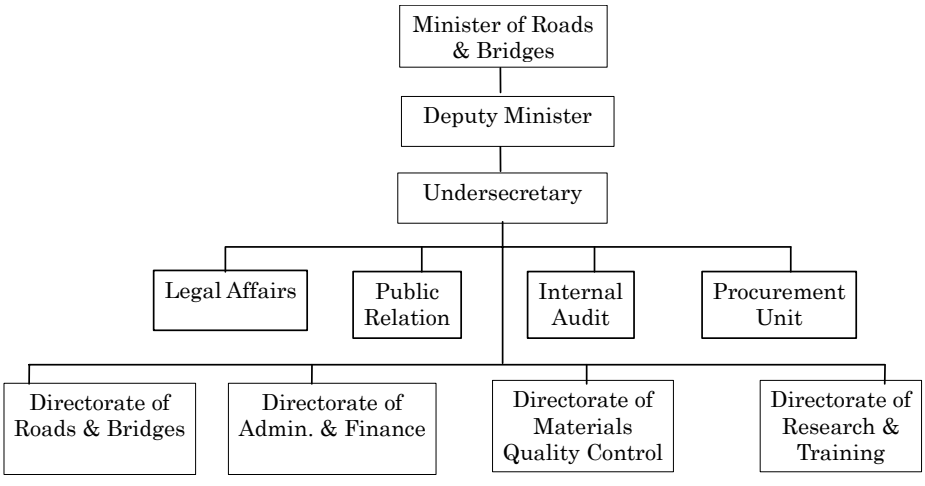


Source: JICA specialist questionnaire document

Fig. 3-10 Organization of road management (Kenya)

3.3.3 South Sudan

The organization responsible is the Ministry of Roads and Bridges. Construction and maintenance management of provincial roads, international roads, and national roads is performed by the Road Authority (RA), for provincial roads it is performed by the Ministry of Physical Infrastructure (MoPI), and for other roads it is performed by city councils. The total length of road is 12,642 km, consisting of interprovincial roads 7,369 km, international roads 1,451 km, and national roads 3,822 km.



Source: JICA specialist questionnaire document

Fig. 3-11 Organization of road management (South Sudan)

4. Status of Pavement Maintenance Management

4.1 Developed countries

[Overview]

- An advanced pavement maintenance management system that includes a database for integrated management of pavement data, a function for formulating optimal investment plans, and a function for preliminary calculation of medium and long-term costs, etc., has been introduced and is operating.

- The concept of pavement maintenance management in networks has permeated, and in United Kingdom and New Zealand outsourcing to the private sector, such as comprehensive commissioning and performance based orders, etc., is actively proceeding.

- Each country has its own characteristics. For example Sweden has a pavement maintenance management system consisting of three hierarchies: strategic, planning, and project; in Canada the pavement maintenance management system is one constituent element of a traffic infrastructure asset management system.

4.1.1 Japan

A pavement maintenance management system is operated for the maintenance management of 21,188 km of national road under the direct responsibility of the Ministry of Land, Infrastructure, Transport and Tourism.

[Inspection]

About once every 3 to 5 years, a private company is commissioned to measure cracks, rutting, and flatness using a road surface property measurement vehicle owned by the private company.

[Evaluation]

The measured road surface property data is stored in a pavement database together with road management information, pavement construction information, inventory data (MICHI), road traffic sensor data, and so on, that is possessed by the office or branch office, and used in evaluation work. Measurement values for cracking, rutting, and flatness, measured by specific methods are evaluated for a total of 100 sections. Also, a maintenance control index (MCI) is calculated.

[Planning]

Each Regional Development Bureau performs a prediction of degradation in the next fiscal year for the roads under their management, using the rate of degradation for each of the road surface properties obtained from results of the survey of road surface properties, they calculate the necessary amount of construction, and request the budget. The rate of degradation is calculated separately for each route and for each repair method used immediately before, as necessary. The amount of construction necessary is calculated in accordance with management standards and construction methods determined by guidelines for maintenance and repair of pavements.

[Implementation]

The national road offices under the eight Regional Development Bureaus, Hokkaido Development Bureau, and Okinawa General Bureau's Development and Construction Department contract out all the maintenance and repair work such as day-to-day maintenance, repairs, etc.

In addition to the above, in most of the local governments such as Shizuoka Prefecture, Kyoto Prefecture, Yokohama city, etc., road surface inspection and property management is implemented, and based on the results future maintenance and repair plans are formulated.

4.1.2 United States of America (Washington State)

In 1969 surveying the condition of the entire state road network commenced, and from the late 1970s they developed their own PMS (WSPMS). Washington State is one of the first pioneers in the use of PMS (taken from the FHWA Transportation Asset Management Case Studies series).

[Inspection and evaluation]

Since 1988 a survey of the properties of the entire state road network has been carried out (flatness, steps, rutting) yearly, and stored in a WSPMS database.

[Planning]

Using the WSPMS analysis function, pavement degradation curves are estimated, and using a Pavement Structural Condition (PSC) index, which represents the structural integrity, the road managers select repair construction that minimizes the life cycle cost. It is being improved to also take the users' costs into consideration.

[Implementation]

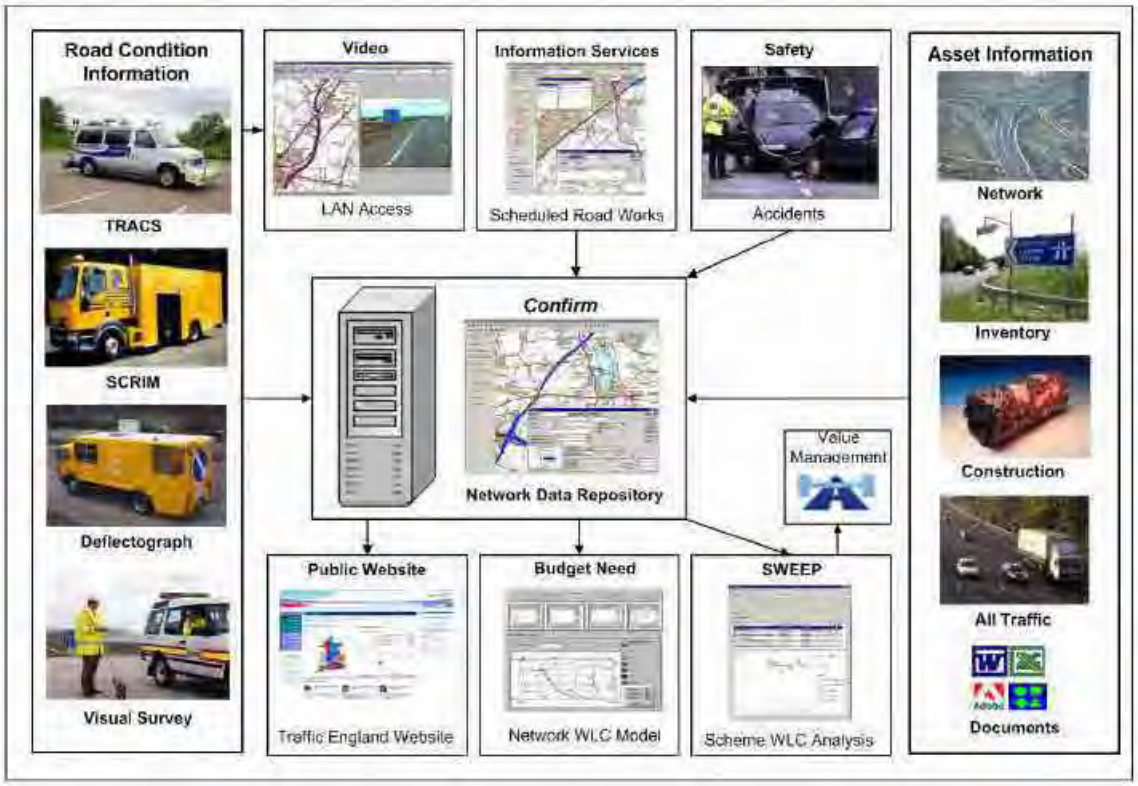
WSPMS is not only used for central network-based planning, but it is also used at project level, such as for selection of construction methods in accordance with site conditions, and design of repair and maintenance work such as rehabilitation, etc.

4.1.3 United Kingdom

The Highways Agency of the Department for Transport manages a 7,754 km road network. The Highways Agency manages pavement maintenance using the HAPMS.

(Main Functions of HAPMS)

- Database function for integrated management of data regarding the national road network, construction, register data, traffic, accident, and pavement property data
- Data analysis function and mapping
- Function to prepare document-based reports
- Function to derive optimum solutions that minimize life cycle costs for pavement maintenance management subject to budget constraints, at project level (scheme level) and at network level
- Function to record and manage information on lane closures



Source: Highways Agency, Department for Transport

Fig. 4-1 Main constituent elements of HAPMS

[Inspection and evaluation]

(Network level measurement)

TRACS (TRAffic-speed Condition Surveys) measurements:
Measurements are carried out every year on the multiple lanes of the entire network

SCRIM (Sideways Force Coefficient Routine Investigation Machine) measurements:
Measurements carried out once every 3 years on the entire network on the lane where the heaviest vehicles pass

(Scheme level measurements)

Deflection measurements by deflectograph (vehicle that measures the pavement strength while travelling at 2.5 km/h)

[Planning]

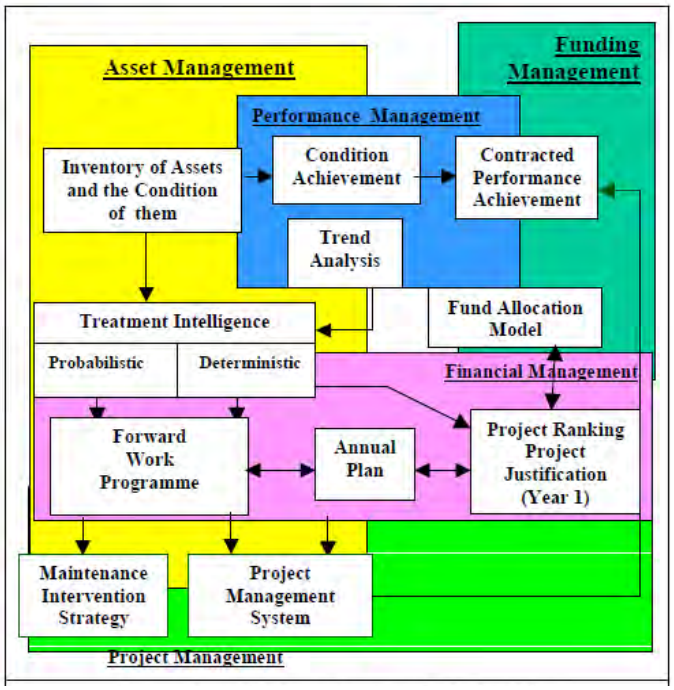
Using the SWEEP (Software for Entire-of-life Economic Evaluation for Pavements) tool, which is a part of HAPMS, maintenance management plans are formulated to minimize the life cycle cost and maximize the cost effectiveness.

[Implementation]

The entire country is divided into 14 regions, and in each region maintenance management is contracted to a private company on a 5-year contract. As part of the contract work, collection of data on the roads managed and analysis of the data by a specific method is required, in order to perform effective maintenance management.

4.1.4 New Zealand

Transit NZ of the Ministry of Transport manages 10,836 km of national road, and all maintenance management work is outsourced to private companies. About 2/3 of the outsourcing is by performance-based contract lasting 5-10 years. Transit NZ strategically manages the outsourcing program, and they are considered to have the world's most advanced asset management. The background to the early development of asset management in NZ is the fact that in the history of development of NZ there were many simple and temporary structures.



Source: Transit NZ

Fig. 4-2 Road asset management scheme (New Zealand)

[Inspection and evaluation]

- Every year Transit NZ visually evaluates 10% of road sections and measures the road surface properties of the entire road network using the high speed travelling measuring machine SCRIMS (Sideways Force Coefficient Routine Investigation Machine). Once every three years the pavement strength is measured using FWD. The SCRIM and FWD measurements are carried out by private contractors.
- Private contractors that carry out the maintenance management are required to have their own road surface property monitoring system, and to daily monitor the performance of the pavements.
- Transit NZ commissions consulting companies to monitor the performance of construction companies. Transit NZ audits the performance of each contractor in about 5% of the length of the road that they manage.

[Planning]

- Transit NZ assigns priority to projects and creates plans using various modules and information.

- Road Asset Maintenance Management (RAMM) is a system that has been operating since the 1980s, to manage registers and records for national roads, pavement properties, and data regarding maintenance management construction. It is linked to pavement design systems. Besides this information, information on traffic is also input.
- National Optimization of Maintenance Allocation by Decade (NOMAD) is a module in RAMM for preparing ten-year investment plans for pavement maintenance and repair.
- dTIMS (a pavement modelling tool) is a module that develops degradation models for predicting the future condition of pavements.

[Implementation]

- Preparation of maintenance management plans is carried out jointly by Transit NZ together with a road Network Management Consultant.

Role	Organization responsible
Providing systems (models)	Transit NZ
Providing input data	NMC
Performing analysis	NMC
Confirmation of data on site	NMC
Correction of data	Transit NZ / NMC
Verification of calibration coefficients	NMC
Management of calibration	Transit NZ

4.1.5 Sweden

The Swedish National Road Administration (SNRA) manages 98,100 km of national road in Sweden. The national roads include 77,100 km of paved road, and 21,000 km of gravel road, and the national roads account for 69% of the traffic in the entire country. The trunk national roads account for only 3.5% of the total length of roads in the country, but they carry 43% of the total amount of traffic. SNRA is organized with headquarters and a local office provided in each of seven regions in the entire country.

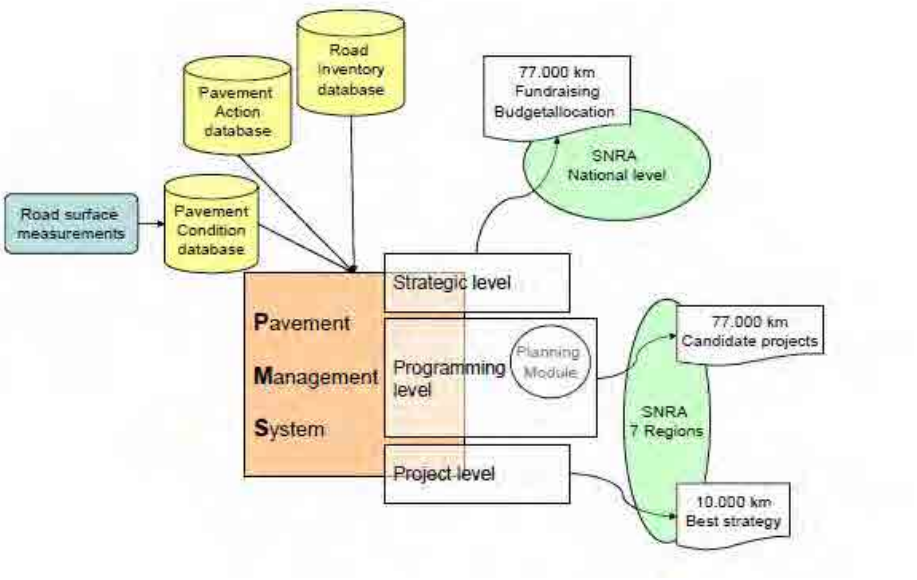
[Inspection and evaluation]

- In cooperation with the Swedish Road and Transport Institute (VTI), SNRA headquarters outsources measurement of the road surface properties of the entire national road network to private companies on a four-year cycle.
- When necessary, the local offices outsource project level road surface property special surveys within their own areas of responsibility.
- The measurement items and methods used in the Swedish road surface property surveys are as follows.

  ✓ Laser RST measurements (network level and project level)
  ✓ Flatness IRI (mm/m), rutting (mm), transverse slope (%)
  ✓ Ground penetrating radar measurements (project level)
  ✓ Thickness of pavement layer, and depths to buried objects, bedrock, aquifers, etc.
  ✓ Cores, boreholes (project level)
  ✓ FWD (project level)

[Planning]

- The Swedish PMS has three layers: the strategic level (budget request and budget allocation), programming (selection of candidate projects for implementation), and project level (design, planning maintenance management work, etc.), and is used at the central level or at local office level depending on the purpose.
- Since 1986, the strategic level PMS uses a system known as HIPS which was developed in Finland.
- The programming level PMS was developed based on PMS2000 which was developed in Norway, and requires more input data, and is based on the HDM-4 model which also estimates user costs.
- The project level PMS is referred to as PMS object 2000, which is a computer model that carries out maintenance management and new construction design planning based on the Swedish pavement design manual (ATV VAG).



Source: SNRA

Fig. 4-3 Pavement management system (Sweden)

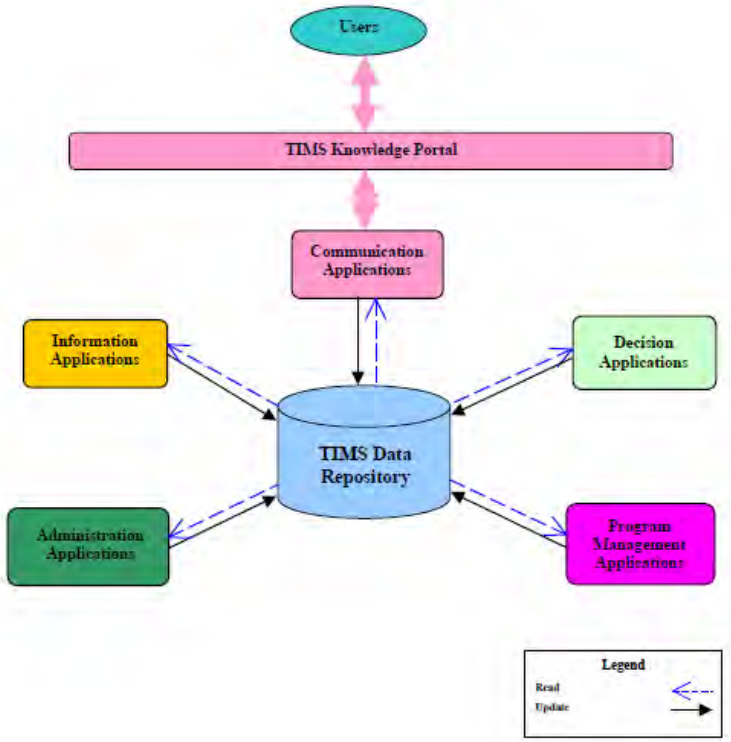
[Implementation]

- SNRA has three bureaus: planning and management bureau, a production bureau, and the consulting bureau.
- The seven local offices carry out maintenance management of national roads under their jurisdiction, but implementation of the maintenance management construction work is all carried out by the SNRA production bureau or is outsourced to private companies. (SNRA's production bureau operates as a company with an independent budget)

4.1.6 Canada (Alberta Province)

In Canada, asset management of infrastructure is the responsibility of provincial governments, and the central government has almost no involvement. In Alberta province, PMS is one constituent element of the traffic infrastructure asset management system, which is operated with the object of integrated optimum management together with other assets. Alberta province operates TIMS (Transportation Infrastructure Management System) for integrated management

of traffic infrastructure assets. TIMS is formed from an integrated database (TIMS Data Repository) and various Decision Support Systems (applications). The PMS that is referred to as HPMA (Highway Pavement Management Application) is one of the Decision Support Systems.



Source: Alberta Province, Canada

Fig. 4-4 Transportation Infrastructure Management System (Canada)

[Inspection and evaluation]

- Measurement of the road surface properties of the entire provincial road network is outsourced. IRI and rutting is measured every year on all roads using a vehicle travelling in one direction. Filming a video log is carried out once every three years, covering lanes travelling in both directions.
- In order to ensure the quality of the data collected by outsourcing, a strict quality control program is implemented.

[Planning]

- The HPMA consists of register data, pavement property data (current state and history), a current repair and improvement needs and future estimation and evaluation module, a maintenance and repair construction selection module, an economic evaluation module, and an optimum investment plan formulation module.
- By inputting management standards such as IRI, SDI (Surface Distress Index), PQI (Pavement Quality Index), and so on, it is possible to calculate the necessary short-term amount of maintenance construction.
- By using a degradation model that is contained within the system, it is possible to estimate the future pavement condition and history, and estimate the future amount of maintenance repair construction that will be necessary based on a decision tree.
- Five-year, 10-year, and 20-year maintenance plans, and optimum plans subject to budget constraints can be formulated.

[Implementation]

- During the economic crisis from the 1980s to the early 1990s, the number of staff in the provincial government was greatly reduced, and the management system of carrying out government work in accordance with business principles became established.
- In Alberta province all road maintenance repair and improvement work is outsourced to the private sector. The main role of the provincial government is to effectively outsource the work and supervise it. Asset management is at the core of the provincial government's work.

4.2 Semi-developed countries

[Overview]

- The use of maintenance management software in the maintenance management cycle at both central and site level is established to a certain degree.

- The following is a summary for the five semi-developed countries (South Africa, Thailand, Malaysia, Brazil, and Chile).

(South Africa)

- From the 1970s preventative maintenance type maintenance management has been implemented, but after the removal of apartheid the maintenance management cycle in most local governments has collapsed.
- On the other hand, especially SANRAL (national roads) and Western Cape Province have accumulate road surface properties and traffic data, etc., and have constructed PMS (using HDM-4, etc.) based on highly accurate degradation models.

(Thailand)

- Inspection and evaluation is carried out by nationwide road network surveys using an automatic measurement vehicle, and daily visual inspection carried out by local offices.
- Five-year maintenance management plans and strategies for budget requests are prepared using TPMS2009 (using the HDM-4 prediction model).

(Malaysia)

- Surveys for maintenance management (road surface properties, rutting, etc.) is carried out by concessionaires, and the expressway companies review them by visual surveys.
- HDM-4 (a degradation model calibrated with accumulated data) is used for formulating medium-term maintenance management plans for asphalt paving.

(Brazil)

- The development and management of national roads and provincial roads by concessions has spread since 1995, and at present 10% of national roads are managed by concessions.
- PMS is actively used on national roads, provincial roads, and concession toll expressways.

(Chile)

- Outsourcing to the private sector is progressing, and comprehensive outsourcing of the national road network and performance-based contracts, etc., is being introduced.
- In both directly managed sections and sections outsourced to the private sector, mainly HDM-4 is used, and the pavement maintenance management cycle is consistently implemented.

4.2.1 South Africa

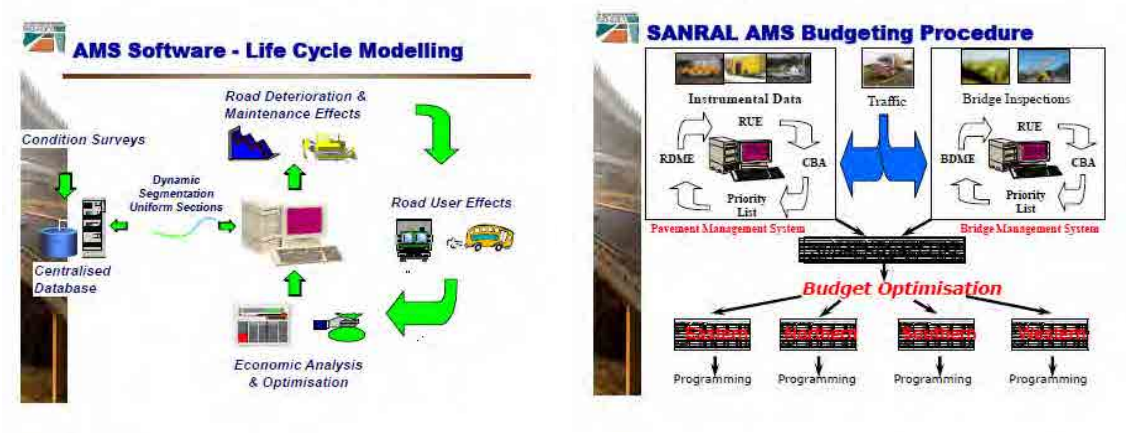
(1) Pavement maintenance management by SANRAL

[Inspection and evaluation]

SANRAL use their own measurement vehicle on which the latest measuring instruments procured from other countries are mounted.

[Planning]

Decision-making is carried out using a decision-making support tool that combines dTIMS and HDM-4.



Source: SANRAL

Fig. 4-5 Pavement maintenance management scheme (SANRAL)

(2) Pavement maintenance management in Western Cape Province

[Inspection and evaluation]

Traffic volumes and road surface property data has been accumulated for more than 15 years, and time series data for 37 test sections has been used for calibration of HDM-4. Surveys of road conditions are outsourced for paved roads, and carried out directly for unpaved roads.

[Planning]

Decision-making is carried out using a decision-making support tool that combines dTIMS and HDM-4.

(3) Pavement maintenance management by TRAC

[Inspection and evaluation]

In accordance with a performance-based long-term contract for expressways, TRAC are required to carry out measurements every year of rutting, flatness, and road surface resistance using a road surface property measurement vehicle.

[Planning]

Repair priorities are determined from pavement strength (FWD values) and fuzzy logic, using Rubicon software.

[Implementation of maintenance and repair work]

Implementation is outsourced to construction companies on a project basis.

4.2.2 Thailand

[Inspection and evaluation]

Nationwide surveys are carried out by the Road Bureau headquarters using an automatic measurement vehicle, and daily visual inspection is carried out by the local road offices. Surveying of the entire national road network is outsourced to three universities (about once every 2 years), and flatness, rutting, cracking, etc., are measured using HawkEyes, manufactured by ARRB. The inspection results of local road offices are stored on a computer together with photographic data.

Source: DOH

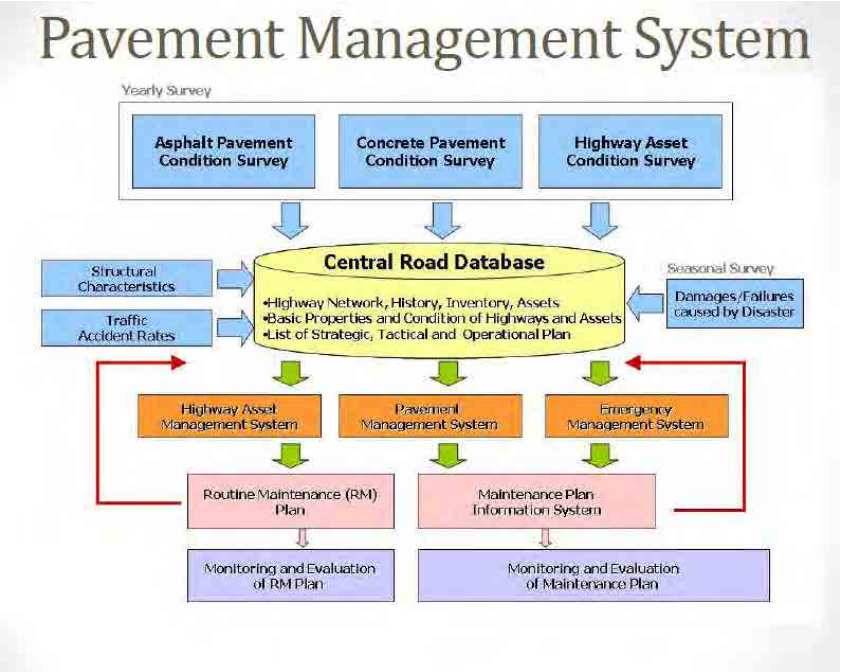
Fig. 4-6 Road surface property measurement vehicle and visual inspection (Thailand)

[Planning]

Road maintenance budget is allocated based on the work load calculated based on the visual inspection results, etc., of each local office. Budgets for special maintenance such as rehabilitation, periodic repairs, etc., are formulated using PMS known as TPMS2009. TPMS2009 is constructed based on the HDM-4 prediction model (pavement degradation, maintenance management construction effect, user cost, environmental impact). They have developed their own optimization model, which has the capabilities of formulating five-year plans for incidence management and carrying out strategic analysis for budget requests. Budget requests for special maintenance requested by the local road offices are prioritized based on TPMS2009.

[Implementation]

The Budget Bureau determines the budget for maintenance and repairs, taking into consideration other elements also, but TPMS is used as a useful means for indicating the basis of budget requests.



Source: DOH

Fig. 4-7 Pavement maintenance management system (Thailand)

4.2.3 Malaysia

(1) Pavement maintenance management of expressways

[Background]

The 1,700 km of expressways in Malaysia has been mostly constructed in accordance with the BOT system, and operation and maintenance management of all lines is carried out in accordance with the concession system. In the concession contracts, all the concessionaires are required to carry out pavement maintenance management, including determining the current condition and formulating maintenance management plans, and expressway companies supervise the work.

[Inspection and evaluation (example of the large concessionaire PLUS)]

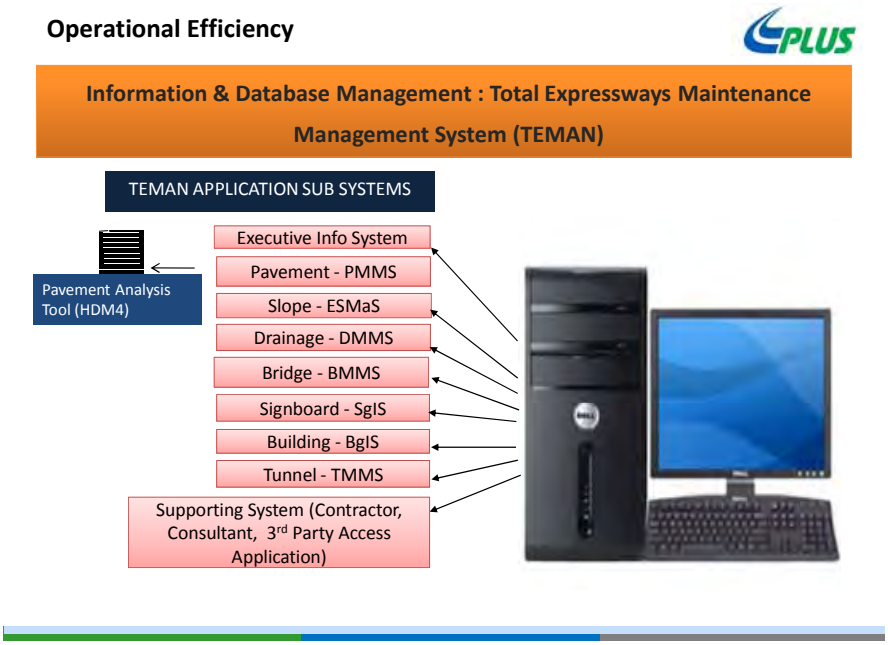
Every year the concessionaire carries out a network level road surface property survey using multi-laser profiler (MLP). Also, once every six months the FWD measurements are carried out for every 250 m, and the structural evaluation results are reported to the expressway companies. The expressway companies carry out direct visual surveys to confirm the reported results. For problem areas that are clearly indicated by the results of the status survey at network level, a detailed survey and analysis is carried out. The pavement evaluation results for each 250 m have been stored in a Total Expressway Maintenance Management System (TEMEN) since 2000.

[Planning (example of the large concessionaire PLUS)]

HDM-4 is used for formulating medium term maintenance management plans for about three years for asphalt paved sections. The HDM-4 degradation model has been calibrated using accumulated data. HMS2 is used for formulating short term plans (periodic maintenance plans). Plans for concrete paved sections, which constitute about 30% of the total, are formulated using Decision Tree.

[Implementation]

The maintenance management work that is to be carried out by the concessionaire is specified in the concession contracts on an input basis, such as the frequency of maintenance management and the time for dealing with problems, etc. As a result of the framework for charges, management standards, and service levels determined by the concession contract, the concessionaire diligently carries out inspection, to minimize the risk of incurring future repair and improvement costs, reducing the cost of maintenance management. The concession contract prescribes matters such as the times of occurrence of congestion associated with road construction, etc., and incentives for carrying out road maintenance construction efficiently are high.



Source: PLUS

Fig. 4-8 Total management system (PLUS)

(2) Pavement maintenance management of national roads

[Background]

Since 2000, the Ministry of Works has divided the road network of the Malay Peninsula into three regions, and maintenance management of the road network in each region is carried out by a concession system. In the concession system, private companies provide the maintenance management service such as daily inspections, cleaning, etc. using their own equipment, in order to satisfy KPI (Key Performance Index) requirements defined in the contract, over a long-term period of 15 years or more. Maintenance and repair plans over and above daily maintenance management work are formulated by the Ministry of Works using PMS, and the concessionaire or a general construction company is instructed to perform the work and is paid in accordance with a specification.

[Inspection and evaluation]

The Ministry of Works has commissioned IKRAM (a privatized company of a government research Institute) to carry out surveys of the conditions of the national roads in the entire country using HRM (High–speed Road Monitor), FWD, and DCP (Dynamic Cone Penetrometer) in accordance with a long-term contract. The measured data is stored in a Road Asset Management Database (RAMS-DB).

[Planning]

IKRAM formulates maintenance management plans for national roads using HDM-4. The HDM-4 input data is prepared from RAMS-DB data using a RAMS interface developed by them. Between 80% and 90% of the budget for rehabilitation and periodic repairs allocated by the financial authorities is based on maintenance management plans formulated by IKRAM.

4.2.4 Brazil

(1) Pavement road maintenance management of general national roads

[Overview]

DNIT manages 63,000 km of national road. Of this, for 5000 km, private contractors are selected and are commissioned to carry out development and maintenance management based on a 2- to 5-year performance-based rehabilitation and maintenance management contract known as CREMA.

[Inspection and evaluation]

DNIT commissions private contractors to periodically collect information such as IRI, FWD, LVC (Live-Virtual-Constructive) Architecture Roadmap (photographic and image map data), etc., over virtually the entire road network excluding the CREMA contract sections. Currently every year measurements are carried out under two companies and 3-year contracts using four measurement vehicles manufactured by DYNATEST (one company has one vehicle, and another company has three vehicles). FWD is carried out every four years. On CREMA roads, the CREMA contractors carry out road surface property surveys, and the road detailed data is submitted to DNIT by the contractors when the contract period terminates.

[Planning]

DNIT determines the priority for pavement road maintenance management work, analyzes the required budget, and formulates maintenance management plans using HDM-4.

[Implementation]

Daily maintenance management and emergency maintenance management of directly managed roads is carried out by the local offices (provided at the rate of one every 300 to 500 km) under the DNIT provincial offices. Construction larger than a particular scale such as periodic repairs, etc., is outsourced.

(2) Pavement maintenance management of concession toll expressways

[Overview]

Based on a long-term contract (25 years) the concessionaires carry out rehabilitation and functional improvements (widening, improvements, etc.) in the initial 10 years, and in the subsequent 15 years carry out operation and maintenance management as a toll road. The concession contract precisely defines the management level of the pavement that must be maintained during the contract period, and the outsourcer (nation, province, etc.) establishes a special supervisory organization to supervise the total operation and management performed by the contractor for the expressway. The concessionaires are required to implement the pavement maintenance management work using PMS based on the outsourcer's supervision. At present the maintenance management software used by the concessionaires on the national roads includes two types: the system by Dynatest and the system by PAVESIS (jointly developed with ITA University).

[Inspection and evaluation]

The concessionaires are required by their concession contracts to have road databases. Therefore road surface property surveys are carried out either directly or outsourced, and the databases are periodically updated. The company CCR visually inspects the surface layer for degradation (rutting, cracking, etc.) and take measurements using measuring instruments. The items measured and their frequency are IRI (every year), skid resistance (every year), and FWD (once every two years). ANTT visually surveys every 15 days, and checks the information input into the road database by the concessionaire.

[Planning]

The concessionaire carries out periodic maintenance based on a periodic maintenance plan as defined in the contract. If the periodic maintenance plan is changed due to the results of monitoring, etc., the concessionaire applies to the supervising organization for a change in plan, and receives authorization. The concessionaire's cash flow associated with the change in plan is adjusted by a change contract, so that the concessionaire neither loses nor gains. The concessionaire does not bear any risk, but on the other hand does not have any incentive to formulate a more rational periodic maintenance plan using the pavement maintenance management software.

[Implementation]

There are two types of construction implemented by the concessionaire: construction defined in advance in the contract, and construction deemed necessary by the concessionaire. The former is constantly monitored by the supervising organization to ensure that it is properly carried out. The latter is proposed to the supervising organization as necessary construction, and is implemented if approved. The pavement performance at the time of completion of the concession is defined in a part of the concession contract, and checked by the supervising organization.

4.2.5 Chile

(1) Pavement road maintenance management of general national roads

[Overview]

Of the 75,000 km of national road managed by the Roads Bureau, 45,000 km is maintained by the private sector under contract. There are three types of private sector contract: global, mixed global, and special contracts, but the majority are global contracts. The global contract commissions management of all the national road network contained within a management area that is set to an appropriate size to one contractor on an input basis (unit cost contract). In the mixed global contract, maintenance management of paved roads within the area is commissioned for five years on a performance-based contract, and unpaved roads are maintained in the conventional way. Special contracts are contracts for maintenance management of a special section of road.

[Inspection and evaluation]

Pavement property surveys are carried out on 15,000 km of paved roads excluding concession sections. Of this, a research Institute of the Ministry of Public Works and private contractors are commissioned to carry out measurement of pavement properties on 9,000 km using ARAN (Automatic Road Analyzer), etc., and on the remaining sections visually surveyed by prefectural employees. Measurements by ARAN is generally carried out once every 2 to 3 years, and the measured items include video images, IRI, cracking, potholes, rutting, and in addition measurements such as FWD, LWD (Light Weight Deflectometer), and sliding resistance are also carried out.

[Planning]

For periodic maintenance of both directly managed sections and sections managed by the private sector, PMS is used, mainly HDM-4, for the entire management cycle including collection of pavement condition data, preparation of databases, formulation of maintenance management plans, budget requests and allocation, and implementation of construction. For periodic maintenance of unpaved roads and routine maintenance of paved roads and unpaved roads, each province determines the budget based on policy in accordance with the results of previous years, emergency situations such as natural disasters, etc.

[Implementation]

The actual periodic maintenance is carried out by prefectural offices and private sector contractors after the provincial offices have checked the current status based on HDM-4 analysis results.

(2) Pavement maintenance management of toll expressways

[Overview]

National roads with particularly heavy traffic (about 3,000 km) are managed by private companies as toll expressways by means of a concession contract. There are 15 sections of concession road (average 200 km) with long-term contracts of 20 to 30 years. At the start of the contract existing road is rehabilitated, the number of lanes increased, and other road facilities are installed, and in the subsequent 20 to 25 years maintenance management that satisfies performance criteria defined by the contract is carried out.

[Inspection and evaluation]

The concessionaires carry out daily inspection as defined by the concession contract. The Ministry of Public Works assigns one inspector for each project, who constantly checks the concessionaire inspection reports to determine whether the criteria are being satisfied. The concessionaire commissions a consulting company to carry out a pavement property survey once a year, and report to the Ministry of Public Works. The concession contract specifies profilers, grip testers, FWD, HWD (Heavy Weight Deflectometer), skid resistance, etc., as measurement items and equipment to be used in measurement.

[Planning]

Based on the pavement property results, etc., every year the concessionaire adjusts the maintenance management plan for the remaining concession period. Most of the concessionaires use HDM-4.

[Implementation]

The concessionaires carry out maintenance work using defined methods in order to ensure the performance (IRI, joints, etc.) that must be maintained during the contract period. For example, if the FWD value drops below the criterion, improvement work (5 cm overlay, etc.) must be carried out. The maintenance and repair construction that can be adopted by the concessionaire (overlay, slurry seal, patching, etc.) is defined in advance in the contract, but the concessionaire may also propose new technology (micro-paving, etc.), and if the performance can be satisfied, the reduced cost is all profit for the concessionaire.

4.3 Developing countries

[Overview]

- Although the maintenance management cycle is carried out at central and site level, there are various levels of inspection and evaluation, etc.
- Pavement management systems (PMS) based on HDM-4 have been introduced, but in most cases they are not being effectively used.
- The following four countries are representative examples.

(Indonesia)

- Databases have been created as an overall system, and daily inspection and periodic inspections are implemented.
- Pavement maintenance management software has been introduced, and is used for formulating annual plans, and budget plans.
- The financial departments do not trust the quality of the budget request documents (inspection results, etc.), so they are not effectively utilized.

(Kenya)

- A road property inspection DB has been introduced, and the road condition evaluation is indicated in five stages.
- HDM-4 has been introduced, but data is not updated, so it is not effectively used.
- There are JICA technical project support inspection criteria, and periodic inspection is implemented.

(Laos)

- PMS and performance-based contracts have been introduced, domestic contractors are used, and daily inspection and repairs are carried out.
- Inspection data is not accumulated, and personnel training is not carried out, so the problem of unevenness in inspection accuracy has been found here and there.

(Uganda)

- There are inspection standards, but daily inspection and periodic inspection based on the manual is not carried out.
- The method of inplementing maintenance and repair of pavements is changing from contract out to direct management.
- HDM-4 was introduced in 2008, but it is not used.

4.3.1 Indonesia

The maintenance management cycle has been established, such as implementation of inspection, introduction of PMS, etc., so road management close to that of developed countries has been achieved. Also, the technical capabilities and personnel capabilities are sufficient.

Status of development of registers	• Databases have been constructed as an overall system
Inspection standards	• Developed
Daily inspection	• Implemented based on visual inspection during patrols by SNDT (national roads office)
Periodic inspection	• Carried out by P2JN (survey and design office) twice a year, using a uniform management system for the entire country • The road surface condition is evaluated in four stages using IRI and SDI (overall index based on potholes, cracking rates, rutting)
Maintenance and repair	• Implemented by SNVT (national Road office) using directly managed budget • Maintenance machinery is owned, and labor is directly employed as standard.
PMS	• Introduced in 1992 with aid from the World Bank, and AUS Aid. • Thereafter improvements have been added up to the present time. • Used for formulating annual plans and budget plans for the following fiscal year. • However, trust has not been sufficiently earned for the quality of the budget request documents

4.3.2 Kenya

The maintenance management cycle has been established, and standards such as manuals for maintenance and repair, etc., have been developed. PMS has been introduced but data is not updated so it is not used.

Status of development of registers	• The road condition inspection database system (Roads Inventory and Condition Survey Database) was introduced by the Kenya Road Board (KRB), and road condition evaluation is indicated in five stages (2002 to 2006)
Inspection standards	• The Road Maintenance Manual (prepared in 2002 in a JICA technical project, officially adopted in 2010) is the standard for visual inspection
Daily inspection	• Not implemented
Periodic inspection	• Implemented directly by road public corporations • Implemented once a year. Because the inspection is visual no equipment is used. • Results are recorded in hard copy form
Maintenance and repair	• Tendered by road public corporations (there is also evaluation of technical proposals) • The Road Maintenance Manual is used
PMS	• A road condition inspection database system (Kenya Roads Inventory and Condition Survey Database) has been constructed mainly focused on asset registers and pavements, with assistance from Norway, and introduced by Kenya Roads Board (KRB) • They have the latest HDM-4, but it is not being effectively used.

4.3.3 Laos

The maintenance management cycle is implemented, but there are issues regarding quantitative inspection, etc. Maintenance management is outsourced with performance-based contracts.

Status of development of registers	• Parameters, etc., are recorded in the Road Management System (RMS) and Provincial and Rural Roads Management System (PRoMMS) managed by the Public Works and Transport Institute (PTI)
Inspection standards	• RMS and PRoMMS inspection specifications (road condition and roughness surveys, etc.) are the inspection standards • Roughness is measured with IRI using a dedicated measuring vehicle, and evaluated. • Road condition is obtained by visual inspection of damage (cracking, potholes, etc.)
Daily inspection	• Daily maintenance management work is contracted out to local contractors using a performance-based contract. • Inspection frequency and methods are specified in the technical specification of the contract documents. Inspection is visual.
Periodic inspection	• Carried out by PTI and each province. • Collection of data on national roads is contracted out to a domestic consultant. • Provincial and rural roads are directly inspected by DPWT. • For collection of data on national roads, in the past assistance was received from the World Bank for the survey costs. • Surveys have been carried out in 2001, 2004/2005, 2008, and 2011.
Maintenance and repair	• Daily maintenance management work is contracted out to local contractors using a performance-based contract.
PMS	• In 2004 the Road Management System (RMS) was developed for national roads based on HDM-4 with assistance from the World Bank. This system is used for formulating short- and medium-term road maintenance management plans, selecting priority projects, and selecting the optimum maintenance methods. • In 2008 this was integrated with the Provincial and Rural Roads Management System (PRoMMS), so it became possible to formulate maintenance management plans for provincial and rural roads too.

4.3.4 Uganda

There are inspection standards, but the maintenance management cycle, such as daily inspection and periodic inspection, is not implemented. HDM-4 has been introduced, but there are few operators, and there are many issues including its use in the future.

Status of development of registers	• Developed
Inspection standards	• The “Road Maintenance Management Manual” has been developed. • The frequencies of daily inspection and periodic inspection are defined.
Daily inspection	• Not implemented
Periodic inspection	• Methods based on standards are not implemented.
Maintenance and repair	• With the introduction of the national policy “Force Account”, there is a trend from contracting out to direct management.
PMS	• HDM-4 was introduced in 2008, but is not being used.

5. Status of Bridge Maintenance Management

5.1 Developed Countries

[Overview]

- Each country has introduced its own system. For example in the USA, bridge maintenance management systems such as PONTIS and BRIDGIT have been introduced in the 1980s, in the United Kingdom SMIS has been introduced, and in France IQOA has been introduced.

- In Australia each province has introduced its own system based on the Austroads guidelines, and Sweden has introduced its own system, BatMan, which is capable of calculating life cycle costs.

- In Japan a bridge maintenance management system has been developed for national roads that are directly managed by the Ministry of Land, Infrastructure, Transport and Tourism, and trial operation is being carried out throughout the entire country. In addition there are other examples in local levels such as the bridge maintenance management in Aomori Prefecture, Gifu Prefecture, and Kyoto Prefecture, where there are cooperative initiatives between universities and local governments under the budget constraint.

5.1.1 Japan

(1) National Roads

Trial operation of a Bridge Management System (BMS) that was developed in 2001 was begun in 2005 by all offices for road bridges on directly managed national roads. The BMS identifies bridges that are already degraded, or bridges with a high possibility of becoming a serious condition in the near future. It is considered to be some of the reference information for investigating the time for repairs or to ensure that repairs are not overlooked.

The BMS has the following four functions, and the functions are provided in accordance with the flow of bridge management.

- Parameters for determining the present condition of the bridge, history of repairs, inspection data, and other associated input data

- Renewal and repair order of priority list based on integrity (degradation) predictions, and other results, list of necessary periodic countermeasures and periodic replacements, list of damaged locations based on periodic inspections, list for identifying bridges that have not been treated

- Short-term planning support function that supports the preparation of outline calculation requirements documents

- Medium-term plan support function for predicting the life cycle costs based on repair scenarios, etc.

(2) Local roads

1) Aomori Prefecture

In Aomori Prefecture, a total management system has been implemented that includes an IT system, engineers, and manuals. The IT system includes an inspection support system for efficiently managing inspections and a budget simulation system for calculating the budgets,

etc. An inspection support system (AMSS) using a PDA (Personal Digital Assistant) has also been developed. Regarding engineers, joint research meetings between industry, academia, and government are held to improve the skills of young prefectural staff through bridge design and repair meetings, etc., to improve the skills of construction companies within the prefecture through bridge inspection technical research meetings, and asset management of bridges through vibration measurement, etc. The objectives are to develop human resources for bridge maintenance management and constructing and developing organizational systems. Also, regarding manuals, basic plans that define the fundamental concepts, countermeasure manuals that define repair rules for long life, a project evaluation manual that defines management rules, a database renewal manual that defines the rules for updating data, and an action plan that defines the five-year project plan have been prepared.

2) Gifu Prefecture

In Gifu Prefecture, asset management is implemented considering the local residents to be part of the maintenance management system, who keep an eye on the maintenance management of social infrastructure including bridges. Also, in a project for developing “social infrastructure maintenance experts (ME)" implemented under the guidance of the Center for Infrastructure Asset Management Technology and Research at Gifu University, the prefectural staff is provided with ME training. The Road Maintenance Section of Gifu Prefecture has created a scheme in which "social infrastructure maintenance supporters (MS)" for city volunteers are developed through lecture meetings at the civil engineering offices in each region, and the volunteers are delegated information providing activities.

3) Kyoto Prefecture

In Kyoto Prefecture, a “Kyoto city town and village bridge life extension and repair plan promotion discussion meeting" was established for 25 cities towns and villages in Kyoto Prefecture apart from Kyoto City, to undertake cooperative asset management of bridges in 2009. Kyoto Prefecture was divided into a northern region and a southern region, and training meetings were held in each region. Support was provided from central government and academia. For example the southern region was supported by the Regional Development Bureau of MLIT and Kyoto University, and the northern region by Maizuru National College of Technology, etc. Support from industry included the Japan Bridge Association, Japan Prestressed Concrete Contractors Association, and the Hanshin Expressway Company, Limited.

5.1.2 United States

In the United States, the National Bridge Inspection Standards (NBIS) was established in 1971, which standardized the requirements for inspection in all states. States are responsible for any inspection results for bridges throughout the entire state, and the Federal Highways Agency allocates budget in accordance with defects, and defective bridges are made public.

Presently, all bridges longer than 20 feet on public roads in the entire country are periodically inspected every two years by state or local government employees or consultants, who are nationally accredited inspectors. The registered data, the road type data, the structural data, and the structural condition data is recorded, evaluated, and improvement measures proposed. Methods to minimize the life cycle costs are selected for repairs, and social costs are taken into consideration such as the effect of detours due to improvements or replacements on traveling time, traveling cost, traffic accidents, and so on. In the investment plans, future investments required and the degree of integrity are estimated, and budgets for bridge repair and improvement are prepared, and the effect of the investment is analyzed.

5.1.3 United Kingdom

In 1984 bridge repairs and strengthening was implemented, and in 1987 inspection standards, evaluation standards, repair standards, etc., were developed. At present a Structures Management Information System (SMIS) has been developed. The concept of entire life cost has been established, and from the necessity of determinging not only the present condition of structural elements but also to predict future degradation and function level, in 2002 the former structures database (NATS) was replaced with a bridge management database. In actual bridge management, all bridges longer than 3 m are inspected twice a year by companies referred to as Managing Agent Contractors (MAC), and this work is supervised by the Highway Agency (HA). The inspection results are input to the database SMIS, the extent of damage and the seriousness for each structural element is determined, the priority, urgency, and damage caused are determined, and the load resistance is evaluated. The order of priority for determination of repairs is by scoring the safety, functionality, sustainability, and effect on the environment of a bridge.

5.1.4 France

In 1979 the “Technical Instructions on Inspection and Maintenance of Road Structures” was developed, which prescribes the system of inspection and maintenance of structures. In 1995 a method of macro evaluation and ranking of the integrity of bridges (IQOA) was introduced to strengthen the inspection and maintenance system. There is a system for inspectors who are employees of the civil engineering research institute that carry out detailed inspection of structures that are managed by the local development bureaus and prefectural governments in the country, but it is not a legally established system. Also, annual inspection and triennial IQOA inspections are carried out on all bridges on national roads with more than 2 meters long. Inspections are carried out by employees in construction offices, structure offices, regional civil engineering research institutes, and so on, and support is also obtained from private consultants. Each structural element in five stages based on the inspection items and graphical illustration of deformation is evaluated. Repair plans are allocated by the structural offices of regional facility bureaus to construction offices and specialist organizations in accordance with the defect and the type of budget, and the order of priority of repairs is determined by the type of defect. Budget is allocated after obtaining the advice of specialists and determining the sequence of carrying out the repair construction.

5.2 Semi-developed countries

[Overview]

- Bridge management is backward compared with pavement management, but in South Africa and Malaysia the preparation of bridge management manuals and organizations are advanced.

- The following is a summary of the situation in the five semi-developed countries (South Africa, Thailand, Malaysia, Brazil, and Chile).

(South Africa)

- Although in most local governments the maintenance management cycle scheme is backward. In SANRAL (management of national roads) and Western Cape Province, the development of inspection and evaluation manuals, training of inspectors, etc., is positively undertaken, and systems have been constructed.

- Maintenance management software called Struman for concrete bridges has been developed and is used, and has even been introduced into neighboring countries.

(Thailand)

- Bridges on national roads and local roads are not inspected, but stopgap repairs are made.
- A demonstration version of BMS is being constructed for national roads under the jurisdiction of the Roads Bureau.
- For local roads, existing BMS is being reconstructed with JICA assistance.

(Malaysia)

- Annual bridge inspections are obligatory, and manuals have been prepared for bridge inspection and bridge maintenance management.
- Inspection results are input to the BMS every year and recorded by several thousand employees who have attended courses on inspection and are qualified.

(Brazil)

- On concession roads the concessionaires carry out initial inspection, periodic inspection, and detailed inspection of bridges, and evaluate the function, structural integrity, and durability as three indices. The results are input to maintenance management software, and maintenance management plans are formulated.
- On national roads inspections are carried out directly, but because of staff shortages collection of the inspection data is delayed, and maintenance management software is not used.

(Chile)

- Inspection and management is carried out on directly managed roads and some concessions, and when it is considered necessary to carry out repairs, the local offices outsource the repair construction.
- They do not have maintenance management software, but bridges are managed using bridge maintenance and repair manuals, parameter and inspection sheets, etc.

5.2.1 South Africa

There are two types of maintenance management software in South Africa. One is Struman, developed by the Council for Scientific and Industrial Research (CSIR), which has been introduced in five of the nine South African provinces, and ony four cities. Overseas, it has been introduced in Botswana, Namibia, Swaziland, Dubai, Taiwan, etc. The majority of bridges in South Africa are concrete bridges, so the system is for concrete bridges. CSIR has prepared manuals on evaluation methods using Struman, methods of using the system, calculation guides, etc.

Each span of a bridge is inspected by qualified inspectors, and the evaluation results for each span integrated with the evaluation for each member are recorded. Only persons with five or more years of experience in bridge design and who have completed a training course on inspection and have successfully passed an exam are qualified to be inspectors. Inspectors visually inspects quinquennially about five bridges per day. The emphasis is on inspections at the network level, and detailed inspections are carried out on a project basis.

Source: CSIR

Fig. 5-1 Bridge management system (South Africa)

Evaluation is carried out in a scheme in which the bridge is divided into 21 member elements, and when damage is inspected, the damage is evaluated in three indices (D: degree, E: extent, R: relevancy). Compared with PONTIS, its feature is that damage is inspected in detail for each member, so the cost is about double. Also, in contrast to PONTIS which uses a method based on a condition index that expresses the average condition of the bridge as a whole, Struman emphasizes a priority index that expresses the urgency of repairs. The method based on the condition index identifies bridges that require a detailed survey, and then evaluates the necessity of repairs, so it is a two-stage process which is inefficient. In the future it will be necessary to expand it to enable determination of priority using a function index based on the amount of traffic and the detour distance during repairs, etc.

5.2.2 Thailand

(1) National roads

Currently bridges are not inspected, but defective repairs are implemented. A demonstration version of bridge maintenance management software is being developed under the jurisdiction of the Bureau of Bridge. Of the 14,000 bridges owned by the DOH, 100 to 200 bridges have been selected, data is being collected and the bridges inspected, supplemented with inventory data collected by the DOH, to create the demonstration version of the software. The software is also checked as one way of checking the existing system, but since data input is voluminous, it is being customized to be practical with the minimum amount of data input.

The software currently being developed includes seven modules: inventory, inspection, evaluation/analysis, prioritization/budgeting, output/report, data administration, and help menu. Regarding inventory, bureau of R&D collected necessary data as well as insufficient data (traffic volumes, damages, etc.) based on bridge data base which was started 5 years ago. Regarding inspection, they have prepared their own manuals, and training is being provided to DOH staff. Inspection is customized in accordance with DOH requirements and technologies. Regarding evaluation/analysis, three items are evaluated: repair method and cost in accordance with the member or form of damage, prediction of the remaining life, and estimation of the load resistance. Prioritization/budgeting are determined based on five items: degree of damage, average daily traffic, road class, the effect of delays due to countermeasures, and the value of the bridge. Regarding value of the bridge, budget is allocated in priority to about 20 bridges such as historical bridges, bridges with high economic value, bridges that cannot be closed due to international relations, etc.

(2) Local roads

Currently bridges are not inspected, but defective repairs are carried out. There is insufficient staff both centrally and on-site, so systems have not been sufficiently developed. Previously there was maintenance management software developed by Chulalongkorn University based on the AASHOT scheme of the US FHWA, but it could only be used for inspection and evaluation by sufficiently trained personnel, so it was not used. Currently maintenance management software is being re-constructed with assistance from JICA. An inspection manual is being prepared and training is being provided for staff, so that consistent inspection data can be obtained, and the system is being simplified to suit the circumstances in Thailand. There is a plan to send five technical staff to Japan for training on inspection, and it is expected that the re-constructed software will be used sufficiently.

(3) Urban expressways

Less than 30 years has passed since the construction of urban expressways, and their focus is still on inspection, repairs, and improvements. Regarding management systems, just inventory data is organized, but there is no management system for formulating maintenance and renewal plans, etc.

5.2.3 Malaysia

In JKR (= PWD: Public Works Department), about 9,200 bridges are managed, including culverts and bridges spanning small scale drainage ditches. The majority are concrete bridges. Since the 1994 Seongsu Bridge collapse accident in Seoul, it has been obligatory to perform annual inspections on bridges in Malaysia. The inspections are carried out by the JKR local office staff, and the inspection results are accumulated in the BMS. A Bridge Inspection Manual and a Bridge Maintenance Manual have already been produced.

(1) Bridge Inspection Manual

The Bridge Inspection Manual consists of 4 chapters: Introduction, Types of Damage, Inspection Procedures and Reporting, and Condition Rating Guide based on Damage. Inspections are classified into the following four items:

- Inventory inspection
  This is the first inspection carried out by a local inspector to collect inventory data on the bridge. The inspection is visual, but measurements, sketching, and photographing are also carried out.

- Routine condition inspection

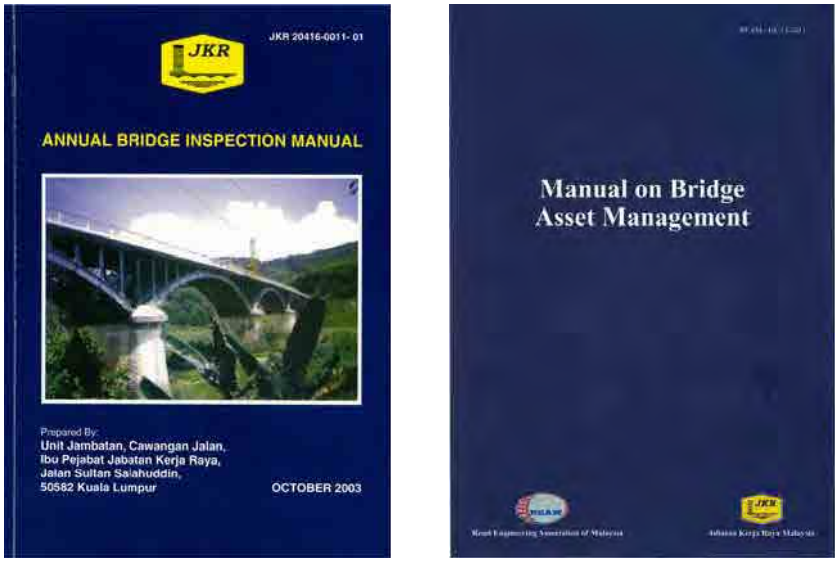
This inspection is carried out by a local level inspector to evaluate physical condition of the bridge. It is performed to ensure the safety of the bridge. Visual inspection is carried out at least once a year, around March after the flooding season.

- Confirmatory inspection
  This inspection is carried out after the routine condition inspection, to confirm that the report by the local inspection team is in accordance with the evaluation index. This inspection is carried out by an inspection team from head office on bridges that are reported to have been damaged.

- Detailed inspection
  This inspection is carried out by Headquarters engineers on bridges for which repair is deemed necessary from the results of the confirmatory inspection. Bridge engineers carry out sample tests on damaged parts, and investigate the cause of the damage, etc.

(2) Bridge Maintenance Management Manual

Bridge parts and members are classified into main members and secondary members, the degree of damage in each member is evaluated into four levels; light, Medium, Severe, and Very severe, and the results are integratedly managed. JKR bridge staff members are required to attend bridge inspection courses, and the inspectors input the data into the BMS. Every year 250 persons attend the courses, and at present there are several thousand members who can inspect bridges.



Source: JKR

Fig. 5-2 Bridge maintenance management manuals (inspection, asset management)

5.2.4 Brazil

(1) Concession roads

Bridges are inspected under three categories: initial inspection, periodic inspection, and detailed inspection. The results of the initial inspection are evaluated into three stages; A, B, and C for three indices; function, structural integrity, and durability. The concession contract prescribes that measures must be implemented within 5 years for A, 2-4 years for B, and 0-2 years for C. The initial inspection and the periodic inspection are all visual, and it is a requirement of the concession contract that periodic inspections be carried out once a year. Detailed inspection is

carried out when the evaluation is C in the periodic inspection, and includes bridge level surveying, ground surveys, etc. The inspection costs are, for initial inspection: R$1000-1500/bridge, periodic inspection: R$500-700/bridge, and detailed inspection: about R$10,000/bridge. The reference estimates submitted by the concessionaire at participating in the tender is about R$2500/bridge. The companies that carry out inspection and surveying, and the companies that carry out repairs or strengthening based on that data are separate. As for coring surveys, the latter contract out the work to research institutes.

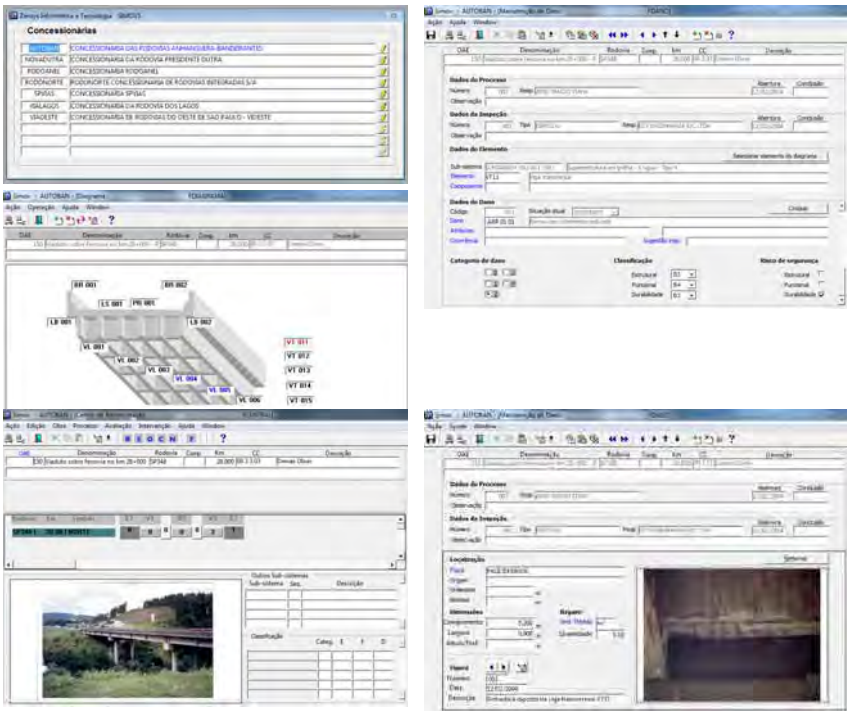
Intervenção		Estado Operacional		
Classificação	Prazo	Bom	Regular	Ruim
Imediata	0			C0
Curto Prazo	1 Ano			C1
	2 Anos			C2
			B2	
Médio Prazo	3 Anos		B3	
	4 Anos		B4	
		A4		
Longo Prazo	5 Anos	A5		

fonte: ARTESP - ET-C21/002

Source: CCR

Fig. 5-3 Bridge inspection evaluation scheme (Brazil)

CCR, who are one of the concessionaires, manage five types of structure: bridges over existing roads, culverts buried below the road, bridges over rivers, pedestrian bridges, and tunnels. The results of periodic inspections, detailed surveys, and construction are input into their bridge management system called SIMOV.



Source: CCR

Fig. 5-4 Bridge maintenance management scheme screens

5.2.5 Chile

(1) Overview

The total length of bridge in Chile is 182 km, the majority of which are concrete bridges, but there are some steel bridges, timber bridges, etc. The Bridge Department of the Ministry of Public Works has 70 members consisting of technical staff 20, administrative staff 50. The approximately 7,000 bridges in the country are centrally managed, and maintenance management is carried out by cooperation between the central Bridge Department and local offices in each prefecture. The local offices prepare reports on bridges that require repair, the central Bridge Department determines whether to carry it out or not, and the local offices contract out the repair construction. Each local office has about 500 members, the total number of staff members engaged in road maintenance management in the entire country is about 4,500. The annual budget for maintenance and repair is about US$30 million, and budget for new construction is about US$120 million.

(2) Inspection

Members of staff directly inspect the bridges daily, and the detailed inspections are carried out when necessary. Even when a fault has been found in a bridge, first the staff carries out an inspection, and it is rare that a private company is contracted to carry out it. In addition there are periodic inspections and unscheduled inspections. Unscheduled inspections are carried out when the water level of rivers increases or when an earthquake is occurred. Large-scale bridges are inspected once a year, but other general ones are not periodically inspected. The objectives of inspection are: to determine damage, to update fundamental information, to evaluate the degree of deterioration, to assess priorities, and to allocate resources. However there is one problem that the data is managed at each local office, and central information collection is insufficient.

(3) Use of data

When an inspection is carried out, the local office updates the parameter and inspection sheet, but the inspections take time due to insufficient drawings. Assistance is being received from JICA for bridge inspection sheets and data accumulation methods. Overloading, earthquakes, and flooding are characteristic problems in Chile. The bridge maintenance and repair manual is currently in its seventh edition, and it clearly indicates the work of the Ministry of Public Works within the scope as recognized by law.

5.3 Developing countries

[Overview]

- Maintenance management of bridges is backward compared with that of pavements, and in almost all countries inspection, maintenance and repairs are not implemented.
- The organizational systems and the deployment of staff are insufficient. Bridge engineers are few, so the human resources that are the basis of maintenance management work are lacing
- Maintenance management software has been introduced into very few countries.
- The following three countries are representative examples.

(Philippines)

- Periodic inspections are directly managed, and inspections using bridge inspection vehicles, crack gauges, etc. are carried out by inspectors annually.
- Maintenance management software include functions for determining the order of priority and formulating medium-term and long-term plans.

(Kenya)

- Road public corporations directly carry out periodic inspections visually by around three persons including an engineer and senior inspector, etc. using the British inspection standards
- Periodic inspections are carried out annually only on around 30 important bridges.

(Kyrgyzstan)

- There is no concept of maintenance management of bridges, and maintenance and repair is not substantially implemented.
- There are no inspection standards, etc., which form the foundation of maintenance management.

5.3.1 Philippines

Although the maintenance management cycle and systems are established to a certain extent, the technical capabilities in maintenance and repair, improvements, refurbishment, etc. are insufficient, and the cycle and systems are not fruitful. They have maintenance management software that includes functions for determining orders of priority and for making medium-term and long-term investment plans.

Status of development of registers	• Parameters are stored in maintenance management software
Inspection standards	• Developed
Daily inspection	• Directly managed by the Department of Public Works and Highways • Carried out once a month • Visual inspection, and results are managed in hard copy form
Periodic inspection	• Directly managed by the Department of Public Works and Highways • Inspections are carried out annually by inspectors (using bridge inspection vehicles, crack gauges, etc.) • Results are stored in a BMS
Maintenance and repair	• Contracted out to construction companies by the Department of Public Works and Highways • Repair manual has been developed by JICA
Maintenance management software	• An overall system for the Department of Public Works and Highways is being developed with assistance from the World Bank. Maintenance management software is a part of this, and was developed in 2003 with assistance from the World Bank and ADB. • The maintenance management software includes functions for determining orders of priority, and formulating medium-term and long-term investment plans.

5.3.2 Kenya

Periodic inspection is carried out on only some of the important bridges. Maintenance management software has not been introduced.

Status of development of registers	• Not developed
Inspection standards	• British inspection standards are used
Daily inspection	• Not implemented
Periodic inspection	• Carried out directly by road public corporations. Visual inspections are carried out by about three persons including an engineer, a senior inspector, etc. • Only about 30 important bridges are inspected annually • X-ray, Schmidt hammer, and other non-destructive testing is carried out when necessary by the Ministry of Roads and by materials testing research institutes
Maintenance and repair	• Road public corporations carry out tenders, and technical proposals are evaluated in some cases.
Maintenance management software	• None

5.3.3 Kyrgyzstan

Kyrgyzstan has none of the technical elements such as inspection standards, etc., which form the foundation of maintenance management. Also, there is no concept of bridge maintenance management, and maintenance and repair are not substantially carried out.

Status of development of registers	• Bridge total lengths, etc., are input into Excel based on hard copy location drawings
Inspection standards	• None
Daily inspection	• Not implemented

Periodic inspection	• Carried out directly twice a year • Visual inspections for faults
Maintenance and repair	• Just replacement of bridge parapet railings
Maintenance management software	• Not introduced

6. Use status of maintenance equipment and materials for road and bridge maintenance management

6.1 Developed countries

Many types of measurement equipment have been developed and introduced for the maintenance management of both pavement and bridges, and this is one of the factors that have promoted the collection of data in asset management.

In the case of pavement, road surface condition measurement vehicles that automatically measure indicators for the condition of the road surface as the vehicle travels along the road are now in general use, making it possible to determine road surface condition on a network level. As a result, hierarchical methods of measurement equipment use — in which FWD tests are performed in the course of detailed studies at locations where repairs are needed — have become firmly established. In the case of bridges, unlike pavement, inspections are mainly conducted at the fixed point where the bridge is located, and the inspections are primarily visual inspections. When the results indicate that a detailed study is needed, nondestructive inspections and tests, etc., are conducted.

The major difference between pavement and bridges is that the pavement constitutes a network, and the condition of the road surface is surveyed by using sensors to monitor the condition as the vehicle travels along the road. For this reason, identifying the measurement location and ensuring accuracy are issues of crucial importance. The process of measuring the condition of the road surface itself is a deliberate survey operation and requires experienced engineers.

Conversely, in the case of bridge inspections, concurrent inspection of many bridges entails an enormous amount of work, and the major problem is how to increase the efficiency and precision of visual inspections. For this reason, nondestructive inspection techniques and other quantitative assessment methods using state-of-the-art measurement equipment are employed. However, the use of measurement equipment does not necessarily guarantee precision, and so reliable inspections are conducted by combining visual inspections with inspections that employ measurement equipment.

In road surface condition survey, FWD survey and other methods of pavement maintenance, measurement equipment plays a major role, and special technologies are needed for operation. For this reason, in most cases the measurement equipment is owned by private sector companies and the survey work is outsourced. The companies that provide the vehicles that measure the condition of the road surface and the FWD test equipment, etc., are limited to some extent, so each companies specializes in developing certain types of specialist equipment.

For bridges, on the other hand, there are cases in which the bridge inspection vehicles and other large-scale measurement equipment is owned by private companies, while in other cases there are mechanisms in which these units can be leased as needed. Even within the category of nondestructive tests and inspection units, they are comparatively easy to operate, and they have more general purpose of uses than pavement inspection equipment. Many companies provide bridge measurement equipment, and many different types and numbers of measurement equipment can be procured.

6.2 Semi-developed countries

In general, as in the case of developed countries, semi-developed countries, are already using road surface condition measurement vehicles, FWD test equipment, bridge inspection vehicles, etc., for survey and inspection.

There are various cases of using measurement equipment for pavement maintenance such as the equipment is purchased from private sector companies and operated by the road administrators themselves, and that the survey work is outsourced to a private sector company. In almost all cases, the measurement equipment is brought in from overseas private companies. The circumstances are considered to differ depending on whether there is an office or agent in these countries for the company supplying the equipment, or whether there is a private company capable of operating the equipment in the target country.

Furthermore, support and maintenance after introduction is extremely important in case of pavement measurement equipment. Whether these services can be adequately provided in the country is also a major issue. Road surface condition surveys in particular are conducted by complex systems consisting of precision equipment installed in the inspection vehicle, and almost all such systems are made-to-order, so in many cases they require specialist engineers for maintenance as well. For this reason, the prompt support is a major issue, when the measurement equipment is introduced from other countries. In the case of the Department of Rural Roads (DRR) in Thailand, support and maintenance has been pointed out as an issue that needs to be resolved when equipment has been introduced from other countries, and an effort is underway in the country to develop a proprietary road surface condition measurement vehicle.

While measurement equipment for bridge inspections has been introduced by Malaysia, Chile, and Thailand for nondestructive inspections in highway management, the primary method is still visual inspection. Some countries have introduced bridge inspection vehicles, but in Chile it was considered sufficient to introduce one unit for the entire country. Although the importance of asset management is different depending on the country, it appears that this is considered more important for pavement than for bridges in overall, and the same trend can be seen in the introduction of measurement equipment.

In addition, some countries like Chile and Thailand have introduced systems for monitoring overloaded vehicles. Overloaded vehicles have been identified as a problem in road and bridge maintenance, and the introduction of such systems in combination with institutional measures is expected to be effective in dealing with this problem.

6.3 Developing countries

Although there are only a few examples of the introduction of measurement equipment for pavement and bridge maintenance in developing countries, there is an increasing need for such equipment for projects in countries where maintenance is considered a priority issue. Based on the situation in developed countries and semi-developed countries, the following issues should be taken into consideration when introducing measurement equipment to developing countries.

6.3.1 Required data precision and equipment specifications

Various types of measurement equipment can be procured, and the price of the equipment and the difficulty of its operation vary according to the specifications. There is a tradeoff relationship with regard to precision of measurement data and equipment cost in particular. It is crucial to identify the relationship between the measurement data precision required in the country and the equipment specifications.

Even in developing countries, however, there are cases in which high-level equipment specifications are needed. The necessary data precision and equipment must be studied from the perspective of future road planning and maintenance policy.

For example, in the case of roads that do not have a large traffic volume at present but whose traffic volume is expected to increase dramatically along with economic growth, it is important to conduct regular monitoring of the damage to the road by increased traffic volume resulting from economic growth. For such roads, measurement equipment should be introduced so that it could monitor the indicators for the deterioration to be anticipated.

6.3.2 Operating cost

When selecting the ideal measurement equipment from the many units that are available, the cost of introducing the equipment should be considered. However, not only the initial introduction cost like equipment cost but the running cost needed for actual operation and the impact should also be taken into consideration when selecting the equipment.

For example, the equipment used to measure pavement conditions may be dynamic (meaning that measurement vehicles acquire data as they travel along the road) or static (meaning that the equipment performs fixed-point observations). In general, the equipment costs will be higher for dynamic equipment. However, from the viewpoint of work efficiency, fixed-point observation equipment requires more time for measurement, and in some cases traffic restrictions are needed for the measurement. Road and bridge maintenance work requires continuing work from the introduction of the equipment to the operation thereafter in accordance with PDCA cycle. Accordingly, it is important to conduct a study to determine the ideal measurement equipment for conducting surveys and tests on an ongoing basis.

6.3.3 Management and support

Once introduced, the measurement equipment will be operated on an ongoing basis. For this reason, it is necessary to check to see whether there is an organization that can adequately handle management and support after the project has concluded. In general, it is desirable to introduce equipment for which support can be provided by a local private sector.

Moreover, the technologies in measurement equipment used for pavement and bridge maintenance are progressing on a daily basis, and make it possible to always incorporate new technologies. For this reason, it is also crucial to consider the ability to accommodate equipment upgrades.

6.3.4 Adaptability to local road conditions

The type of damage that may occur on pavement and bridges may differ dramatically depending on the country. Moreover, the topography and environmental conditions will differ as well at the location where surveys and inspections are conducted. Even if equipment containing measurement devices is introduced in accordance with precedents in developed countries, this equipment may not determine the types of damage that are specific to that local area.

It is important to consider the introduction of equipment taking account of its adaptability to local road conditions, and to consider the possibility of customization during or after introduction.

6.3.5 Calibration and accuracy control for measurement equipment

Similarly, after the introduction of the measurement equipment to the local area, the equipment must be calibrated to verify the accuracy of measurement values at the site.

Regular inspections to control accuracy like performance confirmation tests should be conducted, and an organization and mechanism to surely conduct these inspections are also needed.

6.3.6 Local availability of outfitting for measurement equipment

When it is difficult to bring assembled equipment, particularly large equipment such as road surface condition measurement vehicles into the target country, it is necessary to check in advance into the possibility of having measurement equipment outfitted locally as a joint operation with local engineers. Setting up measurement equipment with local engineers may also lead to the transfer of equipment control and maintenance technologies.

6.3.7 Need for basic training

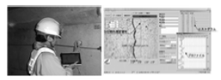
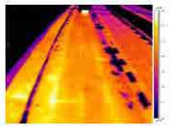
At the same time that the measurement equipment is introduced, the need for basic training of using the equipment and its operation and control should be confirmed. Following confirmation and coordination with regard to the training period and the target institutions for technology transfer, confirmation is required for the way of selecting the equipment to be introduced, way of its introduction, and way of its operation after introduction, etc.

The types of measurement equipment typically needed for pavement and bridge maintenance are shown on the following pages.

Table 6-1 Typical examples of measurement equipment needed for pavement maintenance

Study item		Measurement equipment		Overview	Checkable indicators	Measurement accuracy	Marketability / applicable scope	Cost of measurement equipment	Examples of countries where introduced
Structural assessment	Bearing capacity	(1) FWD <Static>		Measures the amount of deflection from impact load (250-300 kg) to assess the bearing capacity of each layer of pavement	Measures structural health (bearing capacity) of pavement interior based on measured deflection.	-	Commonly used for structural assessment of ordinary asphalt and concrete pavement.	High	• Developed countries, semi-developed countries • Some developing countries
		(2) Compact FWD <Static>		Measures the amount of deflection from impact load (heavy weight of approximately 30 kg) to assess bearing capacity.	Mainly assesses bearing capacity of roadbed, subgrade, etc.	-	Used for structural assessment of unpaved roads and thin layer pavement (simple pavement).	Low compared to (1)	• Developed countries, semi-developed countries • Developing countries (unpaved roads)
		(3) Benkelman Beam <Static>		Puts one side of the beam between tires, and measures the amount of deflection by dial gauge mounted on the fixed stand	Bearing capacity of pavement	Wider variance of measurement accuracy than FWD	More versatile and compact than FWD	Less expensive than FWD	• Developing countries
Road surface assessment	Cracking, rutting, roughness (IRI), levelness	(3) Road surface condition measurement vehicle (precision) <Dynamic>		Measurement system that measures the condition of the road surface (cracking, rutting, IRI, levelness, etc.) while traveling at normal speed and simultaneously acquires location data.	Cracking, rutting, IRI, levelness, etc. (Note: Dependent on type of instruments mounted in vehicle; customizable)	Passing level for performance confirmation test Cracking: Ability to distinguish width of 1mm or greater Rutting: Within measured ratio ± 3 mm Roughness: Within measured ratio ± 30%	Suitable for expressways and other roads that require a high level of management.	Expensive (Note: Dependent on quantity and specifications of sensors and other on-board units)	• Developed countries (Japanese expressways, directly administered national roads) • semi-developed countries
		(4) Road surface condition measurement vehicle <Dynamic>				Accuracy conforming to (3)	Also suitable for national roads and other main roads (management level conforming to expressway).	Slightly less expensive than (3) (Note: Dependent on quantity and specifications of sensors and other on-board units	• Developed countries (mainly roads in Japan managed by local governments) • semi-developed countries • Vietnam, etc.
	Roughness (IRI)	(5) Roughness measurement vehicle (precision) <Dynamic>		Acquires data needed to calculate roughness (IRI) while traveling at normal speed.	Roughness (IRI) Longitudinal profile is measured and IRI is calculated by means of QC simulation.	Equivalent to Class 2 High accuracy when a state-of-the-art measuring instrument is used.	Suitable for road surface assessment of ordinary roads in which only IRI is used as a road surface assessment indicator.	Less expensive than road surface condition measurement vehicle (specialized for IRI)	• Developed countries, semi-developed countries
		(6) Roughness measurement vehicle <Dynamic>			Roughness (IRI) Roughness indicator is measured and converted to IRI using a correlation equation, etc.	Equivalent to Class 2 Dependent on type of measurement machinery used (comparative assessment).	Suitable for determining the current state of mainly unpaved roads and other pavement surfaces for which the management level is low.	Less expensive than (5)	• Developing countries (Uganda, etc)
	Images of road conditions (cracking)	(7) Measurement vehicle <Dynamic>		Camera mounted in ordinary vehicle captures an image of the road in front of the vehicle while it is traveling.	Image of road in front of vehicle and cracking that can be determined from visual inspection of image.	For example, approximately width 10 mm or greater Dependent on performance of camera mounted, measurement environment (field of view) etc.	Suitable mainly for roads with a low traffic volume (residential roads, etc.).	Less expensive than road surface condition measurement vehicle or roughness measurement vehicle	• Developed countries, semi-developed countries (as a simple test)
	Road surface roughness (texture)	(8) Laser profiler <Dynamic>		Unit equipped with a laser sensor that measures road surface irregularities.	Fine-grained level	Accuracy depends on instrument calibration	Suitable for expressways and other roads for which ensuring safety is crucial.	-	• Developed countries, semi-developed countries
	Slip resistance	(9) Slip measurement vehicle <Dynamic>		Recreates the condition of the road surface under wet conditions while the vehicle is traveling and measures slip resistance with a special measurement wheel.	Slip resistance	Capable of measurements that reproduce actual driving conditions	Suitable for expressways and other roads for which ensuring safety is crucial.	Expensive Measurements are large-scale	• Developed countries, semi-developed countries
		(10) DF tester / BPN tester <Static>		Equipment is installed at the measurement location and placed directly in contact with the road surface to measure slip resistance.		Simple method		Less expensive than (9) (compact)	• Developed countries, semi-developed countries
	Water permeability	(11) Transmissibility test unit <Static>		Measures the water penetration time at arbitrary locations on paved surfaces with high porosity.	Amount of water penetrating in assessment target sector	-	Suitable for drainage pavement and other environmentally conscious roads.	-	• Developed countries
	Noise level	(12) Pavement surface noise measurement vehicle <Dynamic>		Measures tire/road surface noise by using a microphone placed adjacent to the special tire noise and contact noise.	Noise value Sound of contact between tire and road surface	-	Suitable for roads that have been made environmentally conscious through noise reduction measures.	Expensive Measurements are large-scale	• Developed countries
		(13) Noise level meter <Static>	-	Noise level meter is placed at the edge of the road or highway to measure noise produced by vehicle engine noise, etc.	Noise value (environmental noise)	-		Less expensive than (12) (compact)	• Developed countries

Table 6-2 Typical examples of measurement equipment needed for bridge maintenance

Inspection method	Inspection items (damage / measurement)		Measurement equipment/inspection method		Overview	Measurement accuracy	Marketability/applicable scope	Cost of measurement equipment	Examples of countries where introduced
Visual inspection	All		(1) Bridge inspection vehicle / elevated lift work vehicle / lift vehicle		Access to bridge in locations where scaffolding cannot be erected (over rivers, over ocean, etc.) and where access is difficult.	-	Suitable for locations where it is difficult to get access to inspection location.	Expensive and large-scale	• Developed countries • Some semi-developed countries • Philippines, etc.
			(2) Simple bridge inspection unit (camera)		Camera is operated remotely from bridge deck to search for flaws by close visual inspection.	Dependent on accuracy of camera	Suitable for locations where access is difficult eve when (1) is used	Less expensive than (1)	• Developed country (Japan)
			(3) PDA system (tablet PC, etc.)		Inspection results are entered on tablet PC or other terminal at the site.	-	Used to increase inspection efficiency	System development costs and licensing costs are needed	-
Use of inspection equipment	Strain		(4) Strain gauge		Mounted on bridge member to measure strain (local sensor).	High accuracy	Wide range of uses and applications	Low	• Developed countries • semi-developed countries (Chile, Malaysia etc.)
	Cracking		(5) Cracking width meter		Measures width of cracks in concrete, etc.	Reduces human error	Applicable to a wide range of ordinary materials	Low	
	Vibration		(6) Acceleration sensor		Installed on bridge pier, etc., to measure vibrations.	-	Used as a sensor for bridge health monitoring systems	Devices themselves are inexpensive (dependent on monitoring system)	
	Displacement		(7) Displacement gauge		Measures bridge displacement.				
	Inclination		(8) Inclinometer		Measures bridge inclination.				
Nondestructive inspection	Steel	Corrosion	(9) Sheet thickness measurement using ultrasonic sheet thickness gauge		Measures member thickness using ultrasonic waves (internal defect detection).	Accuracy is poor if paint layer is thick	Measurement is easy Has been used for many projects	Low (equipment ¥50,000-¥200,000)	
		Cracking	(10) Eddy current examination (ET)		Current is applied to object being measured and defects on surface and in surface layer are judged (surface defect detection).	Affected by material factors other than defects Training is required to take measurements.	Difficult to use if shape is not simple	(equipment ¥50,000-¥1.5 million)	
			(11) Magnetic particle flaw test (MT)		Application of magnetic particles or inspection fluid to magnetized material to detect cracks in or near member surface (surface defect detection).	Simple measurement method Crack depth cannot be detected	Can be used only for steel and other magnetic materials	(equipment ¥100,000-¥200,000)	
			(12) Liquid penetrant flaw test (PT)		Surface defects are detected using capillary action and perceptual phenomena (surface defect detection).	Can only detect surface cracking	No restrictions on materials	Liquid penetrant and other consumables	
			(13) Ultrasonic flaw test (UT)		Ultrasonic wave applied to defect location is reflected, enabling defect to be detected (internal defect detection).	Training is required to take measurements Accuracy is poor if paint layer is thick	Has been used for many projects Easy to transport	(equipment ¥50,000-¥1.5 million)	
		Looseness/falling	(14) Ultrasonic flaw test (UT)						
		Deterioration of anticorrosion function	(15) Film thickness measurement		Resonance is produced by ultrasonic wave to measure film thickness.	-	Has been used for many projects Taking measurements is easy	Low	• Developed countries • semi-developed countries (Chile, Malaysia, etc.)
	Concrete	Measurement of concrete thickness and compressive strength, check for internal defects, cracking depth, spalling	(16) Impact elastic wave test		Concrete is struck and elastic wave is observed by sensor to determine status of concrete surface and interior.				
		Water leakage or free lime, damage or lifting of concrete reinforcements	(17) Infrared method (infrared thermography camera)		Infers the location of the defect from the difference in surface temperature in the abnormal area.	Care is needed when setting the time period for temperature measurement.	Taking measurement is easy Judgment is easy	(equipment ¥100,000-¥1 million)	
		Compressive strength	(18) Schmidt hammer		Concrete is struck and the strength is estimated by the returning impact.	Comparatively low	Equipment is light and measurement is simple and easy Appropriate for preliminary studies, etc.	(equipment ¥100,000-¥500,000)	
		Reinforcement position / depth	(19) Reinforcement survey instrument (RC radar, etc.)		Detects reinforcement covering thickness and bar arrangement by nondestructive means.	Determination of adjacent buried objects is difficult in some cases.	Compact and lightweight, portable and easy to operate	(equipment ¥1.5 million-¥2 million)	
Image processing	Cracking		(20) Camera/image processing system	-	Automatic detection of cracking by means of image processing.	Variations in assessment may occur in some cases.	Effective in reducing the labor required for visual inspections	Unknown	• Developed countries (Japan, U.S., etc.)

7. Study in preparation for assistance to developing countries

7.1 Efforts in developed countries and semi-developed countries for reference

This survey revealed that, while the current situation of road and bridge maintenance management in developing countries varies depending on the country, these countries face common issues: shortages in human resources, lack of technology, and organizational weakness. This section focuses on examples of efforts in developed countries and semi-developed countries that can serve as a reference; and ways in which these can be configured to resolve the problems of human resource shortages and lack of technology particularly in the countries that face these problems. The examples also include efforts implemented in the process of evolving from a developing country to a developed country.

(1) Efforts in developed countries

Even in developed countries, local governments and other entities face the problems of severe budgetary constraints, human resource shortages and lack of technology. It is a serious issue for them to find ways of using limited resources to conduct maintenance.

In order to resolve this issue, in Gifu Prefecture as described in Chapter 4 as an example, Center for Infrastructure Asset Management Technology and Research at Gifu University took the lead in a project to cultivate "Social Capital Maintenance Experts (ME)" that targeted prefectural employees. In addition, regional civil engineering offices in the prefectural Road Maintenance Department hold workshops to invite citizen volunteers to become "Social Capital Maintenance Supporters (MS)." Citizen volunteers who have become Maintenance Supporters provide information on deteriorated pavement, broken signs and protective barriers, etc., so that places that need corrective measures can be located quickly and efficiently. In Kyoto Prefecture, a Promotion Council was set up with municipalities in the prefecture to conduct repairs and ensure a long service life for bridges. The Council is working to conduct asset management for bridges in cooperation with the prefectural government and municipalities. In contrast to the national government, which provides financial assistance to municipalities, the Kyoto Prefectural Government is focusing primarily on personnel training through the holding of training workshops, etc. These examples provide hints for future activities in the sense that asset management is being promoted through joint action rather than in the form of independent efforts by administrators who face the problem of funding, human resources, and technology inadequacies.

(2) Efforts in semi-developed countries

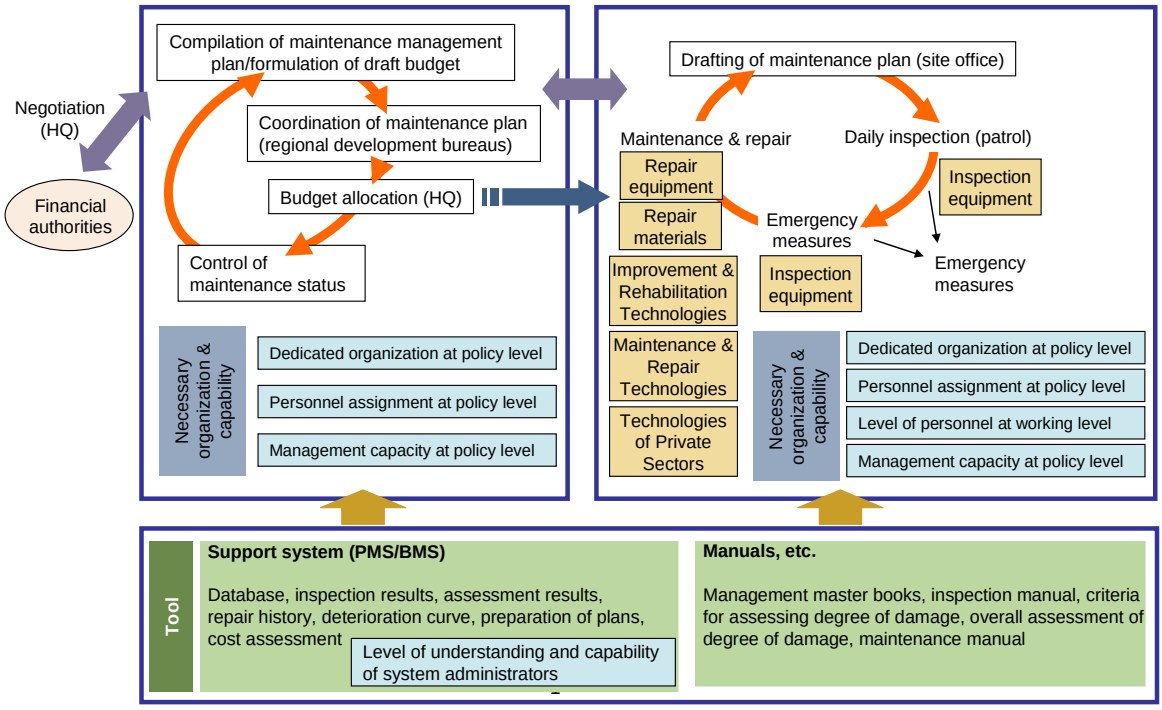
A determination of how the developed countries establish mechanisms for road and bridge maintenance management and how they succeeded in "graduating" from developing country status would be extremely useful as a reference for developing countries. South Africa, for example, already had a mechanism for pavement management in the 1970s. One reason for this is that the country had few engineers and therefore a mechanism was set up through an organization for industry-government-academic cooperation. Government research institutions, private consulting companies and road administrators broke down the barriers between their respective sectors and worked together to build bridge and pavement management system based on theory and practice, and which later enabled their advanced road asset management work. In Thailand, university researchers functioned as the center for the creation of a mechanism and a system for road and bridge maintenance management. In addition, outstanding young technocrats were appointed to key positions in the university and the road management section in the government, and the lateral ties between these individuals were also used to promote the rapid development of the mechanisms and systems. South Africa and Thailand are examples in which a few capable people were appointed to key posts in relevant institutions and acted as a

trigger for the speedy establishment of mechanisms. To developing countries facing human resource shortages, these examples can be seen as one possible effective prescription.

7.2 Proposed index for determining current situation in developing countries

In studying the approach to JICA assistance to developing countries, if the target countries can be categorized in accordance with the level of road and bridge maintenance management in developing countries, it is possible to organize the approach to assistance in each country. As noted earlier, however, the situation in each country is quite different, and therefore, the categorization is really difficult.

Accordingly, in this survey, the mechanism for road and bridge maintenance management is assumed to comprise three components: a cycle that relates to planning and allocation of budgets which is implemented primarily at the head office level), a practical cycle for maintenance which is implemented primarily at the site office level, and the systems and manuals to support these cycles. A proposed index was created in the following pages to determine the level of the target country organizations, personnel, capabilities, etc., in order to achieve these objectives. By using this index, it will be possible to ascertain the current situation and level relating to road and bridge maintenance in the target country.



Source: Prepared by the Study team

Fig. 7-1 Mechanism for road and bridge maintenance management

Table 7.2 Proposed Index for Assessing Current Situation in Developing Countries

		Key Points	High Level	Middle Level	Low Level
Budget receiving cycle (MLIT)	(1) Drafting of maintenance plan (local office)	Formulation of maintenance plan based on regular inspection results and assessment	☐ Capacity exists to formulate a maintenance plan with clear priorities for maintenance. ☐ A specific plan is formulated for repair methods, costs, etc.	☐ A plan to enable locations that need maintenance to be determined can be formulated, but detailed plans outlining priority, etc. are not formulated.	☐ Maintenance plans are not formulated.
	(2) Adjustment of maintenance plan (Regional Development Bureau)	Adjustment and formulation at Regional Development Bureau level of maintenance plan submitted by local office	☐ Capacity exists to formulate a maintenance plan with clear priorities for maintenance. ☐ A specific plan is formulated for repair methods, costs, etc.	☐ A plan to enable locations that need maintenance to be determined can be formulated, but detailed plans outlining priority, etc. are not formulated.	☐ Maintenance plans are not formulated.
	(3) Compiling of maintenance plan and formulation of draft budget (MLIT)	Compiling of overall maintenance plan submitted by Regional Development Bureau and formulation of draft budget	☐ Capacity exists to formulate a maintenance plan with clear priorities for maintenance. ☐ A specific plan is formulated for repair methods, costs, etc.	☐ A plan to enable locations that need maintenance to be determined can be formulated, but detailed plans outlining priority, etc. are not formulated.	☐ Maintenance plans are not formulated.
	(4) Negotiations with financial authorities (MLIT)	Is there the capacity to negotiate the draft budget with financial authorities based on maintenance plan, etc.?	☐ Based on maintenance plan, budget negotiations are conducted with financial authorities and budget is acquired.	☐ Based on maintenance plan, budget negotiations are conducted with financial authorities.	☐ Maintenance plans are not formulated.
	(5) Budget allocation (MLIT)	Capacity to allocate budget to local offices, etc., in accordance with need for maintenance	☐ The local situation is determined and the regions in which investment should be concentrated, etc., are established, and then the necessary maintenance costs are allocated.	☐ The local situation is determined and the necessary maintenance costs are allocated.	☐ Although a budget is allocated, the budget is allocated in a simple manner such as based on the previous fiscal year.
	(6) Management of maintenance status	Has overall status been determined based on results of maintenance?	☐ Databases and the results of regular inspections are used, and quantitative indicators are used to determine the overall status.	☐ Databases and the results of regular inspections are used to make a qualitative determination of the overall status.	☐ The overall status is not determined.
	(7) Management capability of central government (policy level)	Has the importance of maintenance for managed road structures been thoroughly recognized? Have the personnel needed to conduct overall management been secured?	☐ There is a top official (key person) who recognizes the importance of maintenance. ☐ There are sufficient personnel knowledgeable in maintenance.	☐ There are personnel knowledgeable in maintenance, but their number is not sufficient.	☐ There are no personnel knowledgeable in maintenance.
	(8) Dedicated organization in central government (policy level)	Is there a dedicated maintenance department?	-	☐ There is a dedicated maintenance department.	☐ There is no dedicated maintenance department.
	(9) No. of personnel allocated in central government (policy level)	Is number of maintenance personnel sufficient?	☐ The number of personnel allocated is sufficient.	☐ The number of personnel allocated is a bit insufficient.	☐ The number of personnel allocated is insufficient.
On-site cycle (local clerical procedures, etc.)	(1) Daily inspection (patrol)	Implementation of daily inspections (patrols, etc.) to detect damaged locations	-	☐ Inspections (patrols) are conducted regularly.	☐ Inspections (patrols) are not conducted.
	(2) Regular inspection	Status of implementation of regular inspections	☐ Regular inspections (once every 1-5 years) are conducted.	☐ Although irregularly, inspections are conducted based on inspection standards.	☐ Regular inspections are not conducted. ☐ Inspections are not conducted based on inspection standards.
	(3) Status of urgent measures	Measures for major damage discovered during inspections, etc.	-	☐ Emergency repairs are conducted quickly.	☐ It takes time for emergency repairs to be conducted.
	(4) Maintenance	Status of implementation of planned maintenance	☐ Maintenance is generally conducted as planned.	☐ Maintenance is conducted according to plan, but the sufficiency rating is low.	☐ Maintenance is not conducted as planned.
	(5) Management capability of Regional Development Bureau and local	Status of personnel secured mainly at Regional Development Bureau and local office	☐ There are sufficient personnel knowledgeable in maintenance tasks.	☐ There are personnel knowledgeable in maintenance tasks, but their number is not sufficient.	☐ There are no personnel knowledgeable in maintenance tasks.

		Key Points	High Level	Middle Level	Low Level
	office (work level)				
	(6) Technical capability for maintenance	Level of technical capability for maintenance	☐ There are no problems with the technical capability possessed.	☐ There is only a rudimentary level of technical capability.	☐ There is no technical capability.
	(7) Technical capability for improvement/ reconstruction	Level of technical capability for improvement, reconstruction, etc., to extend structure's service life	☐ There are no problems with the technical capability possessed.	☐ There is only a rudimentary level of technical capability. ☐ It is difficult to perform advanced improvements and reconstruction.	☐ There is no technical capability.
	(8) Technical capability of private sector companies	Capability relating to maintenance by private sector companies (including sufficiency of personnel)	☐ There are many private sector companies thoroughly knowledgeable in maintenance and there is no problem with outsourcing.	☐ There are private sector companies that can conduct maintenance. ☐ There are few companies to which maintenance can be outsourced.	☐ There are no private sector companies that can conduct maintenance. ☐ There are no companies to which maintenance can be outsourced.
	(9) Inspection equipment	Sufficiency of inspection equipment	☐ There is a sufficient quantity of inspection equipment.	☐ The quantity of inspection equipment is insufficient. ☐ There are inspection equipment, but they are old or broken.	☐ There is no inspection equipment.
	(10) Repair equipment	Sufficiency of repair equipment	☐ There is a sufficient quantity of repair equipment.	☐ The quantity of repair equipment is insufficient. ☐ There are repair equipment, but they are old or broken.	☐ There is no repair equipment.
	(11) Repair materials	Ease of procurement of repair equipment	☐ It is easy to procure repair materials.	☐ It is possible to procure repair materials, but some materials are difficult to obtain.	☐ It is difficult to procure repair materials.
	(12) Specialist organization at Regional Development Bureau and local office (work level)	Is there a dedicated maintenance department?	-	☐ There is a dedicated maintenance department.	☐ There is no dedicated maintenance department.
	(13) Personnel level at Regional Development Bureau and local office (work level)	Is the importance of maintenance thoroughly understood by the Regional Development Bureau and the local office, and does the worksite have the flexibility to conduct management?	☐ There is a top official (key person) who recognizes the importance of maintenance at the field level. ☐ There are sufficient personnel knowledgeable in maintenance maintenance at the field level.	☐ There are personnel knowledgeable in maintenance at the field level, but their number is not sufficient.	☐ There are no personnel knowledgeable in maintenance at the field level.
	(14) No. of personnel deployed at Regional Development Bureau and local office (work level)	Is the number of personnel allocated sufficient?	☐ The number of personnel allocated is sufficient.	☐ The number of personnel allocated is a bit insufficient.	☐ The number of personnel allocated is insufficient.
Budget, economic scale, etc.	(1) Sufficiency of maintenance budget	Is the maintenance budget sufficient?	☐ The maintenance budget is sufficient.	☐ The maintenance budget is insufficient. ☐ Approximately 50% or more of the necessary amount has been secured.	☐ The maintenance budget is insufficient. ☐ Less than around 50% of the necessary amount has been secured.
	(2) Level of understanding of maintenance	Need for maintenance at the central government in particular	☐ The need for maintenance is thoroughly recognized.	☐ The need for maintenance is recognized as a general matter.	☐ There is absolutely no recognition of the need for maintenance.
Preparation of manuals, etc.	(1) Management master books	Are account books kept in the process of preparing maintenance plans?	☐ Specifications, type of structure, traffic volume and other data are entered in a database.	☐ Specifications are converted into electronic data (may be done using Excel).	☐ Specifications and the like are not converted into electronic data and are managed using paper-based materials. ☐ Specifications are not compiled.
	(2) Inspection manuals	Status of preparation of manual and standards for determining the status of structures in order to implement maintenance	☐ An inspection manual that clearly notes specific inspection methods, equipment to be used, etc., has been prepared. ☐ Inspections indicate mechanical measurements or	☐ Inspection manuals have been prepared, but the inspection methods, equipment to be used, etc., are not clearly specified. ☐ Numerical criteria are not presented.	☐ Inspection manuals have not been prepared. ☐ Inspection criteria exist but are not used.

		Key Points	High Level	Middle Level	Low Level
			numerical standards that enable an objective assessment.		
	(3) Criteria for judging degree of damage	Have standards been established for determining the degree of damage from the measured inspection results (primarily those from regular inspections)?	☐ There are criteria for judging the degree of damage. ☐ The degree of damage is judged objectively (assessed quantitatively).	☐ There are criteria for judging the degree of damage. ☐ The degree of damage is judged by means of a qualitative assessment by the engineer, etc.	☐ There are no criteria for judging the degree of damage. ☐ The degree of damage is judged by means of a qualitative assessment by the engineer, etc.
	(4) Overall evaluation of degree of damage	Is it possible to determine the priority of repairs, etc., from the damage judgment?	☐ A comprehensive determination of the degree of damage for the structure as a whole can be made quantitatively based on the results from each inspection location (rating possible).	☐ A comprehensive determination of the degree of damage for the structure as a whole can be made qualitatively based on the results from each inspection location (rating possible).	☐ A comprehensive determination of the degree of damage for the structure as a whole cannot be made (rating not possible).
	(5) Maintenance manual	Existence of maintenance manuals that indicate repair methods corresponding to the degree of damage	☐ A manual clearly stating specific repair methods, materials to be used, equipment to be used, etc., corresponding to the degree of damage has been prepared.	☐ A manual has been prepared, but the repair methods, etc., are abstract.	☐ No manual has been prepared. ☐ There is a manual, but it is not used.
Status of support systems (PMS, BMS)	(1) Status of database creation	Has a database to serve as the foundation for the support system been created?	☐ Specifications, type of structure, traffic volume and other data are used to create a database in the system.	☐ Only the specifications needed to formulate plans are used to create a database in the system.	☐ No database has been created.
	(2) Reflection of inspection results	Can inspection results be entered into the support system?	☐ Detailed inspection results can be entered.	☐ Only key elements of the inspection results can be entered.	☐ Inspection results cannot be entered.
	(3) Reflection of assessment results	Can assessment results be entered into the support system?	☐ An assessment is conducted automatically based on the inspection results.	☐ Assessment results can be entered.	☐ Assessment results cannot be entered.
	(4) Reflection of repair history	Can the repair history be entered?	☐ A repair history for each location can be entered.	☐ Only a repair history can be entered.	☐ Repair histories cannot be entered.
	(5) Deterioration curve	Is there a deterioration curve? Can the status of future structures be predicted?	☐ A deterioration curve or the like has been defined and the future deterioration status can be predicted.	☐ No deterioration curve or the like has been defined, but the future deterioration status can be predicted (by defining the degree of damage over time, etc.).	☐ The future deterioration status cannot be predicted.
	(6) Automation of plan preparation	Can plans be formulated automatically by the support system from the inspection results, etc.?	☐ A medium- to long-term plan (for approximately 10 years or more) can be automatically generated based on the data for inspection results, etc.	☐ A short-term plan (for approximately less than 10 years) can be automatically generated based on the data for inspection results, etc.	☐ Automatic generation is not possible. ☐ A plan can be generated by hand using the system.
	(7) Calculation of necessary expenses	Can repair expenses, etc., that will arise in the future be calculated?	☐ The ideal repair method is selected and the expenses that will be needed in the future can be calculated.	☐ The (approximate) expenses that will be needed in the future can be calculated.	☐ The expenses that will be needed in the future cannot be calculated. ☐ The expenses that will be needed can be calculated by hand.
	(8) Level of understanding/capability on the part of system administrator	Does the system administrator have a thorough understanding of the system?	☐ There is a top official (key person) who has a thorough understanding of the methods of use and limitations of the system. ☐ There are sufficient personnel who understand how to use the system.	☐ There are personnel who understand how to use the system, but their number is insufficient.	☐ There are no personnel who understand how to use the system.

Important items

Less important items