World

2020
Data Collection Survey on Road Asset Management Platform Technical Support

Final Report

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Japan International Cooperation Agency (JICA)

Japan Expressway International Co., Ltd.
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AASHTO	American Association of State Highway and Transportation Officials
AM	Asset Management
ADB	Asia Development Bank
ASEAN	Association of Southeast Asian Countries
ANE	Administracao Nacional de Estradas, Insituto Pubilico
AfDB	African Development Bank
BMS/ BMMS	Bridge Management System
BMA	Bangkok Metropolitan Administration
BIM	Building Information Modeling
CIM	Construction Information Modeling
CFRP	Carbon Fiber Reinforced Plastics
CMMI	Capability Maturity Model Integration
C/P	Counterpart
CCTV	Closed-Circuit Television
LCP	Life Cycle Planning
DB	Data Base
DOR	Department of Road
DoR	Department of Roads, Ministry of Works and Human Settlement
DOT	Department of Transportation
State-DOT	State-Department of Transportation
US-DOT	US-Department of Transportation
DBST	Double Bituminous Surface Treatment
DOF	Department of Finance
DPC	Department of Planning and Cooperation
DRIMS	Dynamic Response Intelligent Monitoring System
DPWT	Department of Public Works and Transport
DPWH	Department of Public Works and Highways
DOH	Department of Highways
DRR	Department of Rural Roads
DGER	Direction Generale del Entererien Routiner
DE	Direction des Travaux d'Entretien
DX	Degital Transformation
DGPC	General Department of Bridge and Roads
ETA	Expressway and Rapid Transit Authority of Thailand
EXAT	Expressway Authority of Thailand
FS	Feasibility Study
FHWA	Federal Highway Administration
FWD	Falling weight deflectometer
FAST	Fixing America's Surface Transportation Act
GDP	Gross Domestic Product
GIS	Global Information System
HDM-4	Fourth Highway Development and Management Model
MAP21	Moving Ahead for Progress in the 21st Century
ICT	Information and Communication Technology
IDI	Infrastructure Development Institute
IRF	International Road Federation
IRI	International Roughness Index
JICA	Japan International Cooperation Agency
JEXWAY	Japan Expressway International CO., LTD.
JCC	Joint Coordination Committee
JAAM	Japan Asset management Association

MOT	Ministry of Transport
MoWHS	Ministry of Works and Human Settlement
MAC	Maintenance Activity Code
MOU	Memorandum of Understanding
MPWT	Ministry of Public Works and Transport
MCI	Maintenance Control Index
MID	Ministry of Infrastructure Development
MID	Ministre des Infrastructures et du Desenclavement
NEXCO West	West Nippon Expressway Co., Ltd.
NE	NIPPON ENGINEERING CONSULTANTS CO., LTD.
NBIS	National Bridge Inspection Standard
NRFA	National Road Fund Agency
ODA	Official Development Assistance
OPWT	Office of Public Works and Transport
OJT	On-the-Job Training
OPRC	Output Performance Road Contract
PPP	Public Private Partnership
PCI	Pavement Condition Index
PIARC	World Road Association
PTTI	Public Work and Transport Training Institute
PTRI	Public Work and Transport Research Institute
PBC	Performance Based Contract
PDCA	Plan-Do-Check-Action
PMS	Pavement Management System
RAMP	Road Asset Management Platform
RAD	Road Administration Division
RMF	Road Maintenance Fund
RMS/ PRoMMS	Road Management System Provincial Road Maintenance Management System
RDA	Road Development Agency
R/D	Record of Discussion
SIP	Cross-ministerial Strategic Innovation Promotion Program
SIDA	Swedish International Development Cooperation Agency
SMH	Smart Maintenance Highway
SATCC	Southern Africa Transport and Communications Commission
TAM	Transportation Asset Management Guide
TED	Technical and Environmental Division
VIMS	Vehicle Intelligent Monitoring System
WB	The World Bank

Chap.1 Business Overview

1.1 Business Background

Infrastructure development demand in developing countries is high, and the Asia-Pacific region is expected to have approximately $26 trillion in infrastructure development demand by 2030. In addition, the infrastructure that Japan has provided to developing countries since the 1970s is about to pass 50 years, and considering the demand for new construction projects, it is essential to adopt the concept of preventive maintenance and cost reduction through optimizing maintenance.

Currently, JICA is implementing technical cooperation projects for strengthening the maintenance and management capacity of road infrastructure in about 20 countries, and is widely developing core human resources who will be responsible for road administration in developing countries.We believe that support for Road Asset Management (hereinafter referred to as Road AM) for those countries is an issue that should be addressed over the medium to long term.

In addition, in order to implement comprehensive efforts on important development issues in the field of transportation, JICA will establish preventive maintenance of road infrastructure in developing countries that are effectively based on Road AM methods. This aims to work toward the realization of efficient road administration.

Under these circumstances, Road Asset Mangemant Platform (hereinafter referred to as RAMP) was launched in October 2017 to centrally cover from the most advanced domestic efforts of the national and highway companies regarding Road AM to the regional efforts of local governments in developing countries. We have built a system that enables us to respond flexibly to these issues.

RAMP aims to provide efficient and effective road asset support to developing countries through a program approach that combines not only the technical cooperation projects but also issue-based training and country-specific training.

In order to promote JICA Road AM efforts, in addition to examining the trends of Road AM in Japan and overseas, it is necessary to formulate and unify support plans for the establishment of Road AM in developing countries, organize technical guidelines and manuals, arrange good examples of the technical cooperation projects, and accept long-term trainees to Japanese universities.

1.2 RAMP Overview

Asset management in social infrastructure is an idea born in the United States in the 1980s, when insufficient maintenance and repair of infrastructure became a problem, and the idea of “positioning social infrastructure as an asset of the people and maintaining and enhancing the value of assets systematically and strategically” is the main concept.

AM applies the concept of Asset Management (hereinafter referred to as AM) to the maintenance and management of road assets such as roads and bridges, and it realizes a maintenance plan aimed at minimizing life cycle costs by appropriately understanding the current situation, predicting deterioration and damage of assets and ultimately repairing and reinforcing assets at appropriate times.

In October 2017, JICA formulated an efficient support plan for Road AM related to roads and bridges, which is expected to increase in demand in developing countries, and supported and developed the overseas expansion of domestic road asset management technology.

RAMP was established with the aim of developing the core human resources who will lead the road asset management field in developing countries.

In addition, a domestic support committee has been established to promote appropriate and efficient activities in RAMP. Currently, about 20 countries are implementing the technical cooperation projects that are strengthening the maintenance capacity of road infrastructure, gathering domestic and foreign knowledge to solve the problems of road infrastructure maintenance, and managing road assets in developing countries through various efforts.

We are aiming to develop road administration human resources for the establishment of infrastructure. Figure 1.1 shows the activity concept of RAMP.

Figure 1.1 Activity Concept of RAMP

1.3 Purpose of the Survey

Against the above background, the purpose of the survey is to research the maturity level of Road AM in the target countries of the technical cooperation project (Laos, Bhutan, Thailand and Zambia) that contribute to the strengthening of maintenance capacity.

1) Examination of Road AM evaluation method and confirmation of Road AM maturity
2) Extracting issues and formulating support plans for establishing Road AM

Also

3) Domestic and international trend survey on Road AM technology
4) Creation of technical standard outlines applicable to the technical cooperation projects
5) Monitoring activities from previous training (Solomon and Tunisia)

In addition

6) Creating a database of participants in training by group training / issue specific training
7) Gathering information on new technical cooperation projects
8) Investigation of maintenance status of special bridges (Thailand and the Philippines)
9) Preparation of RAMP public relations materials
10) Support service for RAMP support committee activities

1.4 Business Items

1.4.1 Technical Business Implementation Method

1.4.1.1 Formulation of Business Plan and Explanation / Discussion of Inception Report T1

Create a business plan (Japanese) and an inception report (English) that describes the work implementation policy, contents, implementation system, work plan, etc., and, with the approval of JICA, give advice from members of the RAMP support committee. Afterwards, reflect and finalize the plan and report. The JICA local office will hold discussions on the inception report with the parties involved in the target projects listed in the surveyed countries.

1.4.1.2 Examination of Evaluation Method for Road AM T2

Review the model of the evaluation method of Road AM maturity prepared in the previous year's survey and consider the addition and improvement of evaluation items while obtaining technical advice from members of the RAMP support committee, officials of the Japan Asset Management Association, and the technical cooperation projects in the countries surveyed.

1.4.1.3 Confirmation of Maturity of Road AM T3

The countries surveyed are Laos, Bhutan, Thailand and Zambia. Information will be collected through quantitative and qualitative interviews using existing document surveys and interviews with ongoing technical cooperation project personnel, Japanese experts, and Counterparts (hereinafter referred to as C/P).

In qualitative hearings, we focus on local issues that cannot be covered by quantitative hearings, which will be described later, and countermeasures derived from the technical cooperation projects. Also, these hearings allow for the collection of reference information. In the quantitative hearing, the Road AM evaluation sheet will be used to quantitatively clarify the areas where the introduction of Road AM is progressing, the areas where the introduction is delayed, and the areas that need to be enhanced in the future. The evaluation items are broken down to the contents that can be evaluated, scored by detail level, and comprehensively set so that the same items can be evaluated and comparisons between multiple countries are possible.

For Road AM maturity level, evaluation is done on whether the PDCA cycle of technical items (“Inspection”, “Diagnosis”, “Repair Plan”, “Maintenance”, “Repair Work”, “Recording Road”) is working well. Operating items (“Organization”/“System”,“Budget/Financing”, “Bidding/Contract System”) are evaluated from the viewpoint of whether or not the road is maintained.

1.4.1.4 Extraction of Issues for Establishing Road AM T4

Extract issues for asset retention that became clear through the exchange of opinions in **T3** above.

From the extracted issues, for those which require research and development of repair technology, long life technology, and inspection technology, a draft research plan for conducting research at a Japanese university will be drafted, and candidates from universities involved in research will also be listed. **T3**, **T4** and **T5** will conduct domestic work including literature surveys while conducting web meetings with local related organizations and hearings with long-term experts and experts in the technical cooperation projects.

1.4.1.5 Formulation of a Support Plan for Road AM Establishment T5

Based on **T4** above, a support plan will be formulated after the completion of the technical cooperation project. In formulating the plan, we will consider future support plans in close discussion with Japanese experts and JICA officials.

In addition, we will prepare a medium- to long-term support plans with the effective utilization of training projects (group training / issue-specific training / long-term training) in mind.

1.4.1.6 Domestic and International Trend Survey on Road AM Technology T6

We will organize literature and exchange opinions with related parties on the status of efforts and introduction of technologies for the establishment of Road AM, etc., which are being worked on by road administrators in local governments in Japan and then compile seven cases of initiatives and technologies that can be used in developing countries. Also, we will hold two or more interviews with road managers of local governments in Japan.

Also, we will hold hearings with two or more organizations about road administraters of domestic local governments and summarizing them. In addition, we will exchange opinions with donors such as The World Bank (hereinafter referred to as the WB) (USA), The Asian Development Bank (hereinafter referred to as ADB) (Philippines), etc. regarding the efforts of RAMP, such as the maturity evaluation method of road assets.

In addition, we will summarize 10 cases of research and development technologies of universities, research institutes, private companies, etc. and technologies that are expected to be utilized in developing countries. Table 1.1 shows the list of domestic trend survey targets (draft).

Table 1.1 List of Domestic Trends Survey (Draft)

Organization	Points	Outline
Expressway company	General maintenance and management	Conducting a hearing on the latest trends in AM activities on expressways.
MLIT	〃	Summarizing the status of the second inspection compiled by MLIT, the status of activities of the National Conference on Infrastructure Maintenance, etc.

Organization	Points	Outline
Japan Society of Civil Engineers	〃	Summarizing activities of the newly established Infrastructure Maintenance General Committee by integrating maintenance-related committees
Niigata City	Bridge maintenance and management	Understanding the status of activities of the Niigata City Bridge AM Review Committee held in Niigata City, we will conduct interviews on the status, issues, and countermeasures of bridge maintenance and management held by local governments.
Yamagata Prefecture	〃	Conducting a hearing on the status, issues, and countermeasures of bridge maintenance and management held by local governments, centering on the Yamagata Bridge Maintenance and Management System (DBMY) introduced in Yamagata Prefecture.
Niigata University /Nagaoka University of Technology	〃	Conducting a hearing on technical support initiatives to the Niigata City Bridge Asset Management Review Committee held in Niigata City.
Saitama University	〃	Conducting a hearing on the activities of the Saitama Bridge Maintenance Study Group, which is conducted in collaboration with Saitama Prefecture, the Omiya National Highway Office, Institute of Technologists, etc.
Private companies, etc.	Utilization of modern technologies	We will collect, summarize, and create technical outlines of the modern technologies described in the “Inspection Support Technical Performance Catalog (draft) as of June 2020” published by MLIT, (1) Image measurement technology and (2) Non-destructive inspection technology and (3) Measurement and monitoring technology.

1.4.1.7 Creation of Technical Standard Outlines Applicable to Technical Cooperation Projects T7

We will review the manuals and guidelines collected and organized in the previous fiscal year, organize them according to the prescribed items such as inspection, repair, and Maintenance, which are the main activities of maintenance and management work, understand the maintenance and management status of the studied countries, organize issues, consider whether it is possible to develop standards that can be used in these developing countries andwhether there are criteria items that can be adopted, etc.

On that basis, after confirming that it is possible to establish a draft technical standard that can be applied to all countries, we will prepare the outline of the technical standards at JICA.

1.4.1.8 Training Monitoring Activities by Issue for Previous Years T8(Change of Target Country)

We will follow up on the monitoring activities of “Bridge Maintenance and Management”, an issue specific training conducted in the previous fiscal years.

The purpose of this follow-up activity is to confirm and track the status of development in the target countries from a medium-term perspective after the implementation of monitoring activities (implementation status of action plans and activities of trainees related to the dissemination and deployment of technologies acquired in training) conducted six months after the implementation of the task-specific training of “Bridge Maintenance and Management” (March 2016 and February 2017).

Target countries: Solomon Islands, El Salvador (initially) canceled and changed to Tunisia.

(1) Preparations before the Field Survey

After fully grasping the results of the monitoring activities conducted in the previous fiscal year and the individual circumstances of the target countries, we will confirm the status of activities and current issues after monitoring issue specific training by e-mail, video conferences, etc. in accordance with the common questionnaires prepared in advance.

(2) Local Follow-up Activities:

1) Interviews with Trainees and Their Bosses
This is to check the progress of the action plans and understand the activities. In addition to the changes to the action plans, we will also confirm the status of the organization's efforts, such as disseminating the training content through return report sessions by the trainees and/or appointing a successor to transfer technology.
2) Holding Seminars for the Purpose of Improving the Technical Capabilities of the Institution to which the Trainees Belong
The seminar will consist of a program focusing on the issues required in the target country, based on the requests of the trainees, in collaboration with related work.
3) Site visits for the Purpose of Understanding the Status of Road AM in the Target Country
We will conduct on-site inspections of bridges that have particular problems, such as bridges that are significantly deformed, to understand the current situation and provide necessary advice.

(3) Points to Keep in Mind when Implementing

In confirming the issues, we will focus on the priority items that have been set based on the results of the monitoring conducted in the past years and after accurately understanding the individual circumstances of the target country in cooperation with the trainees. In addition, we will explain the merits of monitoring to the concerned parties and obtain their cooperation.

1.4.1.9 Creating a Database of Participants in Training by Country / Issue T9 (New)

We will create a Database (hereinafter referred to as DB) for participants in group training/issue specific training that was conducted in the past years. The DB will summarize names, titles, affiliations, specialties, qualifications, experiences, projects involved, etc., and will be compiled as a simple DB such as in an Excel format, which will be used to provide future support to each country. After examining the items in the DB, we will submit them to JICA for confirmation. The number of training courses to be organized is 50, and the target is about 400 training participants.

1.4.1.10 New Technical Cooperation Project (Collection of Maintenance Information on Roads and Bridges) T10

Among the technical cooperation projects scheduled to be launched, Mozambique and Burkina Faso provide support for organizing the background of requests and collecting information on road and bridge maintenance in the concerned countries (equivalent to a survey on the formulation of detailed design for past work).

1.4.1.11 Training by New Task “High-Quality Infrastructure Development Utilizing DX” T11 (New)

As a new additional task, we will support the formulation of a concept paper for high-quality infrastructure development utilizing digital transformation (hereinafter referred to as DX) training for each new issue.

1.4.1.12 Investigation of Maintenance Status of Special Bridges T12 （New）

Confirmation and analysis of AM evaluation of special bridges and maintenance of special bridges constructed in JICA projects based on materials and information provided by JICA. The survey will be conducted in countries, the Philippines (two bridges) and Thailand (three bridges). and will be on the web.

1.4.1.13 Creation of Materials for RAMP Public Relations T11⇒T13 (Change of Task Number)

We will create a 5-minute video for external publicity of RAMP's activities and a 2 page A4 sized full-color pamphlet. These public relations materials can be distributed at technical exhibitions, meetings to explain the outline of RAMP, etc.

1.4.1.14 Correspondence to Domestic Support Committees T12⇒T14 (Change of Task Number)

We will report the results of the T2-T9 survey to the RAMP support committee, obtain technical advice from external experts, and reflect the contents in the survey. The 2nd (around October 2020) RAMP support committee assumes an explanation of the business plan for this survey, an explanation of the results of the survey (in progress) in the third (around March 2021), and the explanation of the results of the survey (final) in the fourth (around October 2021).

In this survey, the preparation, explanation, and technical advice content of explanatory materials used by RAMP support committee are reflected in the report.

1.4.1.15 Report Preparation T13⇒T15 (Change of Task Number)

The above survey results will be summarized as a report. Figure 1.2 shows an initia flow chart of the entire survey and Figure 1.3 shows revised flow chart of the entire survey.

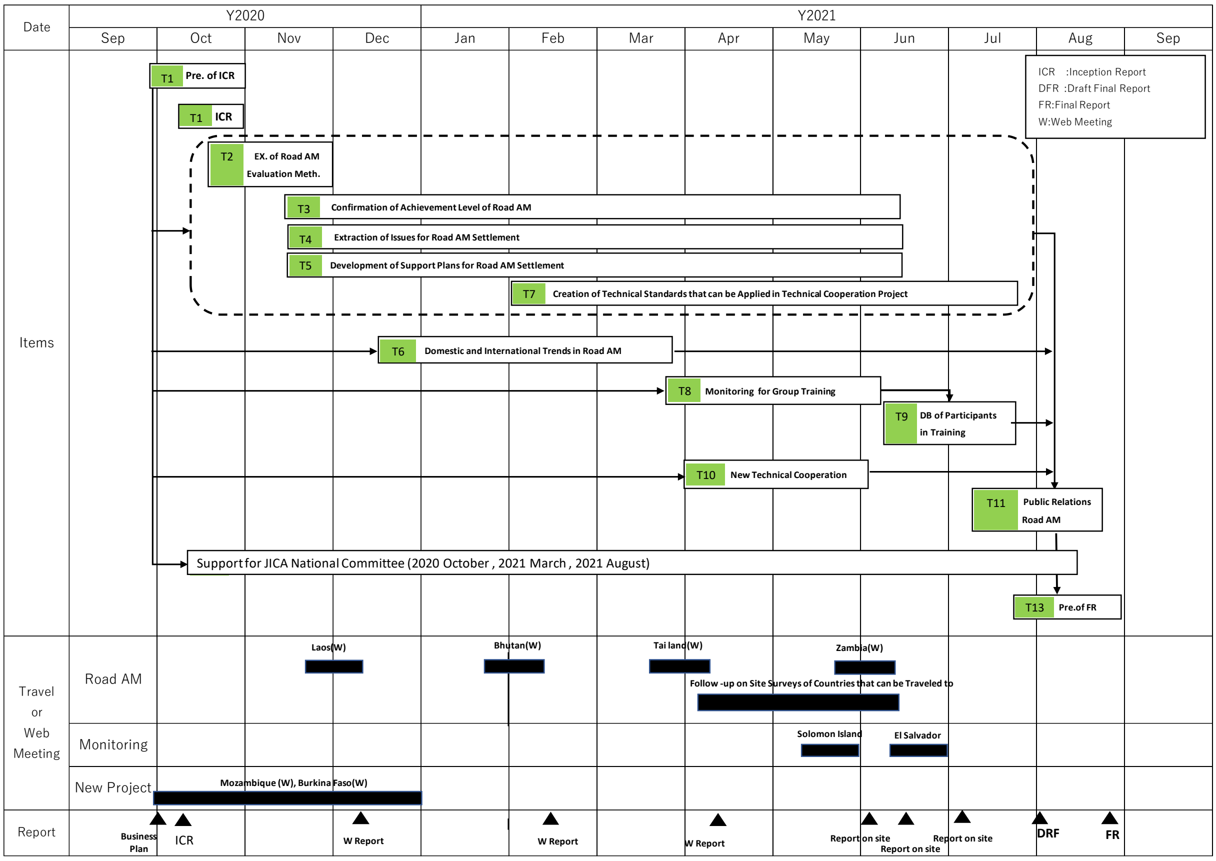


Figure 1.2 Overall Flowchart (Initial)

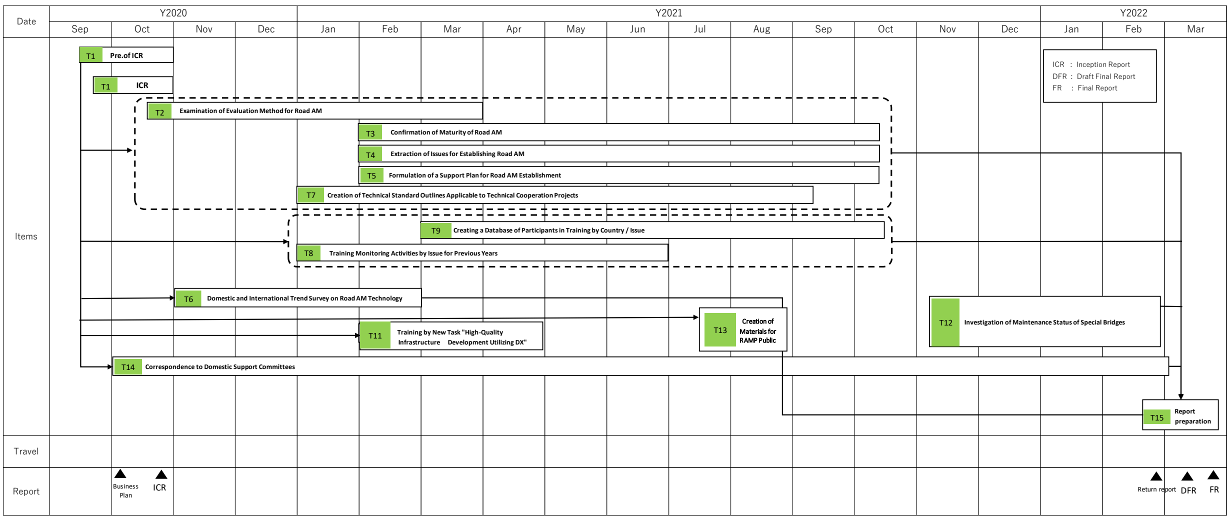


Figure 1.3 Overall Flowchart (Revised)

1.5 Survey Countries and Target Projects

The countries surveyed are shown in Table 1.2.

Table 1.2 Sites Surveyed

Name	Target Projects	Region
Laos	Project for Improvement of Road Management Capability (Implemented) The Project for Capacity Development on Bridge Maintenance and Management (To be implemented)	All
Bhutan	Project for Capacity Development in Construction and Maintenance of Bridges (On-going) The Project for Capacity Development on Countermeasures of Slope Disaster of Roads in Bhutan (On-going)	All
Thailand	The Project for Capacity Development for Maintenance Management of Bridges and Tunnels (on-going) Special Bridge Maintenance Status (Three bridges)	All
Zambia	Project for Improvement of Bridge Maintenance Capability Building in Zambia (On-going)	All
Solomon Islands	JICA Group Training on Bridge Maintenance in 2016	All
El Salvador (Initial) (Suspended)	JICA Group Training on Bridge Maintenance in 2017	All
Tunisia (Added)	JICA Group Training on Bridge Maintenance in 2017	All
Burkina Faso	Project for Improvement of Road Management Capability (To be implemented)	All
Mozambique	Bridge Maintenance Capacity Enhancement Project (To be implemented)	All
The Philippines	Special Bridge Maintenance Status (Two bridges)	

1.6 Partner Country Related Organizations

Table 1.3 shows the target organizations in the partner country.

Table 1.3 Target Organizations in the Applicable Country

Country	Name
Laos	The Ministry of Public Works and Transport
Bhutan	The Department of Roads, Ministry of Works, and Human Settlement
Thailand	The Department of Highways, Expressway Authority of Thailand(Added)
Zambia	The Road Development Agency
Solomon Islands	Ministry of Infrastructure Development
El Salvador (Suspended)	Ministry of Public Works and Transport, Housing and Urban Development
Tunisia (Added)	Direction Générale des Ponts et Chaussées
Burkina Faso	Direction Generale del Entererien Routiner
Mozambique	Administracao Nacional de Estradas, Insituto Pubilico
The Philippines(Added)	Department of Public Works and Highways

1.7 Implementation System

Consultant team meber is shown in Table 1.4.

Table 1.4 Consultant Team Member List

Position	Name	Company
Leader/Road AM 1 (Technical Standards Survey)	Akira Okamoto	JEXWAY
Road AM 2 (Domestic and Overseas Trend Survey 1/Detailed Plan Formulation Survey 1)	Hideo Nagao	NE
Support Program Review 1 (Maturity Level Survey 1)	Takehiko Tsuji (until 2021.6)	IDI
Support Program Review 1 (Maturity Level Survey 1)	Masaki Tsubouchi (from 2021.7)	IDI
Support Program Review 2 (Maturity level survey 2)	Noriyuki Kodama	JEXWAY
Support Program Review 3 (Maturity Level Survey 3)	Toshihiro Kuramoto	NEXCO West
Support Program Review (Domestic and Overseas Trend Survey 2)	Hiroji Kasamatsu	JEXWAY
Support Program Review (Detailed Plan Formulation Survey 2)	Gentaro Nagasawa	NE
Follow-up on Issue Specific Training Database Organization 1	Yasushi Takahashi	IDI
Follow-up on Issue Specific Training /Database Organization 2 (Detailed Plan Formulation Survey 3)	Sachiyo Matsubayashi	NE
Support for RAMP Support Committee /Preparation of Public Relations Materials	Masami Morita	JEXWAY

Chap.2 Road Infrastructure Maintenance Capacity Confirmation Method of the Target Country

2.1 Target of the Chapter

We reviewed the evaluation method model of the Road AM maturity level created in the past year's survey and obtained technical advice from the members of the RAMP support committee, Japan Asset Management Association (hereinafter referred to as JAAM) officials and technical cooperation project officials of the surveyed countries while considering to add or improve evaluation items.

2.2 Overview

Under the supervision of Director Dr. Fujiki of JAAM, the Road AM evaluation sheet was reviewed again. The increase / decrease of major items and middle items and the reasons for the 2019 version are shown below.

	2019	2020	Difference	Reason for Increase or Decrease
Major Item	10	5	-5	“Inspection”, “Diagnosis”, “Repair Plan”, “Maintenance”, “Repair Work”, “Record Storage”, “Organizational Structure”, “Budget Funding”, “Bidding Contract System”, and “System DB” to be changed to the middle item. 【-10】 To be reorganized into “Pavement”, “Bridges”, “Earthworks (slopes)”, “Surveillance (monitoring)”, and “Organizational Management”. Of these, “Earthworks (slopes)” and “Surveillance (monitoring)” are newly added. 【+5】
Middle Item	15	24	9	“Rehabilitation and Reconstruction” is added to the major items; “Pavement” and “Bridges” to encompass the maintenance and repair level up to the strategic and conception levels 【+2】 “Inspection”, “Diagnosis”, “Repair and Rehabilitation Plan”, “Daily Maintenance”, “Repair”, “Rehabilitation and Reconstruction” are added to the newly added major item “Earthworks”. 【+6】 “Traffic Conditions” and “Meteorology and Disaster Prevention” are added to the newly added major item “Surveillance (monitoring).” 【+2】 “Technical Training” is added to the major item “Organizational Management.” 【+1】 “Pavement Records” and “Bridge Records” are divided into the major items “Pavement”, “Bridges”, and “Earthworks (slopes)”, and are incorporated into the details of each item related to the small items “Implementation of Daily Inspections”, “Implementation of Periodic Inspections”, “Diagnosis of Soundness”, “Emergency Measures”, “Implementation of Repairs”, and “Implementation of Rehabilitation and Reconstruction” as “Record Storage and Sharing”. 【-2】

2.3 Method for Confirming Maturity of Road AM

The evaluation sheet for Road AM is used to confirm the maturity level of the Road AM. The evaluation items are broken down to the point where they can be evaluated and scored at a detailed level and, finally, set up comprehensively using the same items so that a comparison between multiple countries is possible. Each score for middle items shall be the simple average of the details contained in the area and each score of major items shall be the simple average of the details contained in the area. The Road AM achievement level is to be evaluated by the evaluation items and contents of the Road AM evaluation sheet shown in Table 2.1.

Achievement levels should be set up in such a way that strengths can be developed, and weaknesses can be overcome through a support plan with the clarification of strengths and weaknesses by scoring the achievement levels of each item.In Table 2.1, the evaluation items are divided into technical, monitoring and operational items, and the technical items need to evaluate whether the PDCA cycle of pavement, bridge, earthwork inspections, diagnosis, repair and rehabilitation plan, daily maintenance, repair, and rehabilitation and reconstruction for road maintenance management is functioning or not.The monitoring items evaluate whether the PDCA cycle of traffic conditions and meteology and disaster prevention is fuctioning or not. Operational items evaluate the development status of platforms that are indispensable for strongly promoting the above PDCA cycle through organizational structure, budget funding, bidding contract system, technical training, etc.

Table 2.1 Evaluation Items and Content

	Middle Items	Content
Technical Items Pavement Bridges Earthworks (Slopes)	Inspection	Check if an appropriate inspection system and manual are in place. Check if the manual is in operation. Check if daily and periodic inspections are conducted appropriately. Check if inspection records are preserved and shared.
	Diagnosis	Check if an appropriate diagnostic system and manual are in place. Check if the manual is in operation. Check if the soundness diagnosis is properly performed.
	Repair and Rehabilitation Plan	Check if asset ledgers, DBs, and management systems are in place and operated. Check if the formulation of the repair and rehabilitation plan is conducted appropriately.
	Daily Maintenance	Check if a daily maintenance system is in place. Check if the appropriate implementation of cleaning and first aid measures is conducted properly.
	Repair	Check if repair systems, quality standards, and repair manuals are in place are operated. Check if repairs are conducted properly.
	Rehabilitation and Reconstruction	Check if an appropriate rehabilitation and reconstruction system is in place. Evaluate whether rehabilitation and reconstruction are conducted properly.
Monitoring Items	Traffic Conditions and Meteorology and Disaster Prevention	Check if traffic, precipitation, temperature, wind, etc. are properly monitored.
Operational Items	Organizational Structure	Check if an appropriate asset management cycle is in place and its organization and control are appropriate. Check if business continuity change management is implemented appropriately. Check if training facilities are properly in place.

	Middle Items	Content
	Budget Funding	Check if budget funding is properly implemented.
	Bidding Contracting System	Check if the bidding contract system is functioning properly.
	Technical Training	Check if the training system for pavement, bridges, and earthworks is properly established.

Transportation Asset Management Guide (hereinafter TAM Guide)[1] scores each item in five (5) stages on a scale of 1 - 5 (Level 1 being the initial stage, 2 being awakening stage, 3 being structured configuration stage, 4 being development stage and 5 being best practice). The definitions are shown in Table 2.2.

Note that among the breakdown items, there are some items that simply ask for presence/absence or implemented/not implemented and the goal of achievement for those items was level 3. In addition, the degree of achievement for the breakdown items calculated at level 3 was 100% when using level 3 as the basis, and the degree of achievement of breakdown items up to level 5 was calculated using level 5 as the basis.

In addition, JAAM defined the five-step common maturity evaluation criteria as the basic concept of evaluation to be applied to all asset management processes. By this common maturity evaluation criteria, it is possible to develop the evaluation criteria in a common way for various processes in various fields. Table 2.3 outlines the common maturity evaluation criteria based on the concept of the process.

Table 2.2 Evaluation Item Level Definition

Level	Definition
Level 1 Initial Stage	There is no effective technical support in asset management. Only data prescribed as duty is collected and they are not being used for communication between internal control and interested persons. Also, there is no internal flow concerning information about business results.
Level 2 Awakening Stage	Basic data collection and processing is performed. Pavement Management System (PMS) and Bridge Management System (BMS), commercially available software, are being used for the mere purpose of controlling the database instead of using them as forecast or decision-making tools. Data collection beyond required items is being conducted to answer or tackle challenges from management. There is no internal flow concerning information about business results.
Level 3 Structured Configuration Stage	The information system forms the nucleus of the activity. Decision makers will be informed of the financial forecasts quantitatively and of the basic information about the mission of an organization. Within an organization, the data is processed vertically, from the bottom to the top, and the target is transmitted from the top to the bottom. Consistency in business results and communication have been promoted within the organization, but they are not summarized. Internal flow concerning information about business results is vertical.

[1] AASHTO: TAM Guide (Transportation Asset Management Guide) 2011.1.

Level	Definition
Level 4 Development Stage	With the aim of implementing resource distribution and cost management, information about business results is used to manage on-going activities. The prediction model is used to predict the outcome of alternative proposals. The current and projected results are communicated to external stakeholders as a means of financing and securing desirable outcomes. The manager relies heavily on this information about business results. The internal flow concerning information about business results is both vertical and horizontal, and it is a prediction of the achievements of a decision.
Level 5 Best Practices	Information technology of asset management is used to regularly design new and more efficient tools and processes. Continuous improvement of informed decision-making and its quality is present at all levels of the organization. The internal flow concerning information about business results is both vertical and horizontal, and it is a continuous process of improvement.

Table 2.3 JAAM Common Maturity Evaluations Criteria[2]

Level 1 Indifference (No Interest)
Organizations are indifferent to the systematic development of asset management. Lack of understanding of the interrelationships between processes often fails to manage forward-looking processes. Also, there is little formalization or documentation of processes. The organization produces normal output, which depends on the individual's ability.
Level 2 Beginner Ambitions (Willingness)
Organizations are eager to develop asset management systematically. Because there is a certain understanding of the interrelationships of process activities, they may succeed in managing forward-looking processes. Although not thorough, process descriptions (inputs, outputs, standard procedures, etc.), exist and are documented. Administrators know have a plan, know how to implement and what they deliver.
Level 3 Intermediate Structure (Structured)
Because organizations have a wide range of organizational developments in asset management, asset management is structured throughout the organization. There is a broad range of forward-looking process management based on an understanding of the interrelationships of process activities. Process descriptions (inputs, outputs, standard procedures, etc.) are formalized, documented, and applied to a wide range of organizations. The structure is managed for process performance and with as quantitative a goal as possible.
Level 4 Mastery (Proficient)
(In addition to level 3 content) The organization's familiarity with asset management has led to an understanding of the interrelationships of sub-processes within the process. Quantitative prediction is done to some extent, and quantitative targeting of processes based on monitoring sub-processes is performed.
Level 5 Advanced Optimization (Optimized)
(In addition to level 4 content) The organization's asset management is optimized for the organization's characteristics, delivering the best results without unnecessary functionality or cost. There is focus on managing organizational performance by analyzing data and improving it based on this. Process improvement is done in the following ways: -Process improvement by quantitative understanding of needs (expectations) -Quantitative approach by cause analysis to process variations and performance -Gradual and innovative improvements in process and technical aspects

[2] JAAM Maturity Evaluation Subcommittee: Asset Management Process and Maturity Evaluation for Practitioners of JAAM Guidebook Series, Nikkan Construction News Agency, 2019.8.20, pp.32-33.

The subject of each level, “optimized,” “proficient,” “structured,” “willingness,” and “no interest” is in regards to the total organization that practices asset management. For example, regarding “no interest,” there may be employees who are interested in asset management and are practicing it in their work, even though the organization is not committed to asset management.

Within this criteria, from level 1 to level 3, from the situation in which the official process as an organization is not in place and, depending on the individual, the process is built into the organization and structured as a system with the official process being maintained and documented. Furthermore, from level 3 to level 5, from the state in which the process was in place with the aim of improving the quality of the output, continuous improvement is built into the process and progress and quantitative evaluation is possible, which shows the process of being optimized according to the characteristics and scale of the organization.

Although the maturity evaluation standards of these five stages are independently established in this guidebook based on the ISO 55000 series, since it is a comprehensive review of the standards such as CMMI (Capability Maturity Model Integration) and the TAM Guide, which has extensive evaluation experience overseas, it is globally acceptable content.

Referring to the above, the definition of the level of these survey items was determined in Table 2.4.
In the technical cooperation projects, we will promote support with the goal of reaching level 3.
The structural diagram of the evaluation sheet (example) is shown in Figure 2.1, and the radar chart of the major items (example) is shown in Figure 2.2.
The thick red line in Figure 2.2 shows the current state and the red dotted line shows the maturity forecast for five years after the end of the technical cooperation project, and the outer gray dotted line shows the case of the highest rating (level 5 or level 3 depending on the question) for all indicators.

Table 2.4 Evaluation Item Level Definition (This Survey)

Level	Definition
Level 1 Initial Stage	There is no effective technical support in asset management. Inspections, diagnosis, daily maintenance, repair, rehabilitation, and reconstruction are not conducted. There is no monitoring of traffic conditions and meteorology and disaster prevention. There is no organizational structure, budget funding, bidding contract system, or technical training. There is hardly any communication within or between organizations.
Level 2 Awakening Stage	Asset management collects and processes basic data. Inspections, diagnosis, daily maintenance, repair, rehabilitation, and reconstruction are partially conducted. Traffic conditions and meteorology and disaster prevention are partially monitored. There is some organizational structure, budget funding, bidding contract systems, and technical training. Communication within or between organizations is limited.
Level 3 Structured Configuration Stage	The asset management system forms the nucleus of the organizational activity. Inspections, diagnosis, daily maintenance, repair, rehabilitation, and reconstruction are conducted. Monitoring of traffic conditions and meteorology and disaster prevention is conducted. organizational structure, budget financing, bidding contract system, and technical training are in place. Communication is promoted within or between organizations, but it is not systemized.

Level	Definition
Level 4 Development Stage	The asset management system is being used for resource allocation, cost management and business result management. Inspections, diagnosis, daily maintenance, repairs, rehabilitation, and reconstruction are systematically conducted. Traffic conditions and meteorology and disaster prevention are partially monitored. There is some organizational structure, budget funding, bidding contract systems, and technical training. Communication is promoted within or between organizations.
Level 5 Best Practices	Information technology for asset management is used to regularly design new and more efficient tools and processes. Inspections, diagnostics, daily maintenance, repair, rehabilitation, and reconstruction are systematically implemented and continuously improved. Monitoring of traffic conditions and meteorology and disaster prevention is systematically implemented and continuously improved. Organizational structure, budget financing, bidding contract system, and technical training are systematically developed and continuously improved. Communication is promoted within or between organizations and is being improved continuously.

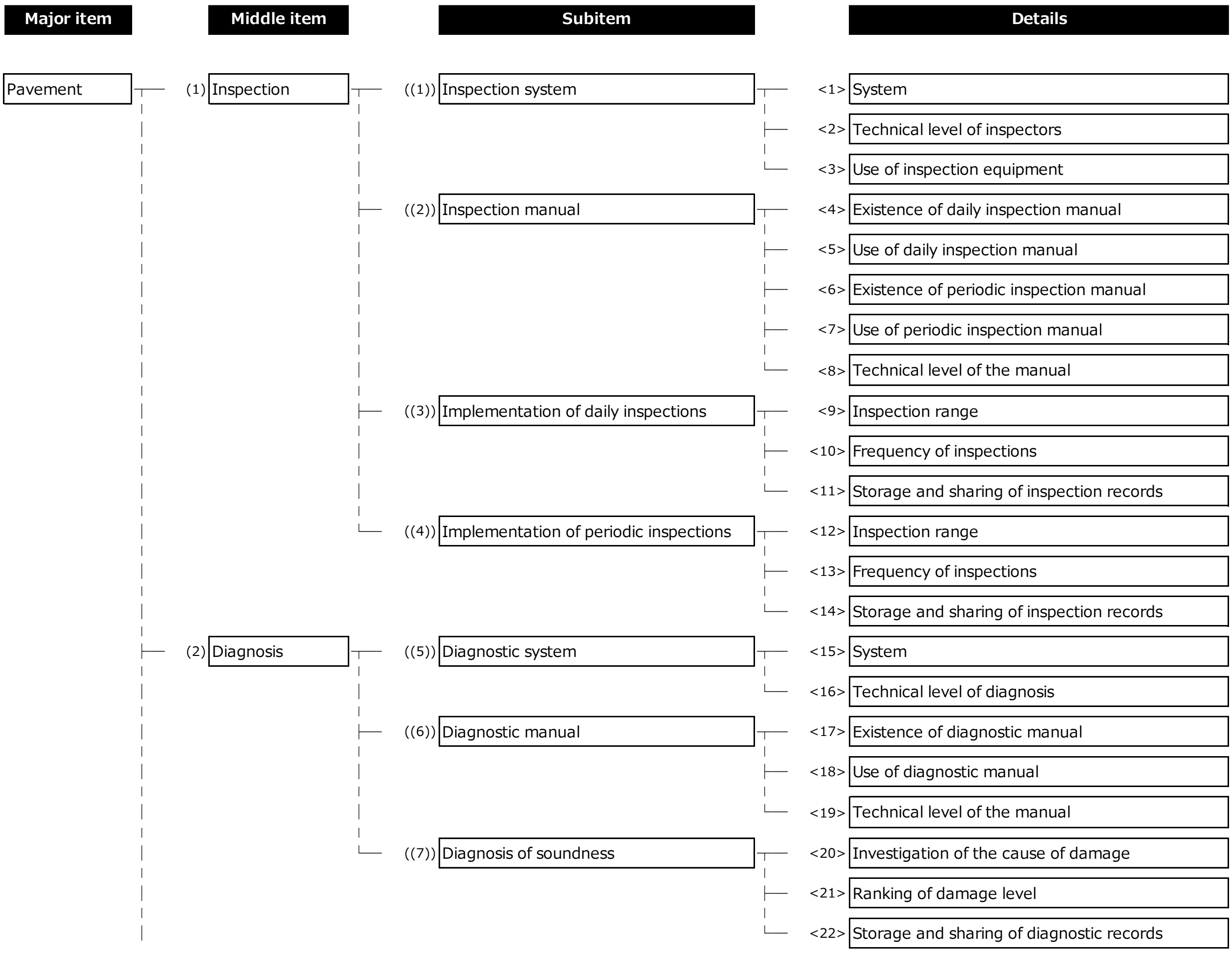
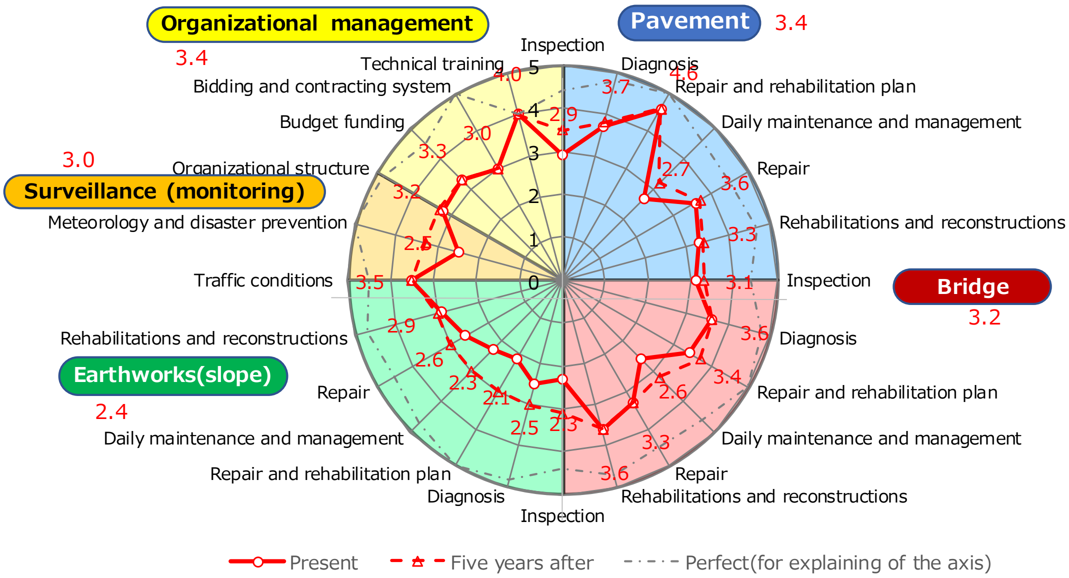


Figure 2.1 Road AM Indicator Structural Diagram (Example)



Note: The thick red line in the figure is currently in progress, and the dotted red line is expected to be mature five years after the end of the technical cooperation project.

The outer gray dotted line is the highest rating (level 5 or level 3 depending on the question) for all indicators.

Figure 2.2 Major Items Radar Chart (Example)

2.4 Road AM Evaluation Sheet Changes

As shown in Table 2.5, the technical items of the Road AM Evaluation Sheet (2019) developed in the "Data Collection Survey on Road Asset Management Platform Technical Support".Information Collection (2019) consists of "Inspection", "Diagnosis", and "Repair Plan", "Maintenance Managemnet", "Repair", and "Record Storage", of which 11 items were middle items, 34 items were small items, and 51 items were detailed items. In addition, the operation items were composed of 4 categories: "Organizational Structure", "Budget Funding", "Bidding Contract System", and "System and DB", of which 4 items were middle items, 11 items were small items, and 20 items were detailed items.

Table 2.5 Road AM Evaluation Sheet Overview (2019)

	Middle Items	Points of Evaluation
Technical Items 6 Categories	Inspection	Set evaluation items from the viewpoint of checking whether the PDCA cycle on maintenance is going well. 5-step evaluation (initial to best practices). Middle items: eleven Small items: thirty-four Detailed items: fifty-one *Some evaluation items that ask whether they are available/not implemented or not conducted are perfect scores of three points.
	Diagnosis	
	Repair Plan	
	Maintenance Management	
	Repair	
	Record Storage	
Operational Items 4	Organizational Structure	Set evaluation items from the viewpoint of verifying that there is a platform in place to support the PDCA for maintenance. 5-step evaluation (initial to best practices)
	Budget Funding	

	Middle Items	Points of Evaluation
Categories	Bidding Contract System	Middle items: four Small items: eleven Detailed items: twenty *Some evaluation items that ask whether they are available/not implemented or not conducted are perfect scores of three points.
	Systems and DB	

As shown in Table 2.6, the Road AM evaluation sheet was reviewed and examined in this survey, and the technical items were composed of six categories “Inspection”, “Diagnosis”, “Repair and Rehabilitation Plan”, “Daily Maintenance”, “Repair”and “Rehabilitation and Reconstruction”, of which 18 items were middle items, 58 items were small items, and 183 items were detailed items. In addition, the monitoring items consisted of two categories, “Traffic conditions” and “Meteorology and Disaster Prevention”, of which 2 items were middle items, 2 items were small items, and 8 items were detailed items.

Furthermore, the organizational management items are composed of four categories, “Organizational Structure”, “Budget funding”, “Bidding Contract System”, and “Technical Training”, of which 4 items are middle items and 11 items were small items, and 28 were detailed items.

Table 2.6 Road AM Evaluation Sheet Overview (2020)

	Middle Items	Points of Evaluation
Technical Items 6 Categories	Inspection	Set evaluation items from the viewpoint of checking whether the PDCA cycle on maintenance is operating well. 5-step evaluation (initial to best practices) Middle items: eighteen Small items: fifty-eight Detailed items:183 *Some evaluation items that ask whether they are available/not implemented or not conducted are perfect scores of three points
	Diagnosis	
	Repair and Rehabilitation Plan	
	Daily Maintenance	
	Repair	
	Rehabilitation and Reconstruction	
Monitoring 2 Categories	Traffic Conditions	Set evaluation items from the viewpoint of confirming that traffic monitoring is conducted appropriately 5-step evaluation (initial to best practices) Middle items: one Small items: one Detailed items: four
	Meteorology and Disaster Prevention	Set evaluation items from the viewpoint of confirming if meteorology and disaster prevention monitoring is conducted appropriately. 5-step evaluation (initial to best practices) Middle items: one Small items: one Detailed items: four
Organizational Management Items 4 Categories	Organizational Structure	Set evaluation items from the viewpoint of verifying that there is a platform in place to support the PDCA for maintenance. 5-step evaluation (initial to best practices) Middle items: four Small items: eleven Detailed items: twenty-eight *Some evaluation items that ask whether they are available/not implemented or not conducted are perfect scores of three points.
	Budget Funding	
	Bidding Contract System	
	Technical Training	

Chap.3 Current Status, Issues, and Support Plan for Road AM in Laos

3.1 Target of the Chapter

To investigate the background of the project to strengthen the maintenance capacity of roads and bridges in Laos, the outline of road maintenance, the outline of the technical cooperation project, and the construction and maintenance capacity and technology level. In addition, using the Road AM evaluation sheet, the level of Road AM maturity in Laos will be confirmed through interviews with the technical cooperation project team and counterparts. In addition, challenges for Road AM establishment will be identified and support plans will be formulated.

3.2 Overview

JICA implemented the Project for Improvement of the Road Management Capability from September 2011 to May 2018 with the aim of supporting the Department of Public Works and Transport (DPWT) of the pilot provinces (Vientiane and Savannakhet) to improve their capacity to develop maintenance plans, technical manuals, and guidelines, and improve the capacity of technicians. Through this, the capacity of the Ministry of Public Works and Transport (MPWT) staff in road maintenance has been improved. Since this project was focused on pavement maintenance and management, the Lao government later requested Japan to implement the Project for Capacity Development on Bridge Maintenance and Management to improve the capacity of the MPWT for bridge maintenance and management. In response to this request, the project has been implemented with a construction period from November 2020 to October 2023.

In this survey, online interviews were conducted four times with the DOR and two times with Japanese companies engaged in the technical cooperation projects in Laos. These were used to understand the general situation of the DOR's construction and maintenance capability and technical level, and to evaluate the maturity of Road AM by the DOR. Based on the results of this study, the status, and issues of asset management for pavement, bridges, and earthworks (slopes) in Laos were identified and organized, and a support plan for establishing Road AM was formulated and proposed.

As for pavement, DBST covers more than 80% of them, and due to the rampant overloading, etc., the deterioration of the pavement is fast and preventive maintenance is not being carried out. For this reason, it is considered necessary to follow up on JICA technical cooperation projects and/or dispatch long-term experts.

As for bridges, although there is an inspection manual, daily inspections are not being carried out, and although the BMS is in operation, repairs are not being carried out systematically because they are symptomatic. These issues are expected to be improved during the JICA technical cooperation project currently underway.

As for earthworks (slopes), there are overall issues and it is necessary to improve from the technical basis and enhance the technical capability. For this reason, it is considered necessary to introduce new JICA technical cooperation projects.

As for organizational management, there are issues such as inadequate budget allocation to necessary projects. For this reason, it is expected to be improved in the ongoing JICA Public Investment Plan Management Improvement Project.

3.3 Background of the Technical Cooperation Project[3]

The real GDP growth rate of Laos has been 7-8% since 2001, which is higher than that of the member countries of the Association of Southeast Asian Countries (hereinafter referred to as ASEAN). Due to the influence of economic development, land transportation, the main means of transportation, has been increasing, and the road length has been growing year by year along with it (total length of about 60,000 km as of 2018). Economic growth is expected to continue in the future, driven by key industries such as mining and hydropower, which will further increase transportation demand.

In addition, Laos is a landlocked country, where about 80% of the land is mountainous, that also borders five countries, and geopolitically it has no choice but to depend on land transportation. Therefore, strengthening physical connectivity is even more important than in neighboring countries, and at the same time, it is expected to have a beneficial effect on neighboring countries, so the development and improvement of the land transportation network is expected with the strengthening of ASEAN connectivity in mind.

However, in the WB's Logistics Performance Index, the quality of logistics infrastructure in Laos is rated 91st out of 167 countries (2018), which is the lowest position among Southeast Asian countries after Myanmar and Cambodia. Also, in the Global Competitiveness Report published by the World Economic Forum, the country's ranking for road length and road condition is the lowest among Southeast Asian countries (93rd out of 141, 2019), behind Cambodia and Vietnam.

Particularly in the road and bridge sector, due to the lack of road maintenance management planning capacity, technical capacity in the field of maintenance management, budget, and human resources, maintenance management has not been properly implemented and has become an obstacle to smooth and safe traffic.

Based on this situation, JICA implemented the "Project for Improvement of the Road Management Capability" (2011-2018) with the aim of improving road maintenance management capacity. On-site training on road maintenance and management planning, technical manual maintenance related to maintenance, and utilization of manuals based on road maintenance management system (hereinafter referred to as RMS) were conducted, focusing on pavement maintenance management. The implementation of the project has improved the road maintenance planning capacity of the Ministry of Public Works and Transport (hereinafter referred to as MPWT) staff and their skills and knowledge in road maintenance management.

On the other hand, to ensure safe and smooth traffic on roads, it is necessary to properly maintain not only pavement but also bridges. Of the approximately 3,000 bridges, including 1,400 bridges on national highways, which exist nationwide as of 2017, 35% need routine repair and 17% in need of emergency repair.

[3] Laos Bridge Maintenance Capacity Enhancement Project JICA Project Competition Manual 2020.7.5.

Of the approximately 3,000 bridges, about 40% are temporary bridges such as wooden bridges and Bailey bridges, which are not originally intended for permanent use, and therefore lack durability and are aging.

3.4 Overview of Road Maintenance in Laos

3.4.1 Road Maintenance and Management Extension

Laos has been focusing on road improvement, and the road extension has reached about 56,000 km in 2015, from about 34,000 km in 2005.The road network map of Laos is shown in Figure 3.1 and the road extension in Laos is shown in Table 3.1.The National Roads are about 7,700 km, which is 13.7% of the total, and provincial roads are about 8,200 km, which is 14.6%. Other categories include District Roads, Urban Roads, Rural Roads, and Special Roads, but local roads account for 24,900 km, accounting for 44.2% of the total.

Looking at the pavement situation, 80% of national highways and 16% of prefectural roads are paved, while 88% of national roads and 91% of prefectural roads are paved using Double Bituminous Surface Treatment (hereinafter referred to as DBST), and the proportion of asphalt pavement and concrete pavement is small. Additionally, the pavement rate is 8% and 1%, respectively when it comes to district roads and local roads, and it is almost unpaved.

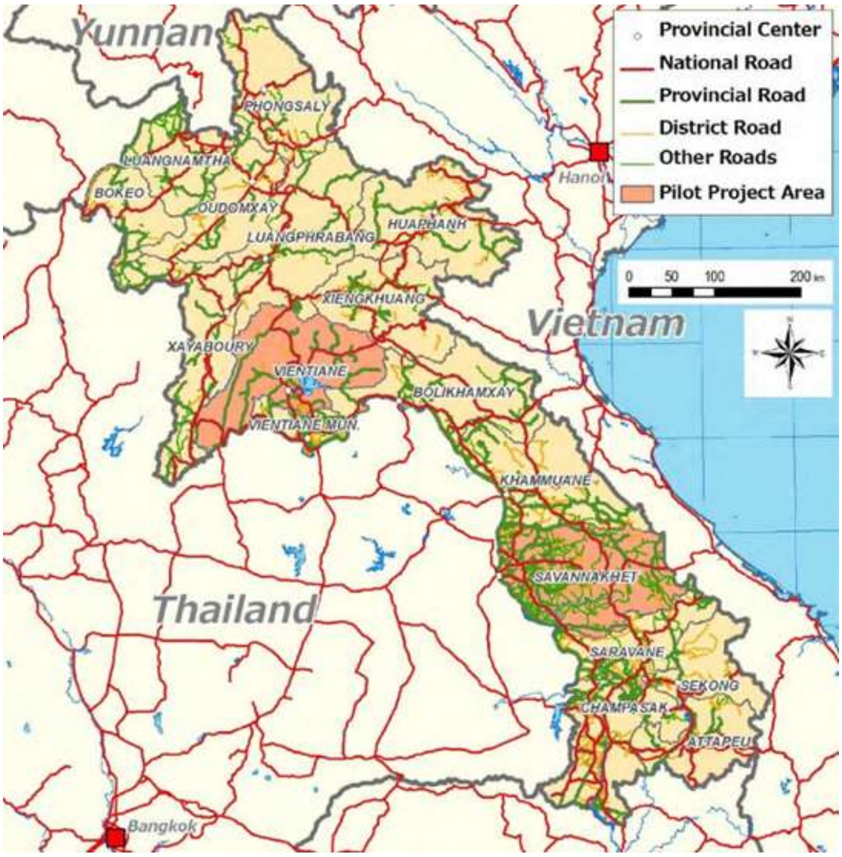


Figure 3.1 Laos Road Network[4]

Table 3.1 Road Extension in Laos, 2015[5]

Road Type	Surface Type	Paved				Unpaved			Total
		Concrete	Asphalt Concrete	DBST	Sub Total	Gravel	Soil	Sub Total	
National	Length (km)	88.2	643.9	5407.9	6140	1225.2	365.8	1591	7,731
	Surface Type (%)	1.1	8.3	70.0	79.4	15.8	4.7	20.6	100
Province	Length (km)	47	65.9	1180.2	1293.1	5565.5	1346.9	6912.4	8,206
	Surface Type (%)	0.6	0.8	14.4	15.8	67.8	16.4	84.2	100
District	Length (km)	21.5	7.5	510.9	539.9	4121.7	2257.7	6379.4	6,919
	Surface Type (%)	0.3	0.1	7.4	7.8	59.6	32.6	92.2	100
Urban	Length (km)	184.4	96.7	1005	1286.1	1177.1	599.9	1777	3,063
	Surface Type (%)	6.0	3.2	32.8	42.0	38.4	19.6	58.0	100
Rural	Length (km)	1.6	4	339.6	345.2	8583.4	15955.3	24538.7	24,884
	Surface Type (%)	0.01	0.02	1.4	1.4	34.5	64.1	98.6	100
Special	Length (km)	26.6	4.3	386.7	417.6	737.9	4373.8	5111.7	5,529
	Surface Type (%)	0.5	0.1	7.0	7.6	13.3	79.1	92.4	100
Total	Length (km)	369.3	822.3	8830.3	10021.9	21410.8	24899.4	46310.2	56,332
	Surface Type (%)	0.7	1.5	15.7	17.8	38.0	44.2	82.2	100

4 JICA: Report on completion of project work to strengthen road maintenance and management capabilities in Laos, 2018.
5 JICA: Information gathering and confirmation survey on the Lao National Transportation and Transport Sector (Transportation and Transport) 2016.

3.4.2 Organizational Structure of the DOR

The organizational structure of the MPWT is shown in Figure 3.2 and Table 3.2. The Department of Road (hereinafter referred to as DOR) of the Ministry of Public Works and Transportation is responsible for the planning, design, construction management, and maintenance of roads and bridges on national highways. The Road Maintenance Division of the DOR consists of the Road Administration Division (hereinafter referred to as RAD) of the Department of Public Works (hereinafter referred to as DOP), which is responsible for maintenance practices, and the Technical and Environmental Division (hereinafter referred to as TED), which develops technical manuals and conducts environmental impact evaluations. The Department of Transportation (hereinafter referred to as DOT) is responsible for transportation-related legislation and licensing. The Transport and Logistic Division (hereinafter referred to as TLD) within the DOT has been cracking down on overloaded vehicles. The Department of Planning and Cooperation (hereinafter referred to as DPC) oversees MPWT's medium and long-term planning, statistical data management, and donor fund management, and it also functions as a contact point for the Ministry of Planning and Investment (hereinafter referred to as MPI).

The Department of Finance (hereinafter referred to as DOF) manages all revenues and expenditures of the MPWT, and the Road Maintenance Fund (hereinafter referred to as RMF) is also managed by DOF. The Public Work and Transport Training Institute (hereinafter referred to as PTTI) provides training for the ministry employees, and the Public Work and Transport Research Institute (hereinafter referred to as PTRI) plans and conducts research in various specialized fields. Until its reorganization in 2017, the PTRI had been managing and updating road maintenance management systems such as RMS and the Provincial Road Maintenance Management System (hereinafter referred to as PRoMMS), but with the transfer of some of its staff to the DOR, these tasks were also transferred.[6]

The Department of Public Works and Transport (hereinafter referred to as DPWT) has been set up to operate in each of the eighteen provinces throughout Laos. Along with its role as the implementing agency for public works projects under the jurisdiction of the MPWT, it also has the role the planning and implementing agency for public works projects implemented by each prefecture. In addition, the Office of Public Works and Transport (hereinafter referred to as OPWT), a subordinate organization of DPWT, is engaged in road inspections, data collection, and supervision and inspections of daily maintenance work.[7]

6 JICA, "Lao National Bridge Maintenance and Management Capacity Enhancement Project Detailed Plan Formulation Survey", 2020.
7 WB, "Project appraisal document of LAO ROAD SECTOR PROJECT 2 p33", 2016.

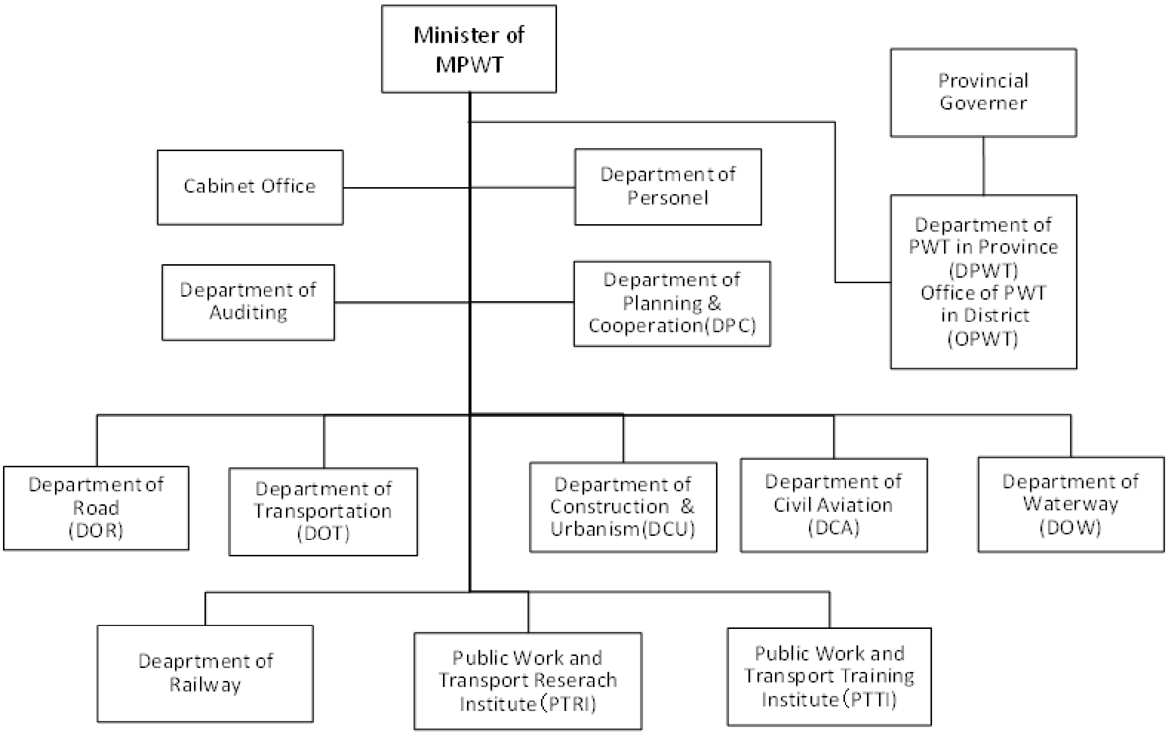


Figure 3.2 MPWT Organizational Chart[8]

Table 3.2 Responsibilities of MPWT Organizations Related to Road AM[9]

Organization	Responsibility
DOR	Various surveys and database updates on national highways Operation and management of road maintenance and management systems Road improvement, repair, maintenance plan, budget plan (mainly national highways) Supervision and monitoring of national highway rehabilitation and repair work Formulation and updating of various technical manuals
DPWT (OPWT)	Various surveys and database updates of local roads Road rehabilitation, repair, maintenance plan, budget plan (mainly local roads) Supervision and monitoring of national and local road rehabilitation and repair work Supervision and monitoring of daily maintenance and management of national and local roads
PTTI	Planning and implementation of various training
PTRI	Environmental impact assessment of rehabilitation projects
DOF	Operation and management of road maintenance and management funds
DPC	Formulation of medium to long-term infrastructure development plans including road rehabilitation and maintenance
DOT	Implementation of overload measures

Regarding the maintenance and management of paved roads and unpaved roads by the DBST, contractors carry out maintenance and management by performance-based contracts. In addition, maintenance of asphalt and concrete paved roads is conducted directly by the MPWT.

8 JICA: Lao Pdh Road Maintenance and Management Capacity Enhancement Project Detailed Plan Formulation Survey, 2020. Road Administration Training Materials 2019.
9 JICA: Detailed Plan for Strengthening Capacity to Maintain and Manage Bridges in Laos, 2020.

3.4.3 Budget for Road Maintenance and Management

The Road Maintenance Fund (hereinafter referred to as RMF) was established in 2001 with the support of the WB to finance road maintenance as a specific source of revenue. The RMF is funded by fuel taxes, tolls, and vehicle weight violation fees. In the early years of the RMF, loans/grants from donors accounted for a large part of the financial resources, but fuel taxes have grown to account for a larger share, accounting for 97% by 2019 (Table 3.3). The share of toll revenue was 15% of the total until 2010, but a 2011 notice from the Prime Minister halted the operation of many toll collection facilities, saying they were an obstacle to promoting international logistics. As a result, toll revenue in recent years has been only about 2% of the total.

The overall revenue was US$2 million at the time of its establishment in 2002 but has increased significantly to US$88 million in 2019. In addition, more than 70% of the total budget is allocated to national highways, indicating the emphasis placed on this area. However, a large part of the budget for national highways is allocated to daily maintenance and improvement works, while the daily maintenance cost is a small amount.

Expenditures have fluctuated significantly over the past five years, due in part to disasters. In 2017, US$23 million was spent due to flooding and slope failures caused by extreme rainfall, and the overall amount was an outstanding US$116 million. In addition, a 2016 Prime Minister's decree has tightened the operation of the RMF, with 72% of total expenditure to be spent on maintenance of national roads, 18% on maintenance of local roads, and 5% on new road improvements.

3.4.4 Support Status of Each Donor on Road AM

(1) WB[10]

The WB and the Swedish International Development Cooperation Agency (hereinafter referred to as SIDA) developed a Road Maintenance System (RMS) for national roads in the Road Maintenance Project Phase I from 2001 to 2004.During the Road Maintenance Project Phase II from 2004 to 2010, the Road Maintenance Management System (PRoMMS) for local roads was completed, and a tool for effective road maintenance and management planning was introduced based on periodic surveys of road conditions. The Lao Road Sector Project Phase II, which is being implemented from 2018 to 2021, will also add a climate change factor to the system with respect to RMS/PRoMMS.

In the JICA technical cooperation project, technical support for the operation of the RMS/PRoMMS was provided, and the WB collected road inventory and road condition data for the RMS/PRoMMS system input and received cooperation among donors to facilitate the operation of the developed system.

The above-mentioned RMS and PRoMMS use HDM-4 and have various simulation functions in maintenance and management formulation and have menu options to consider the best plan. However, the reliability of the input data is low, and the system itself is not being used effectively because of the budget

[10] ADB: Road Sector Governance and Maintenance Project section 2.3, 2015.

being allocated to emergency response for construction work and disasters.[11]

In addition, as shown in Table 3.3, the WB continues to support the improvement and maintenance works of national and local roads along with the technical cooperation projects mentioned above.

(2) ADB

Under the Road Sector Governance and Maintenance Project (2016-2022) to be implemented by the ADB, as shown in Table 3.3, the procurement of overloading countermeasures and road condition monitoring equipment, as well as the revision of road construction/maintenance specifications, road design/maintenance manuals, and performance-based maintenance contracts will be implemented.

Table 3.3 Support Status of Each Donor[12]

Donor	Technical Cooperation Project	Loan/Grant Aid
The WB	1) Road Maintenance Project 1, 2 a) Introduction and operation of road maintenance and management system b) Installation of vehicle weight measuring stations c) Support for introduction of performance regulations maintenance and management contracts d) Management support 2) 2. Road Sector Project I, II a) Response to climate change in Road AM b) Evaluation of performance regulation maintenance contracts c) Project management support d) Traffic safety measures support	1) Regular maintenance of 1,938 km of national highways and 855 km of local roads. daily maintenance of 19,343 km of national routes and 6,000 km of local roads (2001-2004) 2) Regular maintenance and daily maintenance of national and local roads (2004-2010) 3) Rehabilitation project for 171 km of national routes (2010-2017) 4) Regular maintenance of 687 km of national and local roads, daily maintenance of 2,856 km of local roads (2016-2022)
ADB	1) Road sector governance and maintenance project (2016-2022) a) Overload enforcement b) Procurement of road conditions data measurement machinery c) Revised road construction/maintenance specifications d) Revised road design and maintenance manual Preparation of performance regulations maintenance contracts	1) Improvement and daily maintenance of 327 km of national and local roads in the Southern Region (Saravan, Xekong, Attapeu) (2016-2021) 2) Improvement of National Route 6B (Houaphan)
KfW	1) Local road maintenance and management methods 2) Local road maintenance technology	1) Improvement and maintenance of local roads (Sekong, Saravan, Bokeo, Louangnamtha, Oudomxay, Khammouane)
China		1) Improvement of National Route 1B Line (Phongsaly)
Thailand		1) Improvement of National Route 11(Vientiane) 2) Vientiane Urban Road rehabilitation

[11] WB: Road Sector Governance and Maintenance Project2 Appraisal document p4, 2016.
[12] WB: Road Sector Governance and Maintenance Project2 Appraisal Document. Edit from 2016 pp37 etc.

Note: KfW is an abbreviation of The German Finance Corporation for Reconstruction

3.4.5 Status of Collaboration with Japanese Universities

As part of the JICAAM platform activities, Japanese research institutes have accepted long-term trainees from developing countries. The research themes of the trainees dispatched from the MPWT in Laos and the host institutions are shown in Table 3.4.

Table 3.4 Trainees in Laos Accepted by Japanese Universities

Receiving Institution/Supervisor	Research Theme	Research Course	Commencement
Hokkaido University/ Associate Professor Henry Michael	Effects and results of over-loading enforcement and weight measurement technology in AM	Master's Program	April 2018
Nagasaki University/ Associate Professor Takafumi Nishikawa	Study of maintenance models that contribute to extending the life of steel bridges	Doctoral Program	April 2018
Nagasaki University/ Professor Seizo Nakamura	Bridge inspections and evaluation methods for AM	Doctoral Program	April 2017

3.5 Overview of the Technical Cooperation Projects

3.5.1 Goals and Outcomes of the Technical Cooperation Projects

(1) Overall Goals

The Overall Goal of the JICA technical cooperation projects implemented between 2011 and 2018 is "roads and bridges in Laos are properly maintained and managed", and the following items have been set as indices to evaluate the achievement of the overall goal.

1) The RMS/PRoMMS has been properly improved and data updated by PTTI and DPWT.
2) A maintenance budget plan will be developed by the DOR based on the results of the RMS/PRoMMS analysis.
3) Annual road damage amount will decrease, and annual maintenance extension will increase.
4) The number of overloaded vehicles on national roads will be reduced.

(2) Project Goals

The Project Goal is "roads and bridges in the pilot provinces (Vientiane and Savannakhet) are properly maintained and managed", and the following items have been set as indices to evaluate the achievement of the Project Goals.

1) The RMS/PRoMMS will be appropriately improved and updated by PTTI and DPWT in the pilot provinces.
2) A maintenance budget plan will be developed by the DOR in the pilot province based on the results of the RMS/PRoMMS analysis.
3) Annual road damage amount will decrease, and road maintenance extension will increase in the pilot province.
4) The number of overloaded vehicles detected on national roads will decrease.

The OJT will be conducted in Vientiane and Savannakhet provinces, and the pilot project will be in Savannakhet province.

3.5.2 Project Activity Plan and Performance Indicators

Table 3.5 shows project output, activity plans and performance indicators.

Table 3.5 Project Output, Action Plans and Performance Indicators

Results	Activity Plan	Performance Indicator
Results one The ability to formulate maintenance plans for roads and bridges will be strengthened.	1) Review capacity levels for current maintenance planning operations 2) Improvement of data collection methods and work for RMS/PRoMMS 3) RMS/PRoMMS improvements and data updates in pilot province 4) Formulation of optimal maintenance plan utilizing RMS/PRoMMS in pilot province 5) Formulating optimal budget plans using RMS/PRoMMS in pilot province	1) Eighty percent of RMS/PRoMMS engineers in PTRI have a capability evaluation level of five or higher. 2) At least one RMS/PRoMMS engineer with DPWT has a capability evaluation of three or more. 3) RMS/PRoMMS data has been updated during the development of maintenance plans.

Results	Activity Plan	Performance Indicator
	6) OJT implementation of budget planning and updating RMS/PRoMMS database 7) Monitoring activity progress and evaluating the ability to create maintenance plans	
Results two Maintenance manuals for roads and bridges are formulated.	1) Review and improvement of existing technical manuals such as status investigation manuals, inventory manuals, and legal protection manuals 2) Formulation of technical manuals such as inspections, evaluation, and repair manuals 3) Monitoring of the utilization of technical manuals, evaluation of utilization methods, and examination of validity for finalization of manuals	1) The manuals created in the technical cooperation project are approved by the government agency. 2) Approved technical manuals are distributed to the technicians and contractors in charge.
Results three The DOR/DPWT staff improve road/bridge maintenance and implementation capabilities.	1) Understanding the status of maintenance and management practices, checking capacity levels, and formulating training and monitoring plans 2) OJT of road maintenance and management work including inspections, small-scale repair, and quality control is conducted by DPWT staff in the pilot province 3) Improvement of OJT evaluations and the training structure of road maintenance work and other programs 4) Formal establishment of the optimal administrative organization for road maintenance (informal task force, official maintenance department, etc.) 5) Implementation of a pilot project for repair work and supervision capacity of asphalt pavement and quality control in Sabanats province 6) Confirmation of activity progress and evaluation of practical ability to maintain and manage	1) Eighty percent of DPWT maintenance personnel and the DOR in the pilot province will participate in the seminars, workshops, and training organized by the project. 2) The ability evaluation of the DOR /PTRI maintenance technicians is level 5. 3) Eighty percent of the DPWT/DOR engineers in the pilot province who participated in the seminars, workshops, and trainings organized by the project will be evaluated for their ability.
Results four Acquisition of work execution capacity of the DOT/DPWT staff in charge of overload measures	1) Review of the organizational structure and technical recommendations for building sustainable systems for over-loading vehicle control 2) Design, procurement, and installation of a new weighing station on National Route 9 3) Preparation of manuals for crackdown on overloaded vehicles and implementation of OJT in the pilot province 4) Implementation of periodic checks (reporting systems and legal frameworks) for the control of	1) Vehicle weight measurement is resumed, and the DPWT in the pilot province reports the measurement result to the DOR. 2) More than 90% of all vehicles are weighed and measured in the pilot measurement facility.

Results	Activity Plan	Performance Indicator
	overloaded vehicles in the pilot province 5) Spread of measures to control overloaded vehicles of private truckers, carriers, and major shippers 6) Confirmation and evaluation of progress of activities related to overload control	

3.5.3 Manuals Introduced in the Project

The following manuals were prepared for the technical cooperation project. The summary is shown in Table 3.6.

Table 3.6 Manuals Introduced[13]

Manual Name	Overview
Road Maintenance Manual	It describes inspections, evaluation, and maintenance method of asphalt paved roads, and includes not only road surfaces but also drainage facilities, slopes, traffic safety facilities, etc. Daily inspections are conducted once every 1 to 4 weeks, and road surfaces, cut slopes, drainage facilities, signs, etc. are inspected from main road culverts while drainage facilities and embankment surfaces from side roads. One km is a section, and road conditions are ranked in four levels according to each item (road surface, road shoulder, slope, drainage facility, signage, etc.). The damage contents and points are also recorded and finally stored in a database with electronic data. If there is no abnormality in the daily inspections, the judgment is A. It is ranked as B-D according to the degree of damage., and then detailed inspections are conducted. In the detailed inspections, the inspections are conducted preferentially at the C and D ranks, and at B rank only important damage on the road surface and shoulder is inspected. Detailed inspections are conducted once every 1 to 4 months to understand the location of the damage, MAC code, size, number, and damage rank. The countermeasure work according to the damage rank will be identified by the detailed inspections.
Bridge Maintenance Manual	It describes the inspection, evaluation, and maintenance methods of bridges on national and local roads other than Bailey bridges and organizes basic knowledge of bridge maintenance and management. The type, method, and frequency of inspections is set (daily inspections are once a year, periodic inspections are once every five years), and the inspection record format is presented separately for daily inspections and periodic inspections. The degree of damage is judged on a 6-point scale, and the rank is defined for each part of the bridge (upper construction, lower construction, supports, joints, drainage facility, lighting facility, etc.). Specific cases of the damage are presented in photographs, and even beginners can understand the damage.
Slope Maintenance Manual	This is a description of the maintenance and management method for slopes on the roads located in mountainous regions. The inspection method is described after classifying the form of the slope damage generation. The inspections provide a baseline survey every five years, daily inspections conducted several times a year,

[13] The investigation team compiled the outline of the various manuals prepared in the technical cooperation project.

Manual Name	Overview
	detailed inspections to be conducted as necessary, and an emergency inspection in the event of a slope failure. The format of the inspection record used at each inspection is also described. The evaluation of slope damage is ranked by considering the degree of damage and the degree of impact of the slope failure on roads. The implementation method of the daily and emergency maintenance methods, and the slope improvement methods are summarized in the flowchart. In addition, the concept of geological surveys, water level measurement methods, and the design for slope stabilization measures as countermeasure work for the slopes are also described.
Road Maintenance Management Operation Manual) (RMS/PRoMMS)	RMS/PRoMMS was developed with the support of the WB and SIDA and is a system that supports the optimal planning of road maintenance and management by logging the output of road conditions surveys. Input data is inventory information such as road standards, lengths, widths, traffic volume, the pavement state of each section, shoulder status, drainage status, road status information such as IRI measurement values, and cost information such as unit price for maintenance. The output is the quantity and cost of daily maintenance costs and periodic maintenance costs. In addition, the construction costs, such as overlays and bridge reinforcement work, is to be calculated separately as new construction. Further, MAC codes are also associated with the system, and the unit price setting based on the MAC code is set.
VIMS/DRIMS Operation Manual	The outline of DRIMS (Dynamic Response Intelligent Monitoring System: hereinafter DRIMS), which simply measures IRI with a vehicle-mounted measuring instrument, describes the setup of the system and how to install and calibrate the measuring instrument. The method for displaying the measurement data on Google Maps and troubleshooting when using the system are also described.
PBC Operational Guidelines	Daily maintenance work on roads (DBST and others) other than asphalt pavement roads is outsourced by the PBC. The existing regulations on the operation method have been revised. A major revision point is that the contracts from the PBC are limited to the road surface only, and other types of construction were revised to the conventional specification method rather than the PBC contracts, and the recording style, such as inspections, was unified. In addition, guidelines regarding the evaluation of existing inspection results, summaries of the current situations based on the evaluation results, prioritization of maintenance and management plans, selection of repair methods and calculation of construction costs, budget requirements for road maintenance and management plans, implementation of road maintenance and management plans, feedback from road maintenance management are described along with examples of their application. These guidelines are to be used in subsequent projects of the WB and ADB.
Vehicle Weight Gauges and Data Operation Manuals	At the vehicle weight measuring stations, data about the operation procedure of the vehicle and the record item to be weighed, the operation procedure of the simple type of vehicle meter and the fixed type of vehicle meter, the correspondence to the overloaded vehicle, and the jurisdiction of the weighing staff is compiled. In addition, an outline of the measurement data management system and the operation procedure are also described.
MAC (Maintenance Activity Code) Revision	The work code for each item shown when outsourcing maintenance work is shown. It was established in 1999 and revised by the MPWT in 2002, but the contents were only a description of the code number, work name, and work contents. In this project, work procedures and methods, material regulations, inspection methods, and payment methods were established and revised.

The manual prepared in the technical cooperation project provides basic concepts to government officials and contractors to enable them to conduct the cycle of inspections, documentation, maintenance and repair plan, and implementation of maintenance and repair of roads and structures.

As for the improvement and introduction of maintenance management systems such as RMS/PRoMMS and DRIMS, they are positioned as tools for both organizing the data obtained based on the above concepts and formulating effective maintenance and repair plans. In particular, the RMS/PRoMMS system, developed with the support of the WB and SIDA, is being used with improvements implemented in this project, and the feedback to the inspections and repair manuals is needed. It is difficult to improve the system and manuals so that they can be used easily while making use of the existing system and to develop a maintenance management plan using the system. Rather than introducing completely new manuals and systems, it was necessary to build more effective manuals and systems out of those that had been used to date.

3.6 Construction, Maintenance and Management Capabilities, Technical Standards

(1) Pavement

1) In the rehabilitation of National Route 9 done through a Yen loan around the year 2000, a Japanese company investigated and secured a quarry, and the crushed stone plant was used while remodeling the crushed stone plant produced in Thailand. Around 2012, a plant was installed by a local supplier and quarrying was started. There is a shattered stone shop in the market because there is a Chinese trader in the capital. The provinces are doing small scale jobs using these plants. Dredging river gravel is used near the Mekong River in Savannacket Province.
2) The pavement plant was imported from Japan (Tanaka Iron Works) at the time of the rehabilitation of National Route 9. Around 2012, a temporary plant made by Steco of Korea was imported. Asphalt was imported from Thailand in 2000 and around 2012.

(2) Bridges

1) Repair of bridge damage is mainly done as defect filling and floor slab repair, and mortar for cross-sectional defects, resin materials, steel can be procured such as a special coating. Carbon fiber materials may be used for reinforcement.
2) The quality control of concrete is only slumps and temperatures in ready mixed concrete, and the amount of air is not controlled because there is no freezing and thawing in Southeast Asia. Strength tests are conducted.

(3) Earthworks and Others

1) Awareness to improve the road is low and damage such as drainage failure, overload, and erosion is advancing.
2) The consignment of maintenance and management is symptomatically conducting repair of broken parts, but the progress of road damage is considered to remain unchanged if the overloaded vehicle problem is not solved.
3) Since 2001, the daily maintenance of roadside cleaning, mowing, and waterway cleaning has been conducted on a community basis by neighboring residents through small contractors along the roadside by the DPWT's Labor-Based Maintenance (LBM) program in each province. Although the contract form varies depending on the province, it is about one contract every 10 km, and the contract amount is about 2,000 dollars per year for 10 km. If construction is necessary, contractors will conduct repair work and the cost will be paid according to the volume.
4) One of the major problems is that overloaded vehicles park on the shoulder and the drains break. The design shaft weight is eleven tons, but there are cars loaded with two hundred tons, and there

are vehicles with an axis weight of about fifteen tons. The design is based on AASHTO with an as five cm^2 layer, and the design axis weight was nine tons until around 2006, but now the design axis weight is eleven tons.

3.7 Road AM Maturity Level

3.7.1 How to Conduct Maturity Evaluation

The maturity evaluation was conducted by web interviews with the participants and schedule shown in Table 3.7. The evaluation form was distributed in advance and the grading method was explained during the kick-off meeting. In the hearing, participants were asked to explain the reasons and background behind the low and high items that they graded. In addition, if the other party offered to revise the grade point during the hearing, the revision was made on the spot.

Table 3.7 Content of the Maturity Evaluation Hearing

Item	Date	Attendance	Contents
JICA Kick-off Meeting	5/13		Explanation of purpose
DOR Kick-off Meeting	7/1	MPWT/DOR Deputy Sysouphanh CHANSAVAT MPWT/DOR Road Management Division Deputy Lamphoun KHOUNPHAKDY MPWT/DOR Business Monitoring Division Deputy Souksakhone SOUTANNOUVONG MPWT/DOR Technology and Environment Division Engineer Sengsoulin PASERT MPWT/DOR Road Management DivisionEngineer Phouvisay VONGSAY MPWT/DOR Road Management Division Engineer Vannalom THAMMAVONGSA	Explanation of purpose, hearing date and time setting
Pavement, Earthworks	7/9	MPWT/DOR Road Management Division Deputy Lamphoun KHOUNPHAKDY MPWT/DOR Business Monitoring Division Deputy Souksakhone SOUTANNOUVONG MPWT/DOR Technology and Environment Division Engineer Sengsoulin PASERT MPWT/DOR Road Management Division Engineer Phouvisay VONGSAY MPWT/DOR Khamphout	Evaluation sheet scoring
Bridges, Monitoring/Organization	7/2	MPWT/DOR Road Management Division Deputy Lamphoun KHOUNPHAKDY MPWT/DOR Road Management Division Engineer Phouvisay VONGSAY	Evaluation sheet scoring
Draft Evaluation, Support Proposals	8/6	MPWT/DOR Road Management Division Deputy Lamphoun KHOUNPHAKDY MPWT/DOR Business Monitoring Division Deputy Souksakhone SOUTANNOUVONG MPWT/DOR Road Management Division Engineer Phouvisay VONGSAY	Support plan Presentation

Laos Bridge Technical Cooperation Project	7/5	Project Manager Takahashi/International Development Center Co., Ltd. (IDCJ)	Hearings on Road AM
Engaged in the Rehabilitation of Laos National Route 9	8/23	Kamimura/Obayashi Corporation Asia Branch	Hearing on the actual construction of local contractors, etc.

3.7.2 Maturity Evaluation Results

The major items radar chart (evaluation scores) is shown in Figure 3.3.

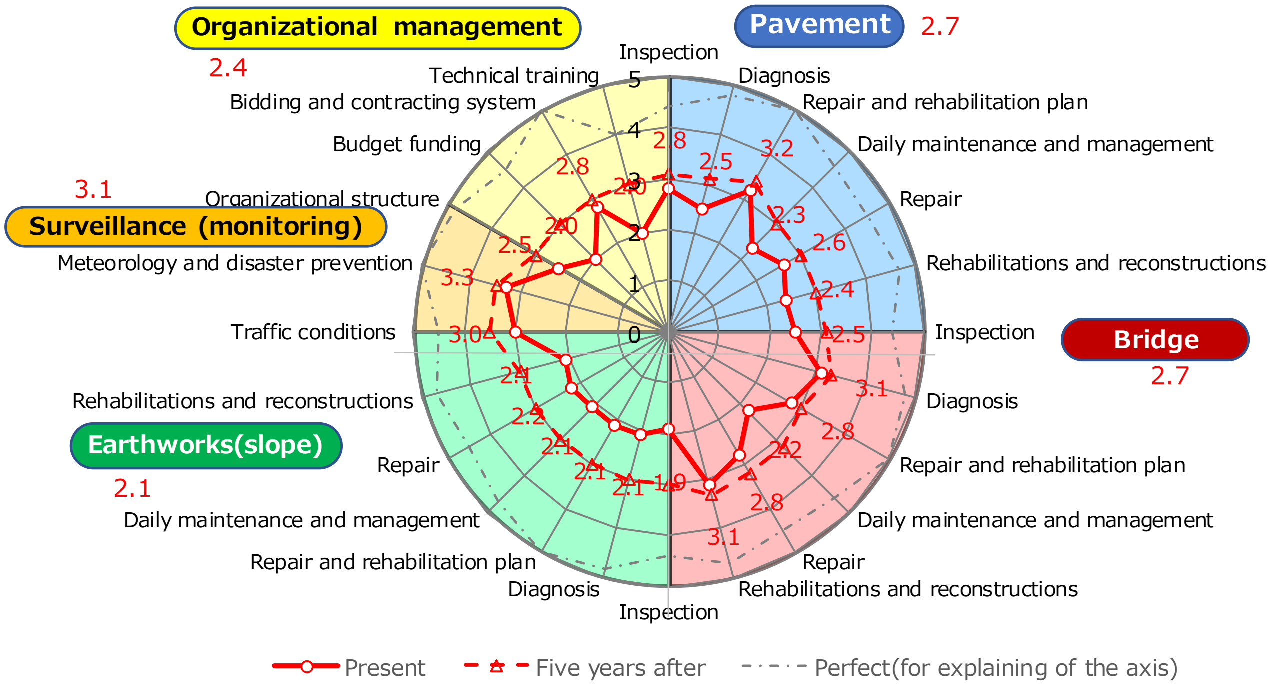


Figure 3.3 Radar Chart of Major Items (Level)

(1) Overall Evaluation

1) The level of pavement and bridge is 2.7, which is close to the evaluation target of level 3 of the JICA technical cooperation project.
2) The level of earthworks is rated 2.1, which is quite low due to general challenges. It is necessary to improve from the basics of technology and raise the level of technology.
3) The level of "Surveillance (Monitoring)" is 3.1, which achieves the evaluation target of the JICA technical cooperation project.
4) The level of "Organizational Management" is low at 2.4. This is due to internal challenges such as securing budget and other factors.

(2) Pavement (Evaluation Level 2.7)

1) The level of "Inspection" is 2.8. This is since the IRI measurement equipment procured by JICA is in operation and requires continuous operational training.
2) The level of "Repair and Rehabilitation planning" is high at 3.2. This is since a Pavement Management System (PMS) is in operation.

3) The “Daily Maintenance” level is 2.3 and “Diagnosis” level is 2.5, which is low. This is due to factors such as inadequate operation of equipment and manuals.
4) “Repair” is at the low level of2.6, while “Rehabilitation and Reconstruction” are at the low level of 2.4. This is due to the lack of equipment and diagnostic techniques in the field, which affects the deficient performance of the DOR and DPWT.

(3) Bridges (Evaluation Level 2.7)

1) The level of “Diagnosis and Rehabilitation/Reconstruction” is at the elevated level 3.1. The “Daily Maintenance” is low at level2.2. This is due to factors such as the low level of technology of the contractors being outsourced.
2) “Inspection” is as low as level 2.5. This is since although there is an inspection manual, daily inspections are not being carried out.
3) The level for “Repair and Rehabilitation plan” is low at 2.8. This is since although the BMS is in operation, repairs are symptomatic and not systematic.

(4) Earthworks (Slopes) (Evaluation Level 2.1)

1) “Maintenance Manual” level is significantly low at1.9. This is since the system is not operated under the DOR and DPWT, inspections are irregular, and daily inspections are not carried out. In addition, the cleaning and mowing of waterways is inadequate.
2) “Repair” is at a low level of 2.2, while “Rehabilitation and Reconstruction” is at the low level of 2.1. This is since the repair is symptomatic and not planned, some of the necessary materials and equipment are not available, quality control of repair and implementation of reconstruction and reconstruction are partial, and emergency restoration for failures, etc. is minimal.

(5) Surveillance (Monitoring) (Evaluation Level 3.1)

1) “Traffic Monitoring “is at level 3, and “Meteorological and Disaster Prevention Monitoring” is at level 3.3, so basic data has been obtained.

(6) Organizational Management (Evaluation Level 2.4)

1) “Organizational Structure” is at level 2.5, and “Bidding and Contracting System” is at 2.8. This is due to the challenges in securing personnel and budget.

3.8 Current Status and Challenges of Road AM

3.8.1 Current Status and Challenges of Pavement AM

(1) Inspection and Diagnosis

1) National highway inspections are conducted irregularly by the DOR on a daily and regular basis with more than 50% of the road under their jurisdictional.
2) All paved national highways are visually inspected, and periodic inspections are conducted each year to measure IRIs. Measuring instruments for IRIs (DRIMS) were procured by JICA, and the DOR continues to educate their staff on how to use them, but Japan's support is still needed from

both a hardware and software standpoint for DRIMS operation.
3) The DOR and DPWT technicians are not at an elevated level. Since there are regular relocations, continuous education is necessary, especially for young engineers.
4) Education on diagnosis is conducted in Lao, but diagnostic guidelines are in English, and efforts are underway to translate English into Lao. In addition, diagnostic guidelines need further improvement as they are not sufficiently comprehensive and lack up-to-date information.

(2) Repair and Rehabilitation Plan

1) The Pavement Management System (PMS) keeps, and updates records of periodic inspections, diagnosis, repair, and reconstruction, but record keeping is limited for unpaved and rural roads. Also, all the data has not been updated.
2) 2-to-3-year repair and reconstruction plans are in place for more than 50% of the routes under their jurisdiction. In rural areas, there are many unpaved roads, and the deterioration mechanisms are unknown, making it difficult to formulate plans.

(3) Daily Maintenance Management

1) Daily maintenance is outsourced with support from the WB and ADB but may be conducted by the DPWT in rural areas. The DPWT's maintenance level is not high.
2) In Laos, LBM (Labor Based Maintenance) is operated on paved national roads. Since the national highway has a DBST of 80% or more and the deterioration speed of the pavement is fast, it exceeds the scope of LBM, so daily maintenance and management related to pavement are not included in the scope except for cleaning.
3) Although daily maintenance and management of pavements are outsourced to contractors, large-scale damage is given priority, so preventive daily maintenance and management in a timely manner is not possible.

(4) Repair, Rehabilitation, and Reconstruction

1) DBST and unpaved pavement, which make up the majority of pavement in Laos, are vulnerable to water.
2) Due to budget constraints, sufficient repair and rehabilitation have not been made.
3) Repair and rehabilitation/reconstruction will be outsourced. About quality control, the private companies that receive the orders are provided with training and development programs, and the technical level of the engineers is improving, but that of the workers is exceptionally low.

3.8.2 Current Status and Challenges of Bridge AM

(1) Inspection and Diagnosis

1) Inspection manuals exist for both daily and periodic inspections, and their contents are sufficient, and the same ones are applied to both national and prefectural roads.
2) Daily inspections are not conducted, but more than 50% of the bridges on the jurisdictional routes are subject to daily inspections by the DOR and DPWT. If any fundamental problem arises, a

consultant will be hired to conduct a detailed investigation. 3) Diagnosis by the DOR and DPWT is the basic principle. If the engineer determines that a special study is needed, a consultant will be commissioned to conduct a detailed study. There is a diagnostic manual.

(2) Repair and Rehabilitation Plan

1) The Bridge Management System (BMS) maintains, and updates records of periodic inspections, diagnostics, repairs, and rehabilitations. 2) Although the need to introduce preventive maintenance is recognized, response to damaged areas due to budget constraints is symptomatic therapy, and repair and rehabilitation plans have been formulated only for the following fiscal year.

(3) Daily Maintenance Management

1) All daily maintenance is outsourced, but the contractor's capacity is lower than the required level and they are not fully equipped, so the qualification requirements are set low.

(4) Repair, Rehabilitation, and Reconstruction

1) All repairs, rehabilitation and reconstruction are outsourced. Quality standards are in place and all processes are supervised, but the application of quality standards is limited.

3.8.3 Current Status and Challenges of Earthworks (Slopes) AM

(1) Inspection and Diagnosis

1) Inspections by the DOR and DPWT, both daily and periodic, are outsourced and conducted on an irregular basis on less than 50% of the road length under their jurisdiction. Diagnosis will also be outsourced. 2) The DOR and DPWT do not have engineers who are familiar with earthworks. The technical level of the inspectors and the inspection equipment are not sufficient, and specialized training for inspectors is needed. There is no daily inspection, but a manual for periodic inspection and diagnosis will be partially developed. 3) Education on diagnosis is provided in Lao, but diagnostic guidelines are in English, and efforts are underway to translate English into Lao. In addition, the diagnostic guidelines need to be updated because they are not sufficiently comprehensive and lack the latest information.

(2) Repair and Rehabilitation Plan

1) Lack of data on slope and geological surveys makes it impossible to determine priorities for slope countermeasures. 2) Although it is recognized that preventive maintenance should be introduced, response to damaged areas due to budget constraints has become symptomatic therapy, and repair and rehabilitation plans have been formulated only for the following fiscal year.

(3) Daily Maintenance Management

1)	Everything is outsourced, but the level of technology is not high. Mowing and cleaning of waterways and signs will be conducted on the jurisdictional routes, some on an irregular basis.

(4) Repair, Rehabilitation, and Reconstruction

1)	All work is outsourced, but quality control is limited (only materials and finished form). In addition, landslide prevention, which requires a large amount of money, is given a low priority as the budget is allocated disproportionately to new construction projects.
2)	Standard slope countermeasures are only basic, and the number of contractors for advanced technologies such as earth anchors is limited.
3)	The repair (design) manual is partial and incomplete. There is a lack of experts on slope disaster prevention.

(5) Training and Research

1)	There is no program to educate technicians. The DOR and DPWT need to be educated. In addition, one Laotian student on slope research has been dispatched to a Japanese university, but there is a desire to dispatch more than one.

3.8.4 Current Status and Challenges of Monitoring and Organizational Management AM

(1) Surveillance (Monitoring)

1)	Traffic monitoring is conducted by human observation at irregular frequencies every two to three years on road lengths of less than 50% on the jurisdictional routes.
2)	Monitoring of precipitation, temperature, and wind is obtained from observations made by other provinces, as needed, and covers more than 50% of the road length on the jurisdictional routes. Monitoring results are recorded, shared, and updated.

(2) Organizational Management

1)	There are 5-, 10-, and 20-year goals, and budgets are planned for 2 to 3 years, but budget allocations are skewed due to financial constraints. In addition, delays in payment have occurred in some cases for contracts that have already been signed.
2)	Internal audits are irregular, staffing for Road AM is inadequate, and the business execution system is weak.
3)	Although there are training facilities for human resource development, both the planning and content of the training are insufficient.

3.8.5 Issues Requiring Research and Development

Among the issues extracted through the Road AM evaluations, the issues that require research and development of repair technology, long life technology, and inspection technology are shown in Table 3.8.

Table 3.9 and Table 3.10 also provide draft research plans and university candidates for conducting research at Japanese universities.

Table 3.8 Issues Requiring Research and Development (Laos)

	Target Issues	Remarks
Pavement	Pavement AM based on preventive maintenance	DBST paved roads and dirt roads, which make up the majority of roads Laos, have a fast road surface degradation speed, making it difficult to formulate preventive maintenance and repair plans that require diagnosis.
Bridge	Technical cooperation project in progress	Hokkaido University and Nagasaki University accept international students
Earthworks	Measures to stabilize slopes	No slope or geological survey data, no experts on slope countermeasures

Table 3.9 Draft Research Plans and University Candidates for Extracted Subjects (Pavement)

<table>
<tr><td>Subject</td><td colspan="2">AM based on the deterioration speed and repair frequency of pavement</td></tr>
<tr><td>Background and Necessity</td><td colspan="2">The national highways in Laos have a fast pavement deterioration rate, because 80% of DBST roads suffer from rampant overloading, and preventive road maintenance that requires diagnosis is not possible. In addition, in rural areas, there are many unpaved roads, and the deterioration mechanism is unknown, making it difficult to formulate a repair plan. Therefore, there are many symptomatic repairs, and there is concern that the maintenance and repair cost will increase further due to the increase in DBST paved roads DBST in the future.
On the other hand, symptomatic repairs are likely to have higher costs for maintenance and repair than preventive maintenance and planned repairs.
Therefore, the repair and rehabilitation plan of the pavement which minimizes the cost related to maintenance and repair with the deterioration of the pavement is required.</td></tr>
<tr><td>Research Plan</td><td colspan="2">Plans to minimize the repair frequency, deterioration mechanism, and life cycle cost related to repair by classifying DBST pavement and unpaved roads scheduled to be paved by DBST in the future by road characteristics such as traffic volume will be studied. The research will be done using technology from Japan for materials and equipment and processing methods necessary for monitoring, and inspections, measurements, analyses, and evaluations will be conducted in collaboration with Japanese and local universities.
Research on pavement durability is conducted by the Ministry of Land, Infrastructure, Transport and Tourism (Civil Engineering Research Institute) and expressway companies (NEXCO Research Institute), and although collaboration with such research institutes is also possible, there are no research institutes related to DBST. For this reason, Japanese universities that are engaged in research from the viewpoint of disaster prevention and pavement materials are candidates.</td></tr>
<tr><td>University Candidates Laos</td><td colspan="2">■National University of Laos
The country's largest national university in Vientiane, founded in 1996.
There is five-year degree with the Faculty of Science, the Faculty of Engineering, the Faculty of Economics and Management, the Faculty of Letters, the Faculty of Education, the Faculty of Architecture, the Faculty of Agriculture, the Faculty of Forestry, the Faculty of Law, the Faculty of Sociology, and the Faculty of Medicine.</td></tr>
<tr><td>University Candidate Japan</td><td>Gifu University</td><td>■Professor. Atsushi Yashima, Associate Professor Koji Kinoshita
JICA international students (master's course) are accepted from Bhutan (investigation into damage to deflective pavement under wet conditions).
In the Department of Social Infrastructure Engineering, the Disaster Prevention Course students conduct research aimed at creating a safe and secure society from both hardware and software standpoints, such as elucidating the mechanism of various disaster occurrences, examining methodologies to reduce damage, and creating systems for residents to cooperate to prepare for disasters.
Prof. Yashima is studying geotechnical engineering, earthquake engineering, geo-disaster prevention engineering, etc.</td></tr>
</table>

	Hokkaido Universit	■Professor. Tatsuya Ishikawa Disaster prevention engineering and geotechnical engineering research on unsaturated geodynamics, freezing, and freezing and thawing behavior of ground, granular roadbed materials, and repetitive behavior are studied.
	Nagaoka University of Technology	■Professor. Osamu Takahashi Structural analysis and structural evaluation of asphalt pavement, evaluation of mechanical characteristics of asphalt pavement materials and development of compound design methods, enhancement of asphalt pavement materials, reuse of industrial waste for various pavement, etc. are studied.

Table 3.10 Draft Research Plans and University Candidates for Extracted Subjects (Earthworks)

Subject	Measures to stabilize slopes in the geology of Laos	
Background and Necessity	The stability of slopes according to geology has been standardized according to the geological classification since the dawn of the construction of the expressway in Japan, and it is the basis of the examination of road design and disaster prevention measures. However, in Laos, with no data on slopes and geology in place, and no standard gradient according to geology, it is difficult to take permanent restoration and prevention measures based on the stability of the slope (making slopes with long life that do not collapse) and appropriate repairs. On the other hand, the stability of slopes depending on the geology does not necessarily suit Laos by the standards formulated in other countries. For this reason, it is necessary to rely on the rule of thumb while conforming to the standard gradient of another country with similar geology, but fundamentally, scientific knowledge on the geology of Laos should be accumulated, and the standard gradient to be applied in Laos should be determined.	
Research Plan	In Laos, the geology necessary for road design and disaster prevention measures will be studied, sorted, and organized into main geological distributions. The standard value will be determined from the soil constant obtained through the test, and the standard gradient will be determined based on the stability analysis of the slope based on this. Research will be provided by Japanese counterparts as necessary for materials, equipment and treatment methods, and on-site surveys, tests, analysis, and evaluations will be conducted in collaboration with Japanese universities, local universities, and junior colleges.	
University Candidates Laos	■National University of Laos The country's largest national university in Vientiane, founded in 1996. There are five-year degrees with the Faculty of Science, the Faculty of Engineering, the Faculty of Economics and Management, the Faculty of Letters, the Faculty of Education, the Faculty of Architecture, the Faculty of Agriculture, the Faculty of Forestry, the Faculty of Law, the Faculty of Sociology, and the Faculty of Medicine.	
University Candidates Japan	Slope stability based on disaster prevention has been studied at many universities, and it is considered that it can be managed if international students can be accepted at universities that can research stability analysis based on soil tests. Standards such as standard gradients have been formulated under the leadership of the Ministry of Land, Infrastructure, Transport and Tourism (Civil Engineering Research Institute) and expressway companies (NEXCO Research Institute), and collaboration with such research institutes is also possible. In addition, in the research from the viewpoint of Road AM and human resource development, domestic universities like Table 3.9 are considered candidates.	
	Yokohama National University	■Associate Professor Tadamu Kikumoto JICA international students (master's program) are accepted from India (Ground contamination by NAPLs). His specialized fields are geotechnical engineering, natural disaster science, and disaster prevention.
	Kyoto University	■Associate Professor Pipatpongsa Thirapong Graduated from The Chulalongkhon University, Thailand, Department of Civil Engineering. From the research of slope stability analysis by numerical geomechanics and granular body models, various research is conducted on subjects such as physical model experiments, ground composition rules, numerical calculation methods, and on-site application, including material property experiments

		aimed at improving accuracy and efficiency improvement to predict the behavior of ground and soil structures. At the same time, through international joint research, adaptable technologies are being developed for solving local problems and utilizing research results for underground energy resource development, regional geotechnical environments, and natural disaster prediction.
	University of Tsukuba	■Professor Wataru Matsushima With the aim of predicting deformation, destruction, or flow phenomena of ground and various granular materials from particle-level mechanics, basic theories are being constructed, various experimental and analytical methods are being developed and applied research is being conducted.

3.9 Support Plan for Establishing Road AM

3.9.1 Support Plan for Pavement AM

The support plan for Pavement AM is summarized in Table 3.11.

Table 3.11 Support Plan for Pavement AM

	Issues	Contents	Support Plan
1	Regularly check the condition of all pavements and determine the damage rank by objective indicators	Continuous education and development of inspectors and diagnostics. Update inspection and diagnostic manuals (addition of the latest knowledge on diagnosis, repair and countermeasures, creation of a translated Lao version).	JICA Technical Cooperation Project (Pavement) Follow-up Dispatch of long-term experts JICA Technical Cooperation Project (Quality)
	Establish a maintenance cycle from inspection and diagnosis to repair		
2	Paved roads spread	Formulate a repair plan based on a road pavement plan of more than 5 years	
	Formulation of a medium-term plan of about 5 years		
3	Repair, rehabilitation, and reconstruction conducted under appropriate repair plan and quality control	Appropriate wastewater treatment and early repairs. Pavement of unpaved roads, pavement of asphalt and concrete. Quality control of asphalt mixtures (construction guidance)	
	Improvement of construction worker skills		

3.9.2 Support Plan for Bridge AM

The support plan for Bridge AM is summarized in Table 3.12.

Table 3.12 Support Plan for Bridge AM

	Issues	Support Plan
1	All bridges are regularly inspected to determine the damage	(JICA Bridge Technical Cooperation Project)

	Issues	Support Plan
	level by objective indicators	
	Establish a maintenance cycle from inspection and diagnosis to repair	
2	Conduct necessary repairs systematically and appropriately	
	Formulation of a medium-term plan of about 5 years	
3	Contractors ensure sufficient technical level	Improvement of daily maintenance and management skills in collaboration with industry, government, and academia.
4	Repairs, rehabilitation, and reconstruction are conducted under appropriate repair plans and quality control	(JICA Bridge Technical Cooperation Project)

3.9.3 Support Plan for Earthworks (Slopes) AM

The support plan for earthworks (slopes) is summarized in Table 3.13.

Table 3.13 Support Plan for Earthworks (Slopes) AM

	Issues	Contents	Support Plan
1	The condition of all slopes is regularly inspected to determine the risk by objective indicators.	Training of earthwork engineers (slope problems and geological surveys). Update inspection and diagnostic manuals (addition of the latest knowledge on diagnosis, repair and countermeasures, creation of a translated Lao version).	JICA Technical Cooperation Project (Earthworks)
	Establish a maintenance cycle from inspection and diagnosis to repair		
2	Prioritize slope countermeasures based on data and risk	Securing slope and geological data (survey). Manual creation for slope countermeasures. Gradual introduction of appropriate slope work according to the topography and geology of the severe slopes. Training of earthwork engineers (slope problems and geological surveys).	
	Formulation of a medium-term plan of about 5 years		
	Implementation of slope disaster prevention measures		
3	Address slope issues appropriately /Stability analysis and countermeasures for slopes	Training of earthwork engineers (slope problems and geological surveys). Collaboration with Japanese universities and research institutes.	JICA Training and invitation, acceptance of international students to Japanese universities

3.9.4 Support Plan for Surveillance (Monitoring) and Organizational Management AM

Table 3.14 Summarizes the support plan for monitoring and organizational management.

Table 3.14 Monitoring and Support Plans for Organizational AM

	Issues	Contents	Support Plan
1	Monitor traffic conditions and traffic on necessary roads	In routes and sections with extremely high traffic volumes or important bridges, appropriate traffic planning and suppression of overloaded vehicles will be attempted by installing observation equipment that can measure vehicle speed and shaft weight at all times.	Available in your home country (in some cases, the JICA technical cooperation projects will be utilized)
	Monitoring of weather and disaster prevention is conducted, and judgments on road closures and traffic regulations are conducted appropriately without delay	By installing weather observation equipment and sharing information that can acquire weather data such as rainfall and wind speed in real time as necessary, a system that can implement active disaster prevention measures can be built.	
2	Appropriate budget allocation for the projects needed	JICA Technical Cooperation Project and Public Investment Plan Management Improvement Project JICA Technical Cooperation Project, Invitation, and Acceptance of Trainees (Long- to Short-Term)	
	Secure the necessary personnel for appropriate and smooth business execution		
3	Continuously educate and train engineers	Establish a training program for human resources development. Promotion of educational programs for the development of engineers in collaboration with industry, government, and academia.	JICA Training and invitation, acceptance of international students to Japanese universities JICA trainees accepted (long-term and short-term)
	Put the necessary knowledge in place with technicians		

3.10 List of Road AM Evaluation Results in Laos

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
1 Pavement	2.7	58.2%	(1) Inspection	2.8	63%	((1)) Inspection system	2.7	53%	<1> System	3.0	60%
									<2> Technical level of inspectors	3	60%
									<3> Use of inspection equipment	2	40%
						((2)) Inspection manual	2.5	61%	<4> Existence of daily inspection manual	3	60%
									<5> Use of daily inspection manual	2	67%
									<6> Existence of periodic inspection manual	3	60%
									<7> Use of periodic inspection manual	2	67%
									<8> Technical level of the manual	2.7	53%
						((3)) Implementation of daily inspections	3.0	69%	<9> Inspection range	3	60%
									<10> Frequency of inspections	2	67%
									<11> Storage and sharing of inspection records	4	80%
						((4)) Implementation of periodic inspections	3.0	69%	<12> Inspection range	3	60%
									<13> Frequency of inspections	2	67%
									<14> Storage and sharing of inspection records	4	80%
			(2) Diagnosis	2.5	54%	((5)) Diagnostic system	2.5	50%	<15> System	3.0	60%
									<16> Technical level of diagnosis	2	40%
						((6)) Diagnostic manual (As, Co, D, EXT)	2.1	51%	<17> Existence of diagnostic manual	2	40%
									<18> Use of diagnostic manual	2	67%
									<19> Technical level of the manual	2.3	47%
						((7)) Diagnosis of soundness (As, Co, D, EXT)	3.0	60%	<20> Investigation of the cause of damage	2	40%
									<21> Ranking of damage level	3	60%
									<22> Storage and sharing of diagnostic records	4	80%
			(3) Repair and rehabilitation plan	3.2	64%	((8)) Pavement assets ledger/DB	4.0	80%	<23> Existence of pavement assets ledger/DB	5	100%
									<24> Use of pavement assets ledger/DB	3	60%
						((9)) Pavement management system	4.0	80%	<25> Existence of pavement management system	5	100%
									<26> Use of pavement management system	3	60%
						((10)) Development of the plan	2.6	52%	<27> Planning	3	60%
									<28> Scope of the plan	3	60%
									<29> Prediction of soundness	2	40%
									<30> Understanding of the cost of repairs and rehabilitation	2	40%
									<31> Preventive maintenance	3	60%
			(4) Daily maintenance and management	2.3	52%	((11)) System for daily maintenance and management	2.5	50%	<32> System	2.5	50%
									<33> Technical level of the person responsible for maintenance management	3	60%
									<34> Operation of maintenance work equipment (pavement)	2	40%
						((12)) Cleaning (road surface)	2.0	40%	<35> Cleaning range	2	40%
									<36> Frequency of cleaning	2	40%
						((13)) Emergency measures	2.3	58%	<37> Management of response to deformation and damage	3	60%
									<38> Small repair of deformations (temporary repair)	2	67%
									<39> Emergency restoration of failures, etc.	2	67%
									<40> Storage and sharing of emergency measure records	2	40%
			(5) Repair	2.6	59%	((14)) Repair system	3.0	60%	<41> System	3.0	60%
									<42> Technical level of repair	3	60%
									<43> Procurement of materials and equipment	3	60%
						((15)) Quality standards (As, Co, D, EXT)	3.0	73%	<44> Existence of quality standards	3	60%
									<45> Application of quality standards	3	100%
									<46> Quality control	3	60%
						((16)) Repair (Design) manual	2.3	55%	<47> Existence of repair (design) manual	2	40%
									<48> Use of repair (design) manual	2	67%
									<49> Technical level of the manual	2.8	57%
						((17)) Implementation of repairs	2.3	52%	<50> Construction planning and process management	3	60%
									<51> Repair (radical repair)	2	67%
									<52> Management of changes	2	40%
									<53> Storage and sharing of repair records	2	40%
			(6) Rehabilitations and reconstructions	2.4	52%	((18)) System for rehabilitations and reconstructions	2.7	50%	<54> System	3.0	60%
									<55> Level of technology for rehabilitations and reconstructions	3	60%
									<56> Procurement of materials and equipment	2	40%
						((19)) Implementation of rehabilitations and reconstructions	2.3	52%	<57> Implementation plan	2	40%
									<58> Rehabilitations and reconstructions	2	67%
									<59> Management of changes	2	40%
									<60> Storage and sharing of records of rehabilitations and reconstructions	3	60%

Figure 3.4 List of Road AM Evaluation Results in Laos【Pavement】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Bridges	2.7	59.1%	(7) Inspection	2.5	57%	((20)) Inspection system	3.0	60%	<61> System	3.0	60%
									<62> Technical level of inspectors	3	60%
									<63> Use of inspection equipment	3	60%
						((21)) Inspection manual	2.6	63%	<64> Existence of daily inspection manual	3	60%
									<65> Use of daily inspection manual	2	67%
									<66> Existence of periodic inspection manual	3	60%
									<67> Periodic inspection manual operation	2	67%
									<68> Technical level of the manual	3.0	60%
						((22)) Implementation of daily inspections	1.0	24%	<69> Inspection range	1	20%
									<70> Frequency of inspections	1	33%
									<71> Storage and sharing of inspection records	1	20%
						((23)) Implementation of periodic inspections	3.3	76%	<72> Inspection range	3	60%
									<73> Frequency of inspections	2	67%
									<74> Storage and sharing of inspection records	5	100%
			(8) Diagnosis	3.1	66%	((24)) Diagnostic system	3.0	60%	<75> System	3.0	60%
									<76> Technical level of diagnosis	3	60%
						((25)) Diagnostic manual (M, Co, EXT)	2.7	62%	<77> Existence of diagnostic manual	3	60%
									<78> Use of diagnostic manual	2	67%
									<79> Technical level of the manual	3.0	60%
						((26)) Diagnosis of soundness(M, Co, EXT)	3.7	73%	<80> Investigation of the cause of damage	3	60%
									<81> Ranking of damage level	3	60%
									<82> Storage and sharing of diagnostic records	5	100%
			(9) Repair and rehabilitation plan	2.8	56%	((27)) Bridge assets ledger/DB	3.0	60%	<83> Existence of bridge assets ledger/DB	3	60%
									<84> Use of bridge assets	3	60%
						((28)) Bridge management system	3.0	60%	<85> Existence of bridge management system	3	60%
									<86> Use of bridge management system	3	60%
						((29)) Development of the plan	2.6	52%	<87> Planning	2	40%
									<88> Scope of the plan	3	60%
									<89> Prediction of soundness	3	60%
									<90> Understanding of the cost of repairs and rehabilitation	3	60%
									<91> Preventive maintenance	2	40%
			(10) Daily maintenance and management	2.2	49%	((30)) System for daily maintenance and management	2.0	40%	<92> System	2.0	40%
									<93> Technical level of the person responsible for maintenance and management	2	40%
									<94> Operation of maintenance and management work equipment (bridges)	2	40%
						((31)) Cleaning (road surface)	2.0	40%	<95> Cleaning range	2	40%
									<96> Frequency of cleaning	2	40%
						((32)) Emergency measures	2.5	60%	<97> Management of response to deformation and damage	2	40%
									<98> Small repair of deformation (temporary repair)	1	33%
									<99> Emergency restoration of failures, etc.	2	67%
									<100> Storage and sharing of emergency measure records	5	100%
			(11) Repair	2.8	63%	((33)) Repair system	3.0	60%	<101> System	3.0	60%
									<102> Technical level of repair	3	60%
									<103> Procurement of materials and equipment	3	60%
						((34)) Quality standards (M, Co, EXT)	2.7	62%	<104> Existence of quality standards	3	60%
									<105> Application of quality standards	2	67%
									<106> Quality control	3	60%
						((35)) Repair (Design) manual	2.6	62%	<107> Existence of repair (design) manuals	3	60%
									<108> Use of repair (design) manual	2	67%
									<109> Technical level of the manual	2.9	60%
						((36)) Implementation of repairs	3.0	67%	<110> Repair planning and process management	2	40%
									<111> Repair (radical repair)	2	67%
									<112> Management of changes	3	60%
									<113> Storage and sharing of repair records	5	100%
			(12) Rehabilitations and reconstructions	3.1	67%	((37)) System for rehabilitations and reconstructions	3.0	60%	<114> System	3.0	60%
									<115> Level of technology for rehabilitations and reconstructions	3	60%
									<116> Procurement of materials and equipment	3	60%
						((38)) Implementation of rehabilitations and reconstructions	3.3	72%	<117> Implementation plan	3	60%
									<118> Rehabilitation and reconstruction	2	67%
									<119> Management of changes	3	60%
									<120> Storage and sharing of records of rehabilitations and reconstructions	5	100%

Figure 3.5 List of Road AM Evaluation Results in Laos【Bridges】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
3 Earthworks(Slope)	2.1	46.0%	(13) Inspection	1.9	45%	((39)) Inspection system	2.3	47%	<121> System	3.0	60%
									<122> Technical level of inspectors	2	40%
									<123> Operation of inspection equipment	2	40%
						((40)) Inspection manual	1.5	39%	<124> Existence of daily inspection manual	1	20%
									<125> Use of daily inspection manual	1	33%
									<126> Existence of periodic inspection manual	2	40%
									<127> Use of periodic inspection manual	2	67%
									<128> Technical level of the manual	1.7	33%
						((41)) implementation of daily inspections	2.0	49%	<129> Inspection range	2	40%
									<130> Frequency of inspections	2	67%
									<131> Storage and sharing of inspection records	2	40%
						((42)) Implementation of periodic inspections	2.0	49%	<132> Inspection range	2	40%
									<133> Frequency of inspections	2	67%
									<134> Storage and sharing of inspection records	2	40%
			(14) Diagnosis	2.1	46%	((43)) Diagnostic system	2.5	50%	<135> System	3.0	60%
									<136> Technical level of diagnosis	2	40%
						((44)) Diagnostic manual (Slope, utility and drainage structures, retaining walls)	2.0	49%	<137> Existence of diagnostic manual	2	40%
									<138> Use of diagnostic manual	2	67%
									<139> Technical level of the manual	2.0	40%
						((45)) Diagnosis of soundness (Slope, utility and drainage structures, retaining walls)	2.0	40%	<140> Investigation of the cause of damage	2	40%
									<141> Ranking of damage level	2	40%
									<142> Storage and sharing of diagnostic records	2	40%
			(15) Repair and rehabilitation plan	2.1	43%	((46)) Earthwork assets ledger/DB	2.5	50%	<143> Existence of earthwork assets ledger/DB	2	40%
									<144> Use of earthwork assets ledger/DB	3	60%
						((47)) Development of the plan	2.0	40%	<145> Planning	2	40%
									<146> Scope of the plan	2	40%
									<147> Prediction of soundness	2	40%
									<148> Understanding of the cost of repairs and rehabilitations	2	40%
									<149> Preventive maintenance	2	40%
			(16) Daily maintenance and management	2.1	45%	((48)) System for daily maintenance and management	2.3	45%	<150> System	3.0	60%
									<151> Technical level of the person responsible for maintenance and management	2	40%
									<152> Operation of maintenance and management work equipment (earthworks)	2	40%
									<153> Operation of maintenance work equipment (accessories)	2	40%
						((49)) Mowing	2.0	40%	<154> Mowing area	2	40%
									<155> Frequency of mowing	2	40%
						((50)) Cleaning (waterways)	2.0	40%	<156> Cleaning range	2	40%
									<157> Frequency of cleaning	2	40%
						((51)) Cleaning (signs)	2.0	40%	<158> Cleaning range	2	40%
									<159> Frequency of cleaning	2	40%
						((52)) Emergency measures	2.0	53%	<160> Management of response to deformation and damage	2	40%
									<161> Small repair of deformation (temporary repair)	2	67%
									<162> Emergency restoration of failures, etc.	2	67%
									<163> Storage and sharing of emergency measure records	2	40%
			(17) Repair	2.2	50%	((53)) Repair system	2.3	47%	<164> System	3.0	60%
									<165> Technical level of repair	2	40%
									<166> Procurement of materials and equipment	2	40%
						((54)) Quality standards(Slope, retaining wall, drainage structure)	2.3	56%	<167> Existence of quality standards	3	60%
									<168> Application of quality standards	2	67%
									<169> Quality control	2	40%
						((55)) Repair (Design) manual	2.0	50%	<170> Existence of repair (design) manuals	2	40%
									<171> Use of repair (design) manual	2	67%
									<172> Technical level of the manual	2.0	43%
						((56)) Implementation of repairs	2.0	47%	<173> Construction planning and process management	2	40%
									<174> Repair (radical repair)	2	67%
									<175> Management of changes	2	40%
									<176> Storage and sharing of repair records	2	40%
			(18) Rehabilitations and reconstructions	2.1	47%	((57)) System for rehabilitation and reconstruction	2.3	47%	<177> System	3.0	60%
									<178> Level of technology for rehabilitations and reconstructions	2	40%
									<179> Procurement of materials and equipment	2	40%
						((58)) Implementation of rehabilitations and reconstructions	2.0	47%	<180> Implementation plan	2	40%
									<181> Rehabilitations and reconstructions	2	67%
									<182> Management of changes	2	40%
									<183> Storage and sharing of records of rehabilitations and reconstructions	2	40%

Figure 3.6 List of Road AM Evaluation Results in Laos【Earthworks (Slopes)】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
4 Surveillance (monitoring)	3.1	65.8%	(19) Traffic conditions	3.0	67%	((59)) Traffic volume	3.0	67%	<184> Monitoring range	2	40%
									<185> Monitoring frequency	2	67%
									<186> Monitoring sites	3	60%
									<187> Information sharing and utilization of monitoring results	5	100%
			(20) Meteorology and disaster prevention	3.3	65%	((60)) Precipitation, temperature, wind	3.3	65%	<188> Monitoring range	3	60%
									<189> Monitoring frequency	3	60%
									<190> Monitoring sites	2	40%
									<191> Information sharing and utilization of monitoring results	5	100%
5 Organizational management	2.4	52.4%	(21) Organizational structure	2.5	52%	((61)) Asset management cycle	2.7	53%	<192> Setting management goals	3	60%
									<193> Conducting internal audits	2	40%
									<194> Implementation of management review	3	60%
						((62)) Organization	2.5	50%	<195> Role-sharing	3	60%
									<196> Manpower allocation	2	40%
						((63)) Control	2.7	67%	<197> Commitment from the top	3	100%
									<198> Influence of the organization	2	40%
									<199> Motivation and ability of counterpart	3	60%
						((64)) Business continuity	2.0	40%	<200> Responding to accidents	3	60%
									<201> Responding to rainfall	2	40%
									<202> Responding to earthquakes	1	20%
						((65)) Operational support facilities	2.5	50%	<203> Training facility	3	60%
									<204> Communication facilities	2	40%
			(22) Budget funding	2.0	47%	((66)) Budget	2.5	50%	<205> Budget planning	3	60%
									<206> Budgetary allocation	2	40%
						((67)) Raising funds	1.5	43%	<207> Short-term financing	2	67%
									<208> Long-term financing	1	20%
			(23) Bidding and contracting system	2.8	56%	((68)) Bidding and contracting system	2.8	56%	<209> Cost estimation standard	2	40%
									<210> Prevention of collusion	3	60%
									<211> Contract method	3	60%
									<212> Procurement process	3	60%
									<213> Contract change	3	60%
			(24) Technical training	2.0	53%	((69)) Pavement training	2.0	53%	<214> Training plan	2	67%
									<215> Contents of training	2	40%
						((70)) Bridge training	2.0	53%	<216> Training plan	2	67%
									<217> Contents of training	2	40%
						((71)) Earthwork training	2.0	53%	<218> Training plan	2	67%
									<219> Contents of training	2	40%

Figure 3.7 List of Road AM Evaluation Results in Laos【Surveillance (Monitoring), Organizational Management】

Chap.4 Current Status, Issues, and Support Plan for Road AM in Bhutan

4.1 Target of the Chapter

To investigate the background of the project to strengthen the maintenance capacity of roads and bridges in Bhutan, the outline of road maintenance, the outline of the technical cooperation projects, and the construction, maintenance capacity and technology level. In addition, using the Road AM evaluation sheet, the level of Road AM maturity in Bhutan will be confirmed through interviews with the technical cooperation project team and their counterparts. After, a support plan for Road AM establishment is formulated through identifying the issues.

4.2 Overview

JICA is implementing the Technical Cooperation Project for Capacity Development in Construction and Maintenance of Bridges with a construction period from August 2016 to June 2022 with the aim of improving the technical capacity of the Department of Roads, Ministry of Works and Human Settlement (DoR) and enable them to carry out construction supervision and maintenance of bridges by themselves. Moreover, to strengthen the capacity for the development and maintenance of sustainable countermeasure works for road slope disaster prevention, the Project for Capacity Development on Countermeasures of Slope Disaster on Roads is being implemented with a construction period from December 2018 to January 2023. As a result, the DoR's technical capacity has improved through the acquisition of basic knowledge on bridges and slopes and the preparation of technical manuals for maintenance and management.

In this survey, online interviews were conducted 6 times with the DoR and 7 times with Japanese companies engaged in the technical cooperation projects in Bhutan. These were used to understand the general situation of the DoR's construction, maintenance capability and technical level, and also to evaluate the maturity of Road AM at the DoR. Based on the results of this study, the current status and issues of asset management for pavement, bridges, and earthworks (slopes) in Bhutan were identified and organized, and a support plan for establishing Road AM was formulated and proposed.

As for pavement, although the damage status of road surfaces is ranked, there is no inspection/diagnosis manual and the rationale is not clear. Currently, ADB is providing support for the evaluation of road surface conditions, and these are expected to be improved.

As for bridges, fundamental manuals have been developed through the ongoing JICA technical cooperation project. However, there are still some issues that need to be addressed, such as the steady implementation and recording of periodic inspections and diagnois, medium- to long-term planning, on-site development of repair methods, and training of engineers and technicians. These issues are expected to be improved by enhancing the technical capabilities as technology transfer progresses.

As for earthworks (slopes), there are overall issues, such as mainly corrective action after the incidents occur, and it is necessary to improve from the technical basis and enhance the technical capability. For this reason, it is considered necessary to introduce new JICA technical cooperation projects.

4.3 Background of the Technical Cooperation Project

Most of Bhutan (land area 38,394㎢: about 90% of Kyushu) is mountainous, and the most important means of transportation and traffic is road transportation. The Ministry of Works and Human Settlement (hereinafter referred to as MoWHS) formulated the Road Sector Master Plan in 2006, which calls for the expansion and widening of the road network, including national and provincial roads, rehabilitation and improvement of feeder roads, maintenance and repair of bridges, and replacement of bridges over a period of 20 years until 2027.

Among these, the ministry is prioritizing the widening and improvement of major national highways. However, of the bridges maintained by the Department of Roads under MoWHS (hereinafter referred to as DoR), 45% are emergency Bailey bridges, which have limited load carrying capacity and width. In addition, most of the bridges built in the 1970s and 1980s have exceeded their service life and are used in hazardous conditions with reduced load carrying capacity. In addition, although the service life of permanent bridges is generally estimated to be about 80 to 100 years, most of them break down after 40 to 50 years of service due to lack of proper maintenance and inspections. In light of these issues, the Bhutanese government requested for Japan to undertake a technical cooperation project called the "Project for Capacity Development in Construction and Maintenance of Bridges" to strengthen the capacity of bridge construction quality management and bridge maintenance management in order to ensure the safety of bridges.

In addition, since most of Bhutan's roads pass through steep slopes, slope collapses occur frequently during the monsoon season, interfering with the shipment of crops and the movement of people. Although the DoR has taken slope countermeasures by combining revegetation and reinforcement, it is difficult to carry out sufficient slope countermeasures due to lack of technology and experience, and slope disaster prevention measures are urgently needed.

In light of these issues, the Bhutanese government requested for Japan to undertake a technical cooperation project called the "Project for Master Plan Study on Road Slope Management" (July 2014 to March 2017) for technical cooperation to strengthen the capacity of the DoR to identify areas that require slope countermeasures and subsequently implement countermeasures. Based on the results of the project, the Bhutanese government requested for Japan to implement the "The Project for Capacity Development on Countermeasures of Slope Disaster on Roads" (December 2018 to January 2023), which aims to support capacity enhancement for the development and maintenance of road slope countermeasure works.

4.4 Overview of Road Maintenance in Bhutan

4.4.1 Road Maintenance and Management Extension

Figure 4.1 shows a location map of the major roads in Bhutan. The southern east-west corridor is currently under construction, and at present, the only national road connecting the east and west is Route 1.

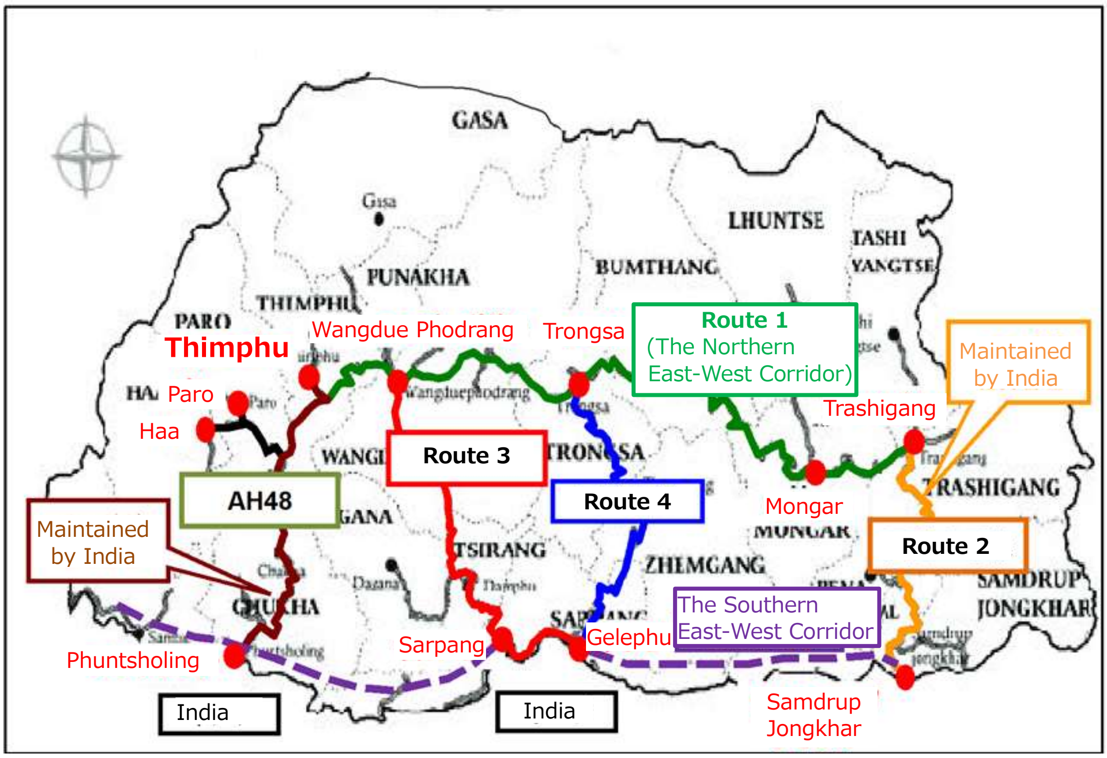


Figure 4.1 Location Map of Major Arterial Roads[14]

As shown in Table 4.1 and Table 4.2, the total length of roads in Bhutan, including agricultural roads, is about 18,000 km. The paving rate of national roads is 87%.

Table 4.1 Road Length by Road Type/Road Administrator (2019)[15]

Unit: km

	DoR	Department of Agriculture	Prefecture	City	Government of India	Total
Expressway				6.2		6.2
Trunk-necked national highway	1,268.7				519.5	1,788.2
Semi-trailer National Highway	906.7				106.0	1,012.7
Access Road	382.7		1,286.2			1,668.9
Prefectural Road			2,115.7			2,115.7
Farm Road		11,196.2	157.8			11,354.0
Urban Road			88.8	328.4		417.1
Total	2,558.1	11,196.2	3,648.3	334.6	625.5	18,362.7

14 Bhutan National Highway Route 4 Replacement Plan Preparatory Survey.
15 Ministry of Public Works and Settlement [2019], ANNUAL INFORMATION BULLETIN 2019.

Table 4.2 Percentage of National Roads that are Paved (2019)[16]

	Trunk-necked National Highway	Semi-trailer National Highway	National Road Total
Pavement Length (km)	1,228.6	668.0	1,896.6
Unpaved Extension (km)	40.1	238.0	278.1
Total	1,268.7	906.4	2,174.7
Pavement %	97%	74%	87%

Table 4.3 shows the bridges managed by the DoR as of 2015, by type. About half of all bridges are Bailey bridges, and the ratio of steel bridges is high.
The ratio of RC bridges is about 30%, and PC bridges are also managed slightly. According to the hearing, the number of bridges under the jurisdiction of the DoR is 235 as of June 2021 due to the transfer of management of some bridges to local governments.

Table 4.3 Number of Bridges Managed by the DoR (October 2015)[17]

RC	PC	Metal	Bailey	Other	Total
79	9	33	136	15	272

4.4.2 Organizational Structure of the DoR

The Ministry of Public Works and Resettlement (MoWHS) is responsible for road administration, and the implementing agency is the Department of Roads (DoR) within the Ministry. The DoR has a Bridge Department, Design Department, Construction Department, Maintenance Department and nine regional offices with a total of 429 staff as of 2019, of which 102 are women. The organizational chart of the Ministry of Public Works and Resettlement is shown in Figure 4.2.

16 Ministry of Public Works and Settlement [2019], ANNUAL INFORMATION BULLETIN 2019.
17 JICA [2016], Bhutan National Bridge Construction Supervision and Maintenance Capacity Improvement Project Business Plan.

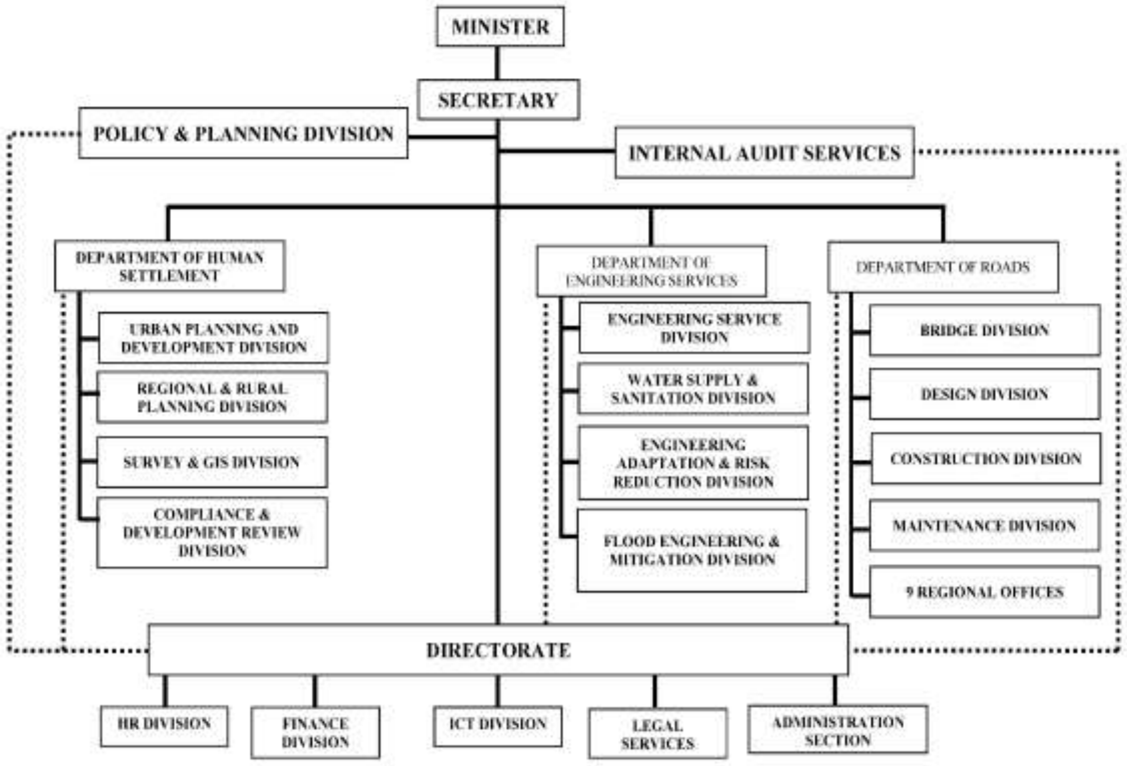


Figure 4.2 Organizational Chart of the Ministry of Public Works and Resettlement[18]

Figure 4.3 shows the DoR organizational chart and Figure 4.4 shows the regional office organization. The office has about 25 to 30 staff members, who are mainly involved in road maintenance and management, and manage maintenance work by conducting regular road inspections and formulating annual maintenance management plans. In addition, each office has one chief engineer, one executive engineer in charge of construction, one executive engineer in charge of maintenance, and one engineer specializing in bridges. The bridge specialist engineers are involved in all bridge-related work and also provide guidance to young engineers.

[18] Ministry of Public Works and Settlement [2019], ANNUAL INFORMATION BULLETIN 2019.

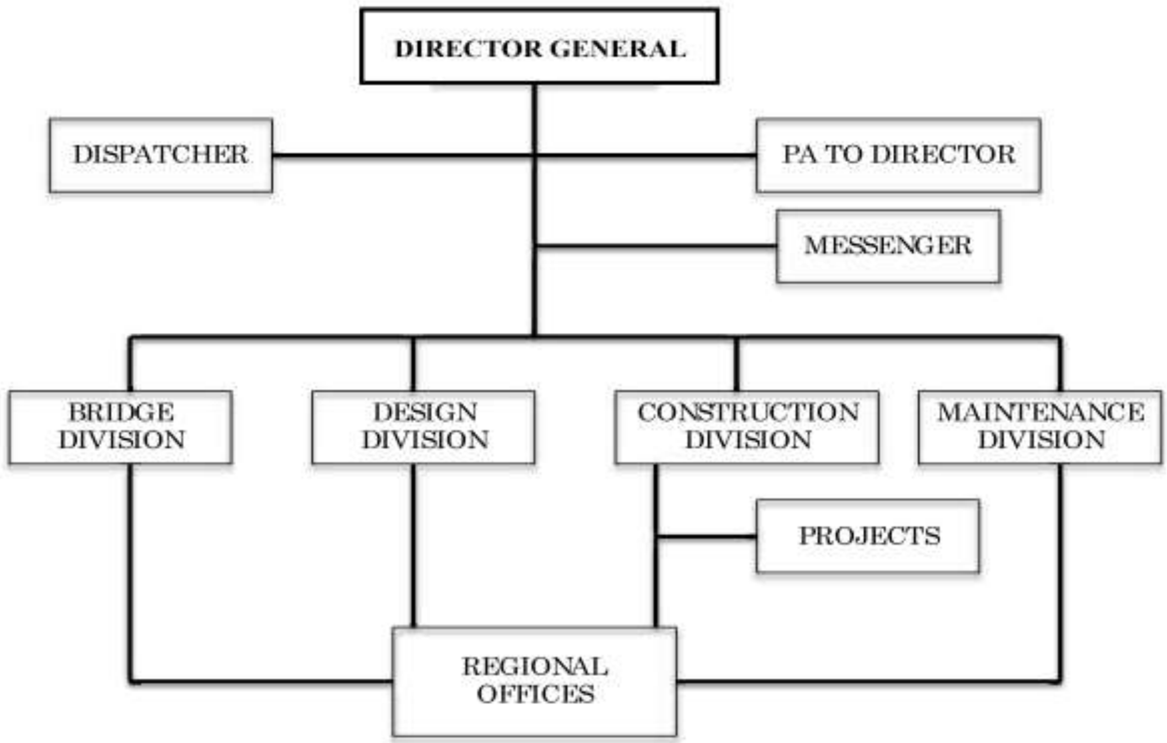
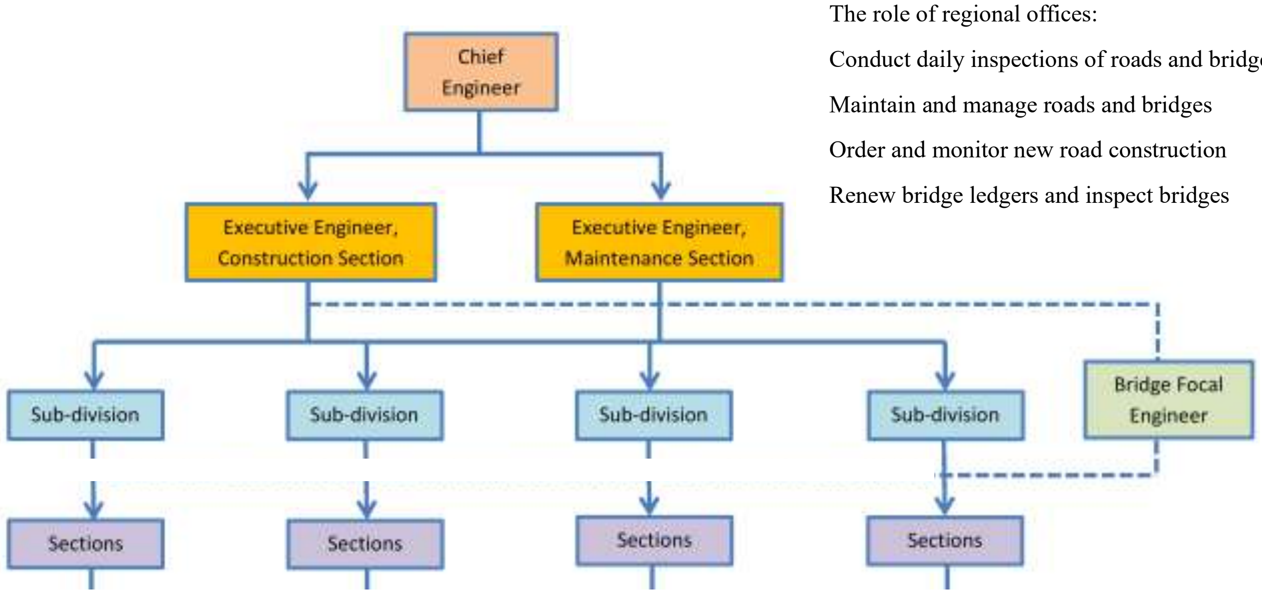


Figure 4.3 DoR Organization Chart[19]



The role of regional offices:

Conduct daily inspections of roads and bridges

Maintain and manage roads and bridges

Order and monitor new road construction

Renew bridge ledgers and inspect bridges

Figure 4.4 Regional Office Organizational Chart[20]

[19] Ministry of Public Works and Settlement [2019], ANNUAL INFORMATION BULLETIN 2019.
[20] Obtained during the road station hearings.

4.4.3 Budget for Road Maintenance and Management

Table 4.4 provides a breakdown of the road-related budget (2019-2020). For construction, the ratio of domestic funds to foreign funds is about the same. The maintenance budget accounts for 40 % of the national budget for roads and bridges. In addition, the maintenance budget for bridges is only 2.6% of the total maintenance budget, which is very small.

Table 4.4 Breakdown of Bhutan's Road-related Budget (2019-2020)[21] [22]

(Unit: million yen, mNu in parentheses, 1Nu = 1.44 yen)

Category	Financier	Construction	Maintenance and Management				Other	Total	Remarks
			Daily Maintenance Management	Regular Maintenance Management	Emergency Maintenance Management	Total			
Pavement Geotechnical Other	Domestic Funds	955.1 (691.1)	433.0 (300.7)	189.4 (131.5)	269.3 (187.0)	891.6 (619.2)	371.4 (257.9)	2,258.1 (1,568.2)	
	Foreign Support	952.6 (661.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	952.6 (661.5)	ADB, Support for Netherlands
	Subtotal	1,947.7 (1,352.6)	433.0 (300.7)	189.4 (131.5)	269.3 (187.0)	891.6 (619.2)	371.4 (257.9)	3.210.7 (2,229.7)	
Bridge	Domestic Funds	10.9 (7.6)	23.0 (16.0)			23.0 (16.1)	0 (0)	33.9 (23.6)	
	Foreign Support	13.0 (9.0)	0 (0)			0 (0)	0 (0)	13.0 (9.0)	India Support
	Subtotal	23.9 (16.6)	23.0 (16.0)			23.0 (16.0)	0 (0)	46.9 (32.6)	
Total	Domestic Funds	1,006.0 (698.7)				914.6 (635.3)	371.4 (257.9)	2,292.0 (1,591.8)	
	Foreign Support	965.6 (670.5)				0 (0)	0 (0)	965.6 (670.5)	
	Subtotal	1,971.6 (1,369.2)				914.6 (893.1)	371.4 (257.9)	3,257.6 (2,262.3)	

Note: For bridges, the breakdown of maintenance was not available, so only the total amount is given.
Others includes the DoR staff salaries and software purchasing costs. Maintenance costs account for 40% of domestic funds.
The maintenance budget for bridges is 2.6% of the road maintenance budget.

4.4.4 Support Status of Each Donor on Road AM

The Bhutanese government has a strong sense of independence with regard to foreign aid, limiting aid to India, Japan, European countries, and the WB/ADB, and is cautious about accepting international NGOs.

[21] Japan Overseas Consultants Co., Ltd., and others [2016], edited data from JICA bridge construction management and maintenance capacity improvement project business plan.
[22] Summary of Bhutan DoR Presentation Materials.

Aid coordination among donors is led by the Bhutanese government, and each donor selects its own areas of support. Japan's support is focused on infrastructure (bridges and roads with high technical difficulty) and agricultural development. In addition, India is providing assistance in hydropower and infrastructure (relatively simple bridges and roads), while European countries are providing assistance mainly in local administration.[23]

(1) Government of India

When the Bhutanese government implements projects planned in the five-year plan, it selects items from the project expenses approved in the five-year plan and requests support from the Indian government. The Indian government has a system in place to internally review requests from Bhutan and decide whether or not to support the project. The two governments hold Plan Talk meetings twice a year to discuss the implementation of the five-year plan and to adjust the content and amount of assistance.

(2) The WB

The WB supports the development of Road AM systems in Bhutan, which records the condition of roads and bridges, and improves the technical capabilities of the DoR staff.[24]

In 2016, surveys were conducted of 2,000 km of national highways and accompanying bridges, drainage channels, earthworks, etc., and support was provided for collecting all information in the Geographic Information System (hereinafter referred to as GIS) database.[25]

In 2004, the following reports were submitted in relation to Road AM.[26]

1) The DoR employs as many as 4,600 workers directly to maintain 2,100 km of jurisdictional roads. This is a level like no other country, with one worker employed for every 2 km.
2) In the past, the introduction of Road AM systems to determine the priority of daily maintenance and periodic maintenance had been made through foreign support. However, due to insufficient training for staff, these systems have been destroyed. As part of the master plan formulation process, a management system called “dTMIS” was introduced into the DoR, but the training of staff is insufficient, and the system is not operated yet.
3) In the master plan, it is recommended to introduce a road information system, a strategy formulation model of the HDM-4 system, maintenance management, and a pavement and bridge management system. In countries of a size such as Bhutan, it is sufficient to integrate these systems into one and take GIS location information into account.
4) The DoR is also fully aware that these systems are effective in assessing and monitoring road plans. However, the immediate problem is how to grasp the information necessary for the plan by periodically conducting road inspections after measuring traffic volume on a regular basis.

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[23] JICA [2014], "Survey on Information Gathering and Confirmation of Bhutan's Domestic Transportation Network", p2-17.
[24] The WB [2015], Bhutan Country Snapshot.
[25] Ines [2016], Design and implementation of a road infrastructure maintenance management system for Bhutan’s Department of Road.
[26] WB [2004], Bhutan Transportation Sector Note.

(3) ADB

The ADB mainly introduces PMS and databases for support on pavement. Recently, however, daily maintenance and management methods using PBC have been introduced and case studies on tunnels have been conducted. Table 4.5 summarizes the support on Rotad AM carried out by the ADB.

Table 4.5 Support Related to Road AM Provided by the ADB

Subject	Completion Date	Business Description
Introduced Road Decision Model	1993	The DoR began investigating road conditions in the 1990s, but data collection stopped along the way.[27]
Deploy Road Maintenance Management Model (RMMS)	1996	Although the DoR staff were trained to use the system, the use of the system was not carried over within the organization due to movement or resignation within the organization. The system does not have the appropriate inventory information and cannot develop a repair plan.
Road Planning and Management Strengthening	2001/12	Support for the road master plan development and road bill formulation support. Conducted surveys and training on PMS introduction and inspection of road development policies to third countries
Road Network Expansion Project	2003	Grasp the annual maintenance program and maintenance cost using HDM-4.
Development of a Maintenance Management System	—	Development of a Road AM system, but it was too complicated for government officials to master it after the consultant returned home.
Capacity Building in Road Safety Audit and Road Asset Management (Road Network Project)	2009/9	Initially, there was a plan to launch a database, but it was found that the Road AM system was not functioning locally, and the goal changed direction. From 2008 to 2009, the consultant visited Bhutan four times in total, introduced the concept of Road AM, and dispatched the DoR staff for training in Thailand. HDM-4 was purchased in the project and a proposal was made to start data collection after the project ends
TA for Capacity Building of the Department of Roads (Road Network Project II)	2011/12	Best practices were provided for environmental-friendly surveys, designs, and construction on mountain roads, conducted training, and prepared manuals. In addition, the introduction of daily and periodic maintenance contracts by PBC was supported. Created a pilot DB for the Road AM of National Route 1 for 273 km. Implemented operational support for the pilot Road AM system. As of the end of 2011, the DoR has moved on to the next stage of budget planning during the third year of road conditions data collection. Tunnel experts from the technical cooperation projects supported feasibility studies of four tunnels.

In 2009, the ADB support was initiated by PBC on city roads in Thimphu, which is said to have led to cost reductions of 15 to 20%. Daily road maintenance in Bhutan is a system done by muter-roll-based (roster management). The government hires one worker for every 1.5 km of road extension to promote employment and combat local poverty. Workers are paid about 150 yen per day, and according to the government, there are more than 4,000 workers, and a total of 400 residential facilities are provided, one

[27] ADB [2009], "Capacity building in road safety audit and road asset management" p1.

every 5-10 km. They live in the residence with their families. The government also provides food and arranges shuttle buses for children to school.

(4) JICA

JICA has been providing support with an emphasis on the construction of bridges for a long time, but in recent years it has also provided support related to maintenance and slope disaster prevention.Table 4.6 summarizes the Studies and thetechnical cooperation projects implemented or under implementation by JICA.

Table 4.6 Studies and Technical Cooperation Projects Implemented or under Implementation by JICA

Item Name	Completion Date	Name of the Collaborator	Business Description
Bridge Maintenance Plan Survey	1998	—	Conducted basic planning for national road maintenance/bridge replacement and detailed design (hereinafter referred to as FS) for priority projects.
Bridge Long-Term Expert	1998 to 2004	Hanshin Expressway	Prepared bridge ledgers and other documents.
Human Resource Development Project for Bridge Planning, Design, Construction, and Maintenance	2007	—	Conducted training of engineers and improvement of design/construction/maintenance techniques for concrete bridges.
Senior Volunteers	2012 to 2014	IDEA Consultants, Inc.	The project supported the advance provision of information on traffic restrictions due to landslides and road construction.
Capacity Improvement Project for Design and Implementation Supervision of Agricultural Road Bridges	2014/2	Kokusai Kogyo Co., Ltd., Earth System Science Co., Ltd., OYO International Corporation	Improved research design, construction supervision, and maintenance management capabilities for agricultural road overpasses for the Ministry of Agriculture and Forestry's Agricultural Bureau and the prefecture.
Information collection and confirmation survey on domestic transportation network	2014/9	Oriental Consultants Co., LTD., INGÉROSEC Corporation	Surveyed Road and Bridge/Slope Projects.
Preparatory survey for the National Highway No. 1 Bridge Replacement Project	2015/4	Oriental Consultants Co., LTD., INGÉROSEC Corporation	A survey was conducted for grant aid for the replacement of three bridges and the construction of attachment roads and revetments.
Preparatory survey for the National Highway No. 4 Bridge Replacement Project	2016/11	Oriental Consultants Co., LTD., INGÉROSEC Corporation	A survey was conducted for grant aid for the replacement of four bridges and installation road works.
Road Slope Management Master Plan Study	2017/3	Kokusai Kogyo Co., Ltd.., OYO International Corporation., Earth System Science Co., Ltd.., Oriental Consultants Co., LTD	Prepared slope registers by inspecting 460 slopes and ranked the slopes according to their danger level.

Item Name	Completion Date	Name of the Collaborator	Business Description
Bridge Construction Supervision and Maintenance Management Capacity Improvement Project	2016/8 to 2022/3	Japan Overseas Consultants Co., Ltd.., INGÉROSEC Corporation, Hanshin Expressway, Oriental Consultants Global, Earth System Science Co., Ltd., CTI Engineering International Co., Ltd.	The bridge maintenance management cycle was introduced and the BMS was developed to improve bridge construction and maintenance management capabilities.
Road Slope Countermeasure Capacity Enhancement Project	2018/12 to 2023/1	Kokusai Kogyo Co., Ltd., OYO International Corporation, Earth System Science Co., Ltd.	Planning and design of slope countermeasure works, project implementation methods, and strengthening of monitoring system for dangerous slopes are being conducted.

4.4.5 Road Maintenance and Maintenance in Bhutan

4.4.5.1 Road Sector Master Plan (2007-2027)[28]

This plan shows the 20-year road improvement target and includes 2,654 km of new prefectural roads across 132 routes, a new East-West national highway of 794 km, a new national highway of 537 km, and a linear improvement of the existing national highway of 62 km and the construction of 10 tunnels. In the master plan, it is important to take appropriate Road AM and climate change measures.

(1) Master Plan Review

A review of the master plan was conducted by the DoR in 2016. The results are shown below.

1) 506 km of the new East-West national highway of 794 km is new construction, the remaining 288 km is the widening of existing roads.
2) As of the end of 2016, new construction of 141 km and widening work of 39 km were completed.
3) 12 km out of 62 km of the linear change of the national highway was completed.

In addition, the following targets have been set for the 10-year term from 2017 to 2027.

1) Completion of construction of the new East-West national highway.
2) Development of prefectural roads to enhance connectivity in the prefecture.
3) Make existing roads resistant to climate change.
4) Implementation of short tunnel construction that can be realized.
5) Introduction of Road AM system to enhance value-for-money.
6) Promotion of mechanization of road construction and maintenance.

The following ideas are described on Road AM systems and climate change countermeasures.

[28] Ministry of Public Works and Settlement of Bhutan [2017], Review of road sector master plan (2007-2020).

(2) Road AM

1) Road AM is the approach necessary to achieve KPIs through road maintenance and improvement. Road AM can clarify when appropriate maintenance is carried out and minimize damage to structures.
2) The DoR needs to gradually steer to Road AM, collect inventory information on road assets, and improve the capabilities of government officials. It is necessary to introduce software such as IT technology, analyze data, and formulate an investment plan for roads.

(3) Climate Change/Disaster Prevention Measures

1) In the road sector, strong roads that respond to climate change are required because bridges and road washing due to abnormal rainfall occur every year during the flood season.
2) Measures to stabilize slopes and prevent scoriating by appropriate drainage facilities should be incorporated into all road designs.

4.4.5.2 Road Maintenance Manual (2005)[29]

The first edition was created in 1998 and revised in 2005. It is prepared as a guideline for daily maintenance carried out by the DoR staff. The scope of application is pavement surfaces, road shoulders, drainage facilities, etc., and bridges and slopes are not included. Daily maintenance is divided into routine maintenance such as repair of potholes and structures, drainage ditch cleaning and weeding, while perforation maintenance includes replacement and overlay of surface layers, and restoration/emergency maintenance describes the restoration of road facilities due to floods and heavy rains. Another item shown is a routine maintenance calendar that shows each work schedule. Although there is no description of the inspection, countermeasures are described according to the type and cause of pavement damage.

4.4.5.3 Pavement Design Manual (2005)[30]

The idea of the design of asphalt pavement and concrete pavement is described. In the design, it is considered to distinguish between regions where the altitude is high (2,500 m or more) and regions which are not. When the altitude is high, the influence of frost and freezing is incorporated into the design. The pavement design thickness is determined from the cumulative traffic volume and the ground strength of the roadbed.

4.5 Overview of the Bridge Construction Supervision and Maintenance Capacity Improvement Project

4.5.1 Project Goals and Outcomes

(1) Overall Goals

The overall goal is “Work related to bridge maintenance and maintenance by the DoR is improved”, and the following items are set as indicators for evaluating the achievement of the upper target.

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29 Ministry of Public Works and Settlement of Bhutan [2005], Road maintenance manual.
30 Ministry of Public Works and Settlement of Bhutan [2005], Pavement design manual.

1) Quality and safety management is carried out at all new bridge sites under DoR jurisdiction based on the prepared site checklist.
2) XX% increase in the proportion of repaired defective bridges compared to 2016
3) Compared with 2016, the proportion of safe bridges was XX%.

(2) Project Goals

The project goal is "To improve the ability of engineers in bridge maintenance, maintenance, and repair within the DoR", and the following items are set as indicators for evaluating the achievement of project goals.

1) Number of people implementing quality and safety management based on on-site checklists
2) Preventive maintenance (permanent and Bailey bridges) based on the bridge maintenance plan is carried out.
3) Bridges managed by the DoR are inspected based on the procedures in the prepared maintenance manual. Appropriate measures are taken on bridges that urgently need repair.
4) DoR engineers will also be able to partially revise the bridge maintenance manual, site checklists, and BMS.

4.5.2 Project Activity Plan and Performance Indicators

Table 4.7 shows project output, activity plans and performance indicators.

Table 4.7 Project Outputs, Activity Plans, and Performance Indicators

Results	Activity Plan	Performance Indicators
Results one Engineers will acquire the basic knowledge necessary for bridge planning and design, construction supervision, and maintenance management.	1) Lectures (workshops) on basic knowledge of bridge engineering for the DoR staff (headquarters and regional offices) and district engineers, etc., based on an understanding of the technical level of engineers in Bhutan. 2) Select one or two new bridge construction sites under the jurisdiction of the DoR and provide on-the-job training on quality and safety management of construction works to the DoR staff (headquarters and regional offices) and prefectural engineers. 3) Two bridges under the jurisdiction of the DoR (permanent bridges on the national highway and Bailey bridges on the prefectural highway) will be selected and on-the-job training on inspections, diagnosis, repair, and reinforcement will be provided to the DoR staff (headquarters and regional offices) and prefectural engineers.	1) XX people on the fundamentals of bridge engineering. 2) Attend a workshop or seminar and pass the final exam. 3) XX person will be able to participate in workshops and seminars and on-the-job training on quality and safety management and implement them in a leadership position. 4) XX person will be able to participate in workshops, seminars and on-the-job training on inspections, diagnosis, repair, and reinforcement, and implement them in a leadership position. 5) The content and level of difficulty of workshops, seminars, and on-the-job training are appropriate and meet the needs of the participants.
Results two A bridge maintenance management	1) Develop bridge maintenance manuals (inspection, diagnosis, repair, and reinforcement) with the DoR Headquarters engineers.	1) A manual related to bridge maintenance management (inspections and diagnosis) will be developed by 2018. 2) A manual related to bridge

Results	Activity Plan	Performance Indicators
manual will be developed.		maintenance management (repair and reinforcement) will be developed by 2018. 3) The contents of the manuals related to bridge maintenance management are appropriate, easy to understand, and easy to use. 4) By 2019, bridge maintenance related manuals will be distributed and utilized by all the DoR offices and relevant agencies.
Results three On-site checklists for quality control and safety control will be prepared.	1) Based on the activities in Activity 1, develop a field checklist for quality and safety management in new bridge construction together with the DoR headquarters engineers.	1) On-site checklist will be developed by 2017. 2) The contents of the on-site checklist are appropriate, easy to understand, and easy to use. 3) Field checklists will be implemented in all the DoR offices and associated agencies by 2019.
Results four A bridge management system will be established to ensure appropriate budgeting.	1) Understand the contents and issues of the DoR's existing bridge database, and then work with the DoR headquarters engineers to build a new BMS. 2) Inspect all existing bridges (272 bridges) managed by the DoR based on the bridge inspections and diagnosis manual, together with the DoR staff (headquarters and regional offices) and prefectural engineers and collect and organize data for input to the BMS, such as bridge specifications and damage status.	1) BMS will be built by 2018. 2) The 2019 bridge maintenance budget based on the BMS will be proposed. 3) The DoR staff and county engineers will be able to use the BMS in their work without any problems.
Results five An implementation policy for the maintenance of bridges under the DoR jurisdiction will be developed.	1) Draw up bridge maintenance plans (medium-term and long-term plans) for permanent bridges on national roads and existing Bailey bridges on prefectural roads and agricultural roads. 2) Develop a bridge maintenance management plan for the DoR, keeping in mind the effective use of human resources at the DoR regional offices and the prefecture. 3) Develop a bridge maintenance policy for the DoR.	1) Medium- to long-term bridge maintenance plans will be prepared by 2019. 2) Bridge maintenance management system and personnel will be in place by 2019. 3) The DoR's bridge maintenance policy will be prepared by 2019. 4) Use the BMS to prepare a maintenance budget plan that corresponds to the mid-term maintenance plan.

4.5.3 Manuals Introduced in the Project

The following manuals have been created in the project. The outline is shown in Table 4.8.

Table 4.8 Manuals Introduced

Manual Name	Overview
Manual for Inspections and Diagnosis of Bridges	In addition to describing the bridge information required for the inventory, the type, content, and frequency of bridge inspections and the record format are also specified. The inspections are divided into daily inspections (once/week), periodic inspections (once/2-10 years), and emergency inspections. Then, damage evaluation categories are set for each

Manual Name	Overview
	damage type. In addition, the evaluation categories are classified into five levels by damage. Finally, a list of bridges by region is attached at the end of the book.
Manual for Repair and Reinforcement of Bridges	It outlines the cycle of inspections, diagnosis, repair plans, repair, and recording, and describes the concepts of various surveys and selection of repair methods necessary for repairing concrete/steel bridges. Then, it outlines the specific construction methods of the various repair methods and describes points to keep in mind. A wide range of repair methods are described, from localized measures such as concrete cracks and exposed reinforcing bars to reinforcement methods such as floor plate thickening, external cable reinforcement, steel plate reinforcement, and bridge fall prevention devices.
On-site Checklist (safety management)	Describes safety management checkpoints in bridge construction with photographs. Safety meetings, clothing, scaffolding, shoring, construction equipment, electrical equipment, guidance equipment, drainage, slopes, formwork, etc. are also described.
On-site Checklist (quality control)	Describes quality control check items in bridge construction with photographs. Checkpoints are provided for preparation, excavation, foundation, backfill, concrete pouring, formwork/shoring, reinforcement, prestressing, grouting, expansion devices, bearings, drainage facilities, etc.

4.5.4 Project Progress

The project was under construction until June 2021, but has been extended by one year until June 2022. However, according to a hearing from the technical cooperation project team, the remaining work is to hold the final JCC and to give a final explanation to the DoR headquarters and regional offices. The substantial work is finished.

4.6 Overview of the Road Slope Countermeasure Work Capacity Enhancement Project

4.6.1 Project Goals and Outcomes

(1) Overall Goals

The overall goal is "road slopes in Bhutan are appropriately developed and maintained using measures improved in the project", and the following items are set as indicators for evaluating the achievement of the upper target.

1) At two regional offices, the countermeasure work introduced in this technical cooperation project will be constructed in more than 4 places.
2) At the other nine offices, more than 7 countermeasure works introduced in this technical cooperation project will be constructed.

(2) Project Goals

The project goal is "to improve the ability at the DoR for road slope countermeasures", and the following items are set as indicators for evaluating the achievement of project targets.

1) The countermeasure work introduced in this technical cooperation project is constructed in more than 4 places.
2) More than 70% of the DoR staff will be able to implement advance traffic restrictions.
3) The annual budget for implementation of countermeasure works introduced in this technical cooperation project will be formulated by the DoR.

4.6.2 Project Activity Plan and Performance Indicators

Table 4.9 shows project output, activity plans and performance indicators.

Table 4.9 Project Outputs, Activity Plans, and Performance Indicators

Results	Activity Plan	Performance Indicator
Results one The conditions for advanced traffic control will be clarified.	1) Select target routes and slopes based on the results of road disaster prevention inspections. 2) Develop a plan for monitoring surface displacement and rainfall. 3) Obtain basic data on land surface displacement and rainfall. 4) Analyze and evaluate the basic data obtained for the establishment of traffic control sections and reference rainfall values for traffic control. 5) Analyze the current issues of the advanced traffic control system and establish an appropriate system. 6) Conduct a mock drill of local traffic control at the selected restricted section. 7) Prepare a manual for surface displacement and rainfall monitoring and advance traffic control.	1) A section for advanced traffic control will be selected. 2) Rainfall standards for traffic control will be set. 3) Manuals for surface displacement, rainfall and advance traffic control will be prepared and approved by the DoR.
Results two Vegetation works suitable for preventing “sediment slope failure” will be selected.	1) Select target routes and slopes based on the results of road disaster prevention inspections. 2) Survey and evaluate vegetation on existing slopes and organize issues. 3) Study suitable vegetation works for preventing soil slope failure in Bhutan. 4) Test construction of vegetation works on model slopes. 5) Prepare design and construction management guidelines and standard unit price list for vegetation.	1) At least two staff members at the DoR headquarters and regional offices can implement appropriate vegetation works selection and construction supervision. 2) Vegetation design/construction guidelines and standard unit price list are developed and approved by the DoR.
Results three The standard cut slopes for sediment slope failure and rock slope failure have been revised.	1) Select target routes and slopes based on the results of road disaster prevention inspections. 2) Evaluate geological properties and slope stability by field survey. 3) Prepare a manual for rocks and geological classification. 4) Examine the standard slope of the cut slope for each geological feature. 5) Prepare design and construction management guidelines and a standard unit price list for Bhutanese standard cut slopes. 6) Construction management shall be conducted in accordance with the prepared design and construction management guidelines.	1) At least two staff members at the DoR headquarters and regional offices can set the appropriate cut slope and supervising its construction. 2) Standard unit price list for slope cutting is developed and approved by the DoR.
Results four We will be able to implement suitable countermeasur es against	1) Select target routes and slopes based on the results of road disaster prevention inspections. 2) Conduct topographic and geological surveys and analyze and evaluate for the selection of countermeasure works. 3) Select the appropriate countermeasure method for the target route and slope.	1) At least two staff members in the DoR headquarters and regional offices should understand the fallen rock countermeasure

Results	Activity Plan	Performance Indicator
“rock slope failure (rock fall)”.	4) Plan and design the selected countermeasure work. 5) Construct the selected countermeasure. 6) Implement safety management activities for the selected countermeasure work. 7) Prepare design and construction management guidelines and standard unit price list for the selected countermeasure works. 8) Prepare a handbook on slope failure prevention.	work, select appropriately, and supervise the construction. 2) Design and construction guidelines and standard unit price lists for rock fall protection works and slope collapse protection handbook were developed and approved by the DoR.
Results five Appropriate countermeasures against “mudslides” will be introduced.	1) Select target routes and slopes based on the results of road disaster prevention inspections. 2) Survey and evaluate the geomorphology and geology of the debris flow stream. 3) Collect and analyze information on road drainage systems. 4) Plan and design drainage works and drainage facilities. 5) Construct drainage works and drainage facilities. 6) Implement safety management activities related to drainage works and drainage facility construction. 7) Prepare design and construction management guidelines and standard unit price list for drainage works and drainage facilities	1) At least two staff members at the DoR headquarters and regional offices can implement the selection and construction supervision of appropriate drainage facility works. 2) Drainage facility design/construction guidelines and standard unit price lists are approved by the DoR.
Results six The information system for road slope disaster information and traffic control will be improved.	1) Conduct basic GIS training. 2) Understand the status of the DoR GIS database and the information sharing system with regional offices and organize and improve on issues. 3) Improve the road information acquisition system in the DoR regional offices. 4) Improve the system for inputting and managing road information into the GIS database at the DoR Headquarters. 5) Improve the road information sharing system using GIS database. 6) Prepare a manual for road information system using GIS database.	1) Existing GIS database will be improved. 2) Data needed for maintenance and traffic control will be collected on a regular basis. 3) Road information system using GIS database is approved by the DoR.

4.6.3 Manuals Introduced in the Project

In the road slope management master plan survey, the following manual has been prepared. The outline is shown in Table 4.10.

Table 4.10 Manuals Introduced

Manual Name	Overview
Road Slope Inspection Manual (prepared	In addition to defining the method and timing of slope inspections, a check sheet has been prepared so that visual information on slope topography, geology, springs, height, and other factors can be scored to determine the degree of danger. After analyzing the

Manual Name	Overview
through master plan surveys)	correlation between the slope conditions and the results of the risk evaluation by the experts using quantification theory, the scores were weighted and allocated to each item. The check sheets are divided into four categories: rock slopes, sediment slopes, landslide areas, and debris flow areas. Typical slope protection works are outlined at the end of the manual.
Slope Disaster Database Manual (prepared through master plan surveys)	A database that can store the results of slope inspections and share them with the DoR and each office via the Web. The location of each slope is also mapped and can be displayed in GIS. Since Bhutan does not have a base map, the DoR staff can create map information from GIS location information to input road alignments and surrounding facilities.

The following manuals will be prepared in the technical cooperation project.

1) Manual on surface displacement and rainfall monitoring and traffic restrictions
2) Design and construction management guidelines and standard unit price table for vegetation
3) Design and construction management guidelines and standard unit price table for standard cut surface slopes
4) Design and construction management guidelines and standard unit price table for countermeasure work for bedrock slope failure
5) Design and construction management guidelines and standard unit price table for drainage work and drainage facilities
6) Manual for Road Information System using GIS Database

4.6.4 Project Progress

This technical cooperation project is a 49-month project from December 2018 to January 2023, but was suspended due to COVID-19 in January 2020, one year after its start. The suspension period is scheduled to be postponed, and the manuals have yet to be prepared. As of January 2021, rockfall countermeasure work, earth and stone debris flow countermeasure work, and vegetation work have been completed one by one. Vegetation work was constructed in this project, but the construction of rockfall countermeasure work and debris flow countermeasure work was the construction of local governments, and the technical cooperation project team designed and managed the construction.

This technical cooperation project is positioned as a successor to the slope master plan investigation carried out before. In the master plan investigation, a manual was prepared, slope surveys of 470 places were carried out, and slope diagnostic records were prepared. In this technical cooperation project, it is assumed that the countermeasure work is actually constructed based on those data. In addition, since there was no map information in Bhutan, using GIS to create map infrastructure is also included in the menu.

4.7 Construction, Maintenance and Management Capabilities, Technical Standards

According to the JICA Bridge Construction Management and Maintenance Capacity Improvement Project Business Plan (2016)[31], there are more than 3,800 general contractors, including 10 domestic bridge

[31] Japan Overseas Consultants Co., Ltd., and others [2016], Bhutan Bridge Construction Management and Maintenance Capacity Improvement Project Business Plan.

consultants in Bhutan and companies engaged in bridges, and there are also numerous construction companies.

In addition, according to the National Highway No. 4 Bridge Replacement Plan Preparatory Survey Report (2016)[32], construction work is increasing year by year and the number of construction workers is also increasing. However, due to the lack of experienced civil engineers to supervise, on-site supervision is not good, leading to a decrease in quality and delays in the construction period. With regard to the technical capabilities of domestic suppliers, apart from the quality, they have the ability to carry out construction work for BRIDGES and structures with RC structures, but do not have the ability to carry out construction work such as PC structures and large-scale bridges that require precise supervision. The majority of domestic suppliers have a small management scale, the type and number of machines is lacking, and the proportion of equipment in good condition is low. In addition, these companies tend to lack financial power, and if payment from the government is delayed, construction must be suspended, causing construction to be delayed.

The 2004 report from the WB pointed out the following in relation to construction technology.[33] It seems that there are parts that have been considerably improved as of now, but they will be described for reference.

1) From the first road construction in 1959 to the 1990s, most national highway networks were funded by the Indian government (Indian Border Force Technical Force: DANTAK). Even now, 30% of the main roads are maintained by DANTAK.
2) Road construction in Bhutan relies on the import and application of outdated technologies and methods from India, and road construction and maintenance tend to be labor-intensive, less productive, and costly. Therefore, the quality of the roads is poor, the unevenness large, service level low, and the durability of the pavement is also insufficient. Since inappropriate materials are used and construction technology is not good, the pavement life is short despite the low traffic volume. After 3 to 4 years, repairs are required, and it needs to be completely replaced in 7 to 8 years.
3) As for the quality of pavement, the roadbed and each layer are uneven and insufficiently compacted. Mechanized construction has not progressed, and there are many ranges of human power construction. The asphalt pavement is laid by human force, and the compacting and rolling pressure are also made of the old-fashioned three-wheeled steel roller. Moreover, it is often performed in a state where the temperature has already decreased.
4) The DoR's orders for pavement improvement work is limited, and construction companies cannot provide enough funds to procure appropriate machinery. However, the poor quality is largely due to the improperness of construction supervision and quality control.
5) For daily maintenance and management, dead trees are burned on the roadside, asphalt mixtures are heated, and pothole repairs are performed by mixing it with aggregates. In order not to mix aggregates and asphalt in the field, the quality should be ensured by converting the pre-mixed compound to a method of using it through heat treatment.

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32 JICA [2016] Preliminary Survey on Plans to Replace Bridges on Route 4.
33 The WB [2004], "Bhutan country Snapshot" p21.

6) In order to improve quality, it is also necessary to improve the material testing facilities and introduce mobile testing machines. The DoR should consider supporting the introduction of the latest construction/maintenance technology from each donor.

4.8 Road AM Maturity Level

4.8.1 How to Conduct Maturity Evaluation

The maturity evaluation was conducted by web interviews with the participants and the schedule shown in Table 4.11. The evaluation form was distributed in advance and the grading method was explained during the kick-off meeting. In the interviews, we asked them to explain the reasons and background behind the low and high items that they graded. In addition, if the other party offered to revise the grade point during the interviews, the revision was made on the spot.

Table 4.11 Content of the Maturity Evaluation Hearing

Item	Date	Attendance	Contents
JICA Kick-off Meeting	5/11	JICA headquarters、JICA Bhutan Office	Explanation of purpose
DoR Kick-off Meeting	5/25	Dorji Gyeltshen (Maintenance Chief Engineer) Yeshey Penjor (Maintenance Executive Engineer) Kinga Zangpo (Maintenance Engineer) Phuntsho Wangmo (Maintenance GIS Technician) Karma Wangdi (Bridge Chief Engineer)	Explanation of purpose, hearing date and time setting
Bridge, Organization/ Monitoring Field	6/1	M.N Lamichaney (Bridge Specialist) Diwash Subba (Engineer)	Evaluation sheet scoring
	6/8	Karma Wangdi (Bridge Chief Engineer) M.N Lamichaney (Bridge Specialist) Diwash Subba (Bridge Engineer)	Additional hearings
Pavement and Earthworks	6/2	Dorji Gyeltshen (Maintenance Chief Engineer) Yeshey Penjor (Maintenance Executive Engineer)	Evaluation sheet scoring
	6/9	Yeshey Penjor (Maintenance Executive Engineer)	Additional hearings
Evaluation Draft, Support Plan (Organization/ Monitoring)	6/16	Karma Wangdi (Bridge Chief Engineer) Diwash Subba (Bridge Engineer)	Overall summary
Overall summary (Pavement and Earthworks)	6/16	Yeshey Penjor (Maintenance Executive Engineer) One other person	Overall summary
Report of survey results to JICA	7/15	JICA Bhutan Office	Report on Survey Results
	8/5	JICA headquarters	

Remarks: All done through web interviews

In addition to the above interviews, we also conducted interviews with the Technical Cooperation Project Research Team, etc. shown in Table 4.12 in order to grasp the current situation.

Table 4.12 Details of the Supplementary Hearings

Hearing location	Date	Business name	Contents
Japan Overseas Consultants Co., Ltd.	1/7 1/14 6/4 7/5	Bhutan Bridge Technical Cooperation Project	Hearing on Bridge AM
Kokusai Kogyo Co., Ltd.	1/20 1/28	Bhutan Slope Technical Cooperation Project	Hearing on Slope AM
Dai Nippon Construction	6/7	Grant Aid Route 4 Bridge Replacement Project	Interviews with local construction companies on quality control and other issues

Remarks: All done through web interviews

4.8.2 Maturity Evaluation Results

The major items radar chart (evaluation scores) is shown in Figure 4.5.

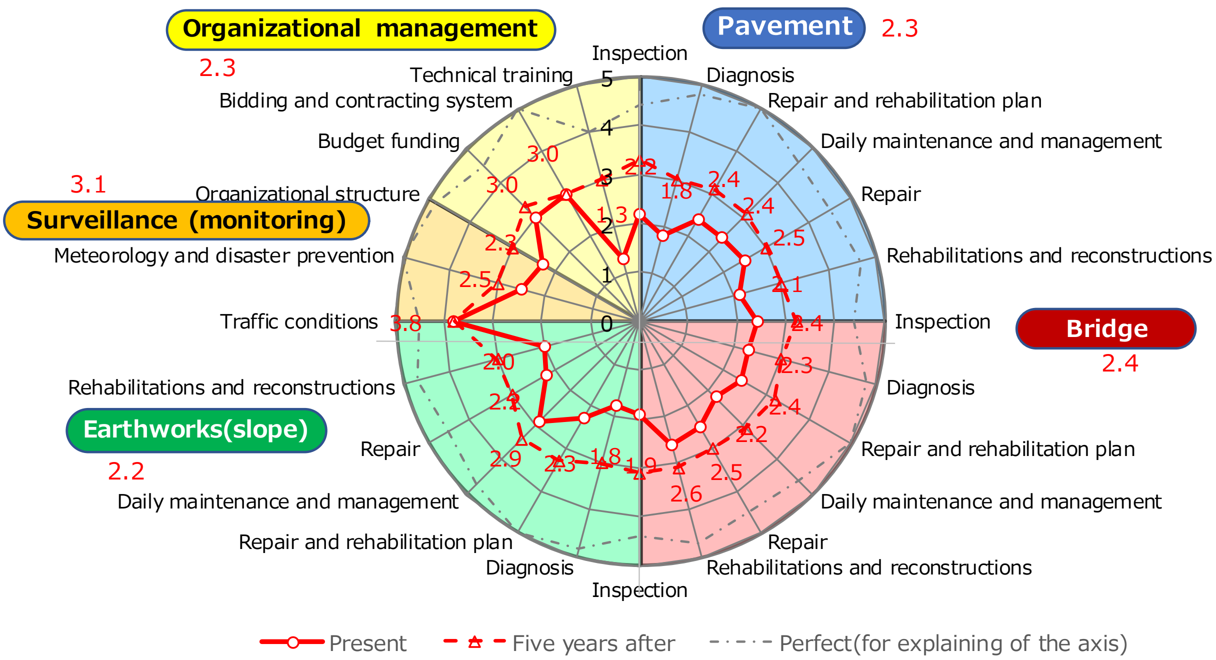


Figure 4.5 Radar Chart of Major Items (Level)

(1) Overall Evaluation

1) The overall average evaluation is between level 2 and 3 and doesn't reach the target level 3 of the JICA technical cooperation projects.

(2) Pavement (Evaluation Level 2.3)

1) The level of "Diagnosis" is as low as 1.8. This is since there is no inspection/diagnosis manual, and the damage situation of the road surface is ranked, but the basis is not clear.

(3) Bridges (Evaluation Level 2.4)

1) The technical cooperation project has prepared basic manuals, and there were no extremely low evaluation items.

(4) Earthworks (Slopes) (Evaluation Level 2.2)

1) The level of “Inspection” and “Diagnosis” is as low as 1.9 and 1.8. This is due to factors such as periodic inspections having not been performed, and that reactive processing corresponding is the main methodology.
2) The level of “Daily Maintenance” is high at 2.9. This is because tasks like cleaning of the waterways and signs and weeding are thorough.

(5) Surveillance (Monitoring) (Evaluation Level 3.1)

1) The level of “Traffic Conditions” is as high as 3.8. This is since the measurement point of the traffic volume is wide, and the frequency is high, and the measurement data is shared.

(6) Organizational Management (Evaluation Level 2.3)

2) The level of “Budget Funding” is 3.0, and a five-year budget plan has been developed, and there are no arrears in paying for outsourced operations.
3) The level of “Bidding Contract System” is 3.0, and the contract system itself is considered to have been established.
4) The level of “Technical Training” is 1.3. This is since overall, there is no systematic training other than JICA-related training.

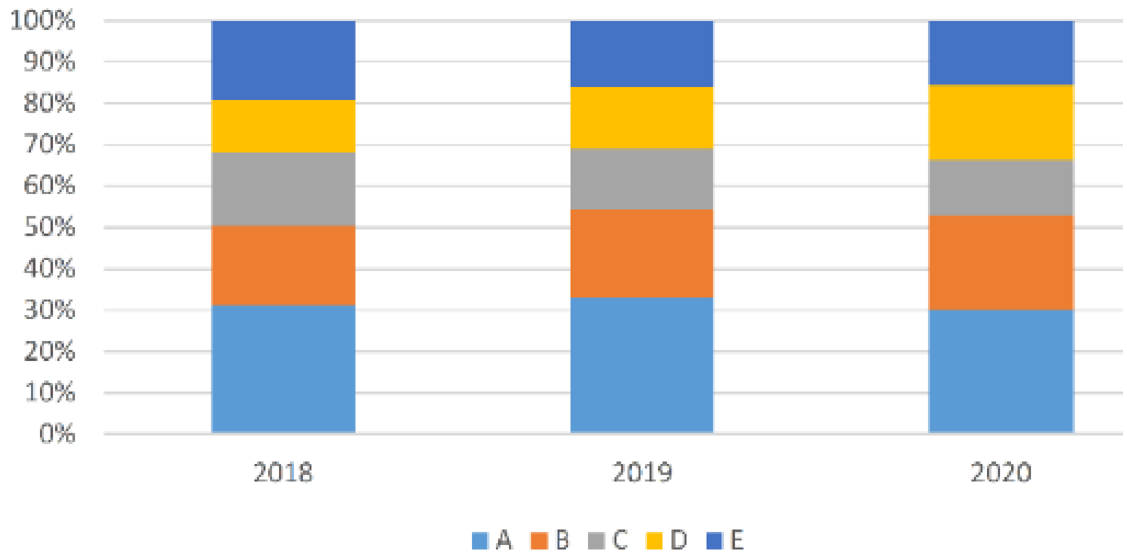
4.9 Current Status and Challenges of Road AM

4.9.1 Current Status and Challenges of Pavement AM

4.9.1.1 Inspection and Diagnosis

1) In addition to checking for abnormalities during monthly patrols, daily inspections of pavement are thoroughly carried out, such as checking the total number of bridges to check their damage in the inspections twice a year before and after the rainy season. However, manuals for daily and periodic inspections or alternative checklists have not been formulated, and it is doubtful that the inspection, diagnosis, and recording processes are uniformly implemented in each region.
2) For periodic inspections, vehicles equipped with video cameras and GPS are run once a year, and the status of each route is evaluated by the photographed images and location information.Figure 4.6 shows the transition of the road surface situation in the past three years. According to the hearing, budget distribution was small from 2019 to 2020, so there were fewer pavement improvement works, and the road surface conditions were slightly deteriorating.
3) The evaluation of the road surface conditions shown above is based on subjective judgments, and since the variation is large, the DoR purchased a road surface condition measurement vehicle with the support of the ADB in April 2021. Objective judgment is made by starting to use the measurement of IRI.

4)	The device was purchased from ROMDAS in New Zealand and staff have received a web-based lecture on measurement methods. In the future, they plans to start IRI measurement and ask ROMDAS for guidance on road surface evaluation methods. The organization hopes to obtain objective data through IRI measurements and to ensure the necessary budgets by explaining reliable data when requesting a budget to the Ministry of Finance.



Note: A (almost new), B (there are a few pothole cracks), C (worse than B but acceptable), D (lots of potholes and cracks), E (dirt roads)

Figure 4.6 Changes in Road Surface Condition Evaluations over the Past Three Years[34]

(1) Formulation of Repair Plan

1)	The repair plan has been formulated only for the following fiscal year. Originally, in addition to the low maintenance and repair costs compared to construction, Bhutan has many disasters due to landslides during the rainy season, and pavement is damaged with the collapse of the slope surface, and it is also necessary to repair them, and the environment makes it is difficult to carry out pavement repair according to the annual plan.
2)	In the plan for every single fiscal year, there is a risk that the idea of Road AM, which makes a priority system and carries out the business, is not acquired. In addition, since the previous fiscal year requires preparation work such as designing and repair method determination and preparing order books, it is necessary to formulate from a standpoint that considers the next two years. In the future, it will be a problem how to formulate an effective repair plan within a limited budget using newly measured IRI data.

(2) Daily Maintenance Management

1)	Daily maintenance such as cleaning work is carried out by laborers employed by the regional office.

[34] Hearing with the Road Authority.

It seems that the DoR regional office employs one person for every 2.0 km of road, and signs are cleaned every year in addition to waterway cleaning. However, with regard to pavement repair such as pothole repairs,are performed to mix and heat aggregates and asphalt using human power on the side of the road, fill it in a pot hole, and compact it. There is a question if the appropriate material is being created and whether the appropriate temperature control is being made.

2) According to the hearings, Bhutan has a track record of repairing potholes with room temperature coalescing materials and asphalt crack injection work, but the budget is small and at present there is no room to repair small potholes. On roads other than highways, the pothole becomes large and cannot be repaired unless it is in a dangerous state for driving. In addition, it was said that overlay repair was carried out when the potholes grew, the numbers increased, and it was not possible to cope with pothole repairs.
3) It is less expensive to deal with the damage at a small stage, but the cost is also large to respond after the damage increases. Since rainwater penetrates during the neglected period and damage to the roadbed under the pavement progresses, there is a high possibility that a vicious cycle of deterioration will occur immediately, even if the potholes are repaired , and there seems to be room for improvement.

(3) Repair

1) Pavement repairs include overlays, pothole repairs, and crack seals. The construction of the overlay was assumed to be construction of a section of 3-4 km at least. According to the hearing, the entire section where road repairs are carried out is bad, and it is not practical to replace only the areas where pavement is damaged due to cutting overlays and patching.
2) In addition, the thickness of the surface layer is as thin as about 25mm to 30mm, and it seems that overlays are carried out every five years. In addition, the place where the base layer and the subbase condition seems to be bad is visually determined, and a CBR test is performed to determine whether the lower layer should be replaced.
3) There is a possibility that overlays are also carried out in both good and bad places of pavement conditions. Instead of overlaying over the entire line, there is room to reduce repair costs by responding to the early stage of damage and focusing on repairing bad parts by pavement replacement.
4) Since there is no daily/periodic inspection manual or checklist, there is a possibility that the uniformity of the inspection method, diagnosis method, and recording method cannot be ensured between regional offices.
5) The DoR will purchase a road surface condition measurement vehicle in April 2021 and make objective judgments by measuring IRI, but it has not been able to create a concrete image of how measurement data can be collection and used for pavement repair planning.
6) It is desirable to set a repair plan in the medium to long term and make an annual plan, but it is formulated only for the following fiscal year.
7) Repair plans based on objective data (e.g. IRI) have not been developed, and cannot be explained to the Ministry of Finance.

8) The budget of the whole country is small, and the capital necessary for road repair is not allocated. Therefore, it has fallen into a vicious cycle in which it becomes a response of post-event maintenance and extra repair costs are required.
9) Small potholes cannot be processed due to lack of budget, and potholes have not been repaired since traffic was hindered. Asphalt composites for pothole repairs are made by mixing aggregates and asphalt on the side of the road and heating them. There is a possibility that the compounding material and temperature control are not performed properly.
10) The repair method uses only overlays, and cutting overlays and partial replacement work have not been adopted. Detailed repairs, such as focusing on bad parts, have not been carried out, and there is a possibility that costs may increase.

4.9.2 Current Status and Challenges of Bridge AM

(1) Inspection and Diagnosis

1) With regard to bridge inspections, monthly patrols are carried out as daily inspections, and inspections conducted twice a year around the rainy season are carried out at all bridges. Although the detailed inspections of all bridges has been completed by 2019 in the JICA technical cooperation projects, it has not been continuously inspected since then, and it has not taken root as a periodic inspections. In addition, as a result of the inspection, knowledge such as investigating the cause of the damage and determining countermeasures has not been prepared for the damage confirmed.
2) In the periodic inspection manual prepared by the technical cooperation project, periodic inspections are prescribed every 2 to 10 years. Lastly, periodic inspections were conducted in 2019, but since only a small number of bridges are good every year, it is important to conduct continuous inspections, constantly monitor the condition of bridges, and systematically pass on inspection and diagnostic technologies.
3) It seems to be felt that it is difficult to diagnose steel bridges in the locale. There are many large vehicles passing through the sites, and how to diagnose fatigue damage to steel bridges is considered to be a problem.

(2) Formulation of Repair Plan

1) The repair plan was only formulated for the next year. Bhutan had many natural disasters, and there was a tendency to spend a lot of effort and money on disaster recovery every year, and carry out repairs with the remaining labor and funds. Therefore, even if a planned repair plan is made, it is unclear how much money can be used every year, so it is not actually planned.
2) The repair plan should be planned in consideration of at least two to three years ahead, and in the year before the construction is carried out, designs and specifications should be examined, order books should be prepared, etc., and a preparatory period should be set up so that the construction can be carried out smoothly in the relevant fiscal year.

(3) Repair

1) Repair manuals have been prepared in the technical cooperation projects, and steel bridge painting, lower-part washing prevention work, Bailey bridge reinforcement, bridge protective fence repairs, etc. have been carried out. However, since the acquisition of materials such as epoxy resin necessary for crack injection work and polymer cement necessary for concrete cross-sectional restoration is unavoidable due to budget constraints, basic repairs on concrete have not been carried out, and as shown in Table 4.13, repair and reinforcement of steel bridges is the main task performed.
2) The budget for bridge maintenance costs is negligible, at about 2% of the total road maintenance costs, and it is not possible to spend a large amount of money on procurement of materials and equipment.
3) The DoR personnel feel that it is difficult to diagnose steel bridges and select repair methods, and how to proceed with repairing steel bridges including repairing Bailey bridges, which account for more than half of the number of bridges, is a problem. There are also some other repair methods shown in the repair manual, there are cases where the start has been delayed due to the problem of material supply.

Table 4.13 Budget for Bridge Repairs (Past Two Years)[35]

Fiscal Year	Repair Details	Amount of Repair (Thousands of yen)
2019-2020	Wooden Balustrade, Replacement of Sidewalk Section、	3,600
	Steel Bridge Repainting	7,200
	Reinforcement of Bridges	2,000
	Subtotal	12,800
2020-2021	Improving the Load-Bearing Capacity of Bailey Bridge 10 bridges	13,000

(4) Training and Research

1) There is a shortage of experts on bridges.

4.9.3 Current Status and Challenges of Earthworks (Slopes) AM

1) Bhutan is costly and labor-intensive to recover, and there are frequent disasters including rockfalls and landslides that cause roads to be closed to traffic during the rainy season. However, measures have been taken after the slope surface collapses have occurred, and it is a situation where periodic inspections and monitoring have not been carried out.
2) Inspection manuals and diagnostic manuals in earthworks are not maintained, and periodic inspections themselves have not been carried out. After-the-fact measures have been taken, such as considering measures after the collapse occurred.
3) In Bhutan, regardless of geological conditions, the slope surface is cut at a gradient of 70degrees,

[35] Obtained from The Bridge Division of the Road Bureau.

and slope collapses frequently occur due to abnormal rainfall. In addition, for slope countermeasure work, measures such as futon baskets and other slope corners are mainly taken, and measures such as concrete spraying and anchor construction have not been implemented.

4) There is a shortage of experts in slope disaster prevention.

4.9.4 Issues Requiring Research and Development

Among the issues extracted through the Road AM evaluation, the issues that require research and development of repair technology, long life technology, and inspection technology are shown in Table 4.14. Table 4.15 and Table 4.16 also provide draft research plans and university candidates for conducting research at Japanese universities.

Table 4.14 Issues Requiring Research and Development (Bhutan)

	Target Issues	Remarks
Pavement	No specific themes	
Bridge	Diagnosis of fatigue damage of steel bridges based on the passage of large vehicles	Difficult to diagnose steel bridges and select repair methods
Earthworks	Measures to stabilize slopes	The cut is 70 degrees gradient regardless of geological conditions, and slope collapse occurs frequently due to rainfall

Table 4.15 Draft Research Plans and University Candidates for Extracted Subjects (Bhutan, Issue 1)

Subject	Diagnosis of fatigue damage of steel bridges based on the passage of large vehicles
Background and Necessity	In Bhutan, bailey bridges (steel bridge) are used as a permanent bridge in many locations. Bailey bridges are not scheduled to be newly installed on the main highway, but many are old, and these inspections and repairs are insufficient for the mountain gorge, and damaged parts are repaired symptomatically in which the parts of the removed old Bailey bridges are diverted. On the other hand, the main industries of Bhutan are agriculture, forestry, and electric power (hydroelectric power generation), and the main export item is electric power. The power is created by hydroelectric power, but the turbines used to generate the power are transported by land to the power plant, and in some places the trailers are forced to pass through Bailey bridges. The Bailey bridges in Bhutan are designed and installed according to Indian military standards, and in the case of new construction, it is assumed that there is a suitable load capacity, but if damage is progressing with old units, the load capacity is unknown. For this reason, for Bailey bridges, which are not in service and have not been replaced, it is necessary to estimate the actual load bearing capacity for the design, reinforce them so that heavy vehicles can run safely, detect weaknesses, and research diagnostic techniques that can identify parts that need to be replaced.
Research Plan	Bailey bridges to be studied are selected, deflection and component strain associated with vehicle traffic are monitored, and the soundness of the structure is verified from the obtained data. If weaknesses are identified, simple first aid measures will be considered. For similar Bailey bridges, diagnostic techniques that can easily estimate the actual load bearing capacity of the design, detect weaknesses, and recommend the replacement of parts will be developed. The research will be provided with technology from Japan for materials and equipment and treatment methods necessary for monitoring, and inspections, measurements, analysis, and evaluations will be conducted in collaboration with Japanese universities and local universities and junior colleges.

<table>
<tr><td rowspan="2">University Candidates Bhutan</td><td colspan="2">■College of Science and Technology (CST)
One of the constituent universities of the Royal University of Bhutan (RUB), founded in 2001.
There are departments of civil engineering, civil engineering and geology, information technology, architecture, electrical engineering, electronic communication engineering, measurement, and control engineering as four-year degrees, and there is architecture as a five-year degree.
It is in Punzoring, in Chuka province, about 144 km by land, south of the capital Thimphu.</td></tr>
<tr><td colspan="2">■Jigme Namgyel Engineering College (JNEC)
One of the constituent universities of the Royal University of Bhutan (RUB), founded in 1972.
Civil engineering, electrical engineering, mechanical engineering, and two-year degrees are offered.
It is located about 400 km east of the capital Thimphu and 18 km from Samdrup Jonkar in eastern Bhutan, about 400 km by land via Indian territory.</td></tr>
<tr><td rowspan="3">University Candidates Japan</td><td>Nagasaki University</td><td>■Professor. Seizo Nakamura, Associate Professor Takafumi Nishikawa
JICA international students (master's program) are accepted from Bhutan (utilization of artificial intelligence (AI) for bridge maintenance in Bhutan).
Research that contributes to the appropriate maintenance and management of structures, such as prediction methods for structural deterioration, correlation between corrosive environment and corrosion situation, and durability evaluation of various anticorrosion methods is being conducted.</td></tr>
<tr><td>Hokkaido University</td><td>■Associate Professor Henry Michael Ward
JICA international students (master's program) are accepted from Laos (effects and effects of overload measures and weight measurement technology in asset management).
Characterization of construction materials, effective use of industrial by-products, long life of concrete structures, and evaluation methods using advanced technology are being studied.</td></tr>
<tr><td>The University of Tokyo</td><td>■Associate Professor Kohei Nagai
JICA international students (master's program) are accepted from Cambodia (utilization and analysis of bridge damage data).
Research includes mature social infrastructure, and research on reinforced concrete and infrastructure maintenance.</td></tr>
</table>

Table 4.16 Draft Research Plans and University Candidates for Extracted Subjects (Bhutan, Issue 2)

Subject	Measures for stabilization of slopes in the geology of Bhutan
Background and Necessity	The stable gradient of slopes according to geology has been standardized according to the geological classification since the dawn of the construction of expressways in Japan, and it is the basis of the examination of road design and disaster prevention measures. However, in Bhutan, with no data on slopes and geology in place, and the standard gradient according to geology having not been established, it is difficult to take permanent restoration and repair measures based on the stability of the slope (durability and long life that does not collapse) and appropriate repairs. On the other hand, the stable gradient of slopes that differ depending on the geology does not necessarily suit Bhutan following the standards formulated in other countries. For this reason, it is necessary to rely on the rule of thumb while conforming to the standard gradient of another country with similar geology, but fundamentally, scientific knowledge on the geology of Bhutan should be accumulated, and the standard gradient to be applied in Bhutan should be determined.
Research Plan	In Bhutan, the geology necessary for road design and disaster prevention measures needs to be understood, and the main geological distribution needs to be sorted and organized. The standard value is determined from the soil constant obtained by the test, and the standard gradient is determined based on the stable analysis of the slope based on this. Research will be provided by Japanese counterparts as necessary for materials and equipment and treatment methods, and on-site surveys, tests, analysis, and evaluations will be conducted in collaboration with Japanese universities and local universities and junior colleges.

University Candidates Bhutan	■College of Science and Technology (CST) One of the constituent universities of the Royal University of Bhutan (RUB), founded in 2001. There are departments of civil engineering, civil engineering and geology, information technology, architecture, electrical engineering, electronic communication engineering, and measurement and control engineering as four-year degrees, and there is architecture as a five-year degree. It is in Punzoring, in Chuka province, about 144 km by land, south of the capital Thimphu.	
	■Jigme Namgyel Engineering College (JNEC) One of the constituent universities of the Royal University of Bhutan (RUB), founded in 1972. Civil engineering, electrical engineering, mechanical engineering as two-year degrees It is located east of the capital Thimphu, about 400 km by land via Indian territory, 18 km from Samdrup Jonkar in eastern Bhutan.	
University Candidates Japan	Slope stability based on disaster prevention has been studied at many universities, and it is considered that it can be managed if international students can be accepted at universities that can research stable analysis based on soil tests. Standards such as standard gradients have been formulated under the leadership of the Ministry of Land, Infrastructure, Transport and Tourism (Civil Engineering Research Institute) and expressway companies (NEXCO Research Institute), and collaboration with such research institutes is also possible.	
	Yokohama National University	■Associate Professor Tadamu Kikumoto JICA international students (master's program) are accepted from India (Ground contamination by NAPLs). Specialized fields are geotechnical engineering, natural disaster science, and disaster prevention.
	Kyoto University	■Associate Professor Pipatpongsa Thirapong Graduated from The Chulalongkhon University, Thailand, Department of Civil Engineering. From the research of slope stability analysis by numerical geomechanics and granular body model, research is conducted on subjects like physical model experiments, ground composition rules, numerical calculation methods, and on-site application, including material property experiments aimed at improving accuracy and efficiency improvement to predict the behavior of ground and soil structures.
	University of Tsukuba	■Professor Wataru Matsushima With the aim of predicting deformation, destruction, or flow phenomena of ground and various granular materials from particle-level mechanics, basic theories are constructed, various experimental and analytical methods are developed and applied research is conducted.

4.10 Support Plan for Establishing Road AM

4.10.1 Support Plan for Pavement AM

It is considered that the support shown in Table 4.17is necessary based on the above-mentioned problems. It is desirable to systematically materialize the support plan after grasping the local pavement state, pavement improvement technology in Bhutan, and the procurement possibility of materials. Therefore, it is considered that it is effective to visit the site regularly by the scheme of the technical cooperation project, and to give due consideration to the local situation.

Table 4.17 Support Plan for Pavement AM

	Issues	Contents	Support Plan
1	Evaluation of road surface condition by IRI measurement	The IRI measurement vehicle is used to quantitatively grasp and evaluate road surface conditions.	ROMDAS, a NZ company, is providing guidance to the DoR on how to measure and set

	Issues	Contents	Support Plan
			control levels with support from the ADB.
2	Formulate repair plan based on IRI measurement data	Prioritize the routes and identify the priority areas for repair. They will also make future projections of damage and be able to provide convincing explanations to the Ministry of Finance.	Supported by the JICA technical cooperation projects.
3	Effective Response to Frequent Pothole Occurrences	By dealing with potholes from a minor damage stage, the strength of the underlying roadbed is improved, and the life cycle cost is reduced. Improve asphalt mixture preparation method and construction management method to support durable pothole treatment.	
4	Improving the design and construction of pavement improvement projects	The introduction of cutting overlays and pavement replacement works will enable the adoption of repair methods that focus only on the bad areas of the pavement. The pavement configuration will be reviewed and a pavement configuration with durability will be considered. Use FWD testing equipment to identify areas of poor roadbed condition in the subgrade.	

4.10.2 Support Plan for Bridge AM

It is necessary to steadily carry out periodic inspections and to enhance diagnosis and records. It is hoped that the periodic inspections are not carried out all at once but executed little by little every year. Make sure that the inspection, diagnosis, and recording cycles are rooted in the issues. Then, as shown in Figure 4.7, the state of the bridge should always be monitored and reflected in the budget request.

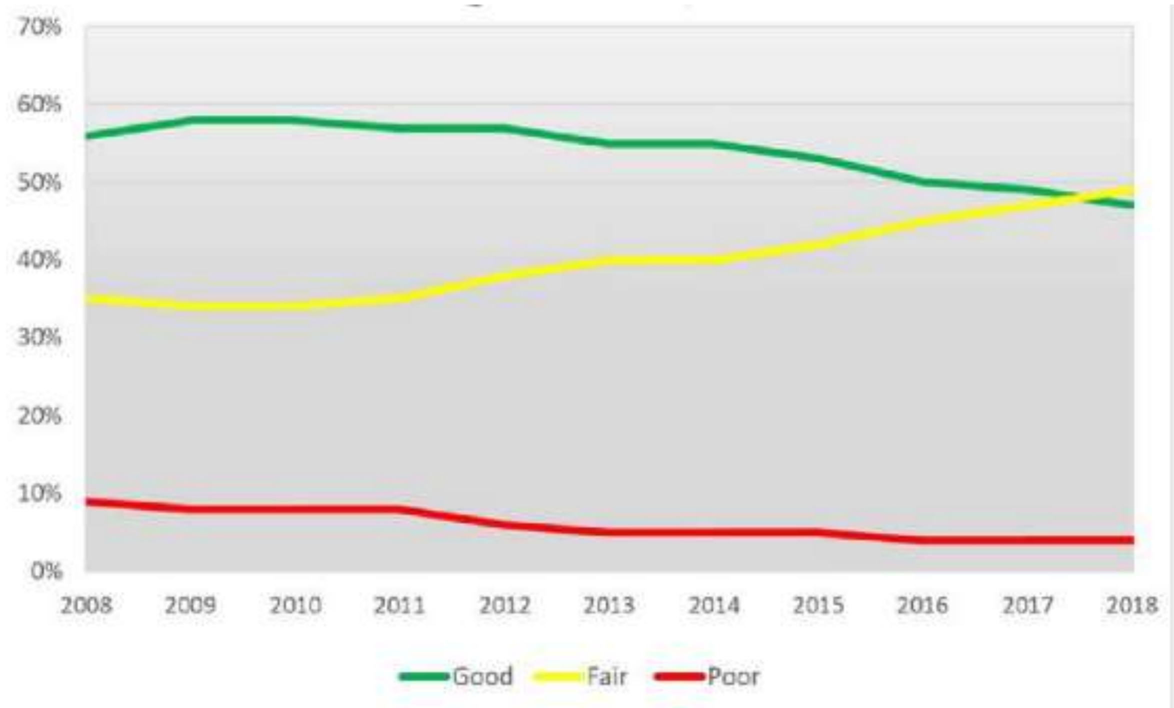


Figure 4.7 Example of Monitoring for Condition Evaluation of Bridges[36]

In addition, it is necessary to formulate repair plans that anticipates at least two to three years ahead and prepares design examinations, specification examinations, construction ordering materials, etc. by the previous fiscal year. Support the creation of medium-term repair plans using BMS.

In addition to deploying the repainting, prevention of basic scuffling of lower construction, and repairs of bridge protection fences in all regions, which were introduced in the technical cooperation project, procurement routes for repair materials that are difficult to obtain locally, such as concrete repair materials, will be secured so that appropriate repairs can be adopted at the proper time. In addition, it is necessary to create a study flow for diagnosis and repair when reinforcing steel bridges so that the steel bridges can be appropriately reinforced. Table 4.18 describes a support plan for Bridge AM.

It is considered effective to continue to support bridges in conjunction with pavement bassed the technical cooperation projects, taking into account the budget constraints in the bridge field of the DoR, with the intention of ensuring that the content supported by the current technical cooperation projects will be developed locally.

Table 4.18 Support Plan for Bridge AM

	Issues	Contents	Support Plan
1	Steady implementation of periodic inspections, diagnosis, and recording	The inspection plan should be formulated based on the premise of the location and age of the structure, the occurrence of abnormalities, as well as the organizational structure, budget, and quantity. Install equipment required for periodic inspections and conduct detailed surveys.	The project will be implemented as a technical cooperation project for pavement and bridges.

[36] DOT, Colorado, USA [2019], Risk-based asset management plan version 2.

	Issues	Contents	Support Plan
2	Formulation of medium and long-term plans	Develop a plan for at least the next two years. Research, design, and prepare bidding documents from the previous year.	
3	Supporting the local deployment of repair methods	Establish a system to implement Road AM, from inspections and diagnosis to planning and implementation of repairs. Appropriate repair plans and preventive maintenance will reduce required funds overall.	
4	Training of engineers and cooperation with local universities	Train engineers who are familiar with bridges. Share issues and collaborate with local universities.	JICA Training and Invitation and acceptance of international students to Japanese universities
5	Securing the budget	Explain to the financial authorities the need for maintenance and repair quantitatively using objective data. Increase efficiency of pavement maintenance and consider increasing the bridge budget.	Respond in your own country

4.10.3 Support Plan for Earthworks (Slopes) AM

Table 4.19 Support Plan for Earthworks (Slopes) AM

	Issues	Contents	Support Plan
1	Training of engineers and cooperation with local universities	Train engineers who are knowledgeable about slope disaster prevention. Share issues, collaborate with local universities, and research institutions.	JICA Training and invitation and acceptance of international students to Japanese universities

4.11 List of Road AM Evaluation Results in Bhutan

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Pavement	2.3	51.0%	(1) Inspection	2.2	51%	((1)) Inspection system	1.7	33%	<1> System	1.0	20%
									<2> Technical level of inspectors	2	40%
									<3> Use of inspection equipment	2	40%
						((2)) Inspection manual	1.1	27%	<4> Existence of daily inspection manual	1	20%
									<5> Use of daily inspection manual	1	33%
									<6> Existence of periodic inspection manual	1	20%
									<7> Use of periodic inspection manual	1	33%
									<8> Technical level of the manual	1.3	27%
						((3)) Implementation of daily inspections	3.3	80%	<9> Inspection range	5	100%
									<10> Frequency of inspections	3	100%
									<11> Storage and sharing of inspection records	2	40%
						((4)) Implementation of periodic inspections	3.3	80%	<12> Inspection range	5	100%
									<13> Frequency of inspections	3	100%
									<14> Storage and sharing of inspection records	2	40%
			(2) Diagnosis	1.8	37%	((5)) Diagnostic system	1.5	30%	<15> System	1.0	20%
									<16> Technical level of diagnosis	2	40%
						((6)) Diagnostic manual (As, Co, D, EXT)	1.3	31%	<17> Existence of diagnostic manual	1	20%
									<18> Use of diagnostic manual	1	33%
									<19> Technical level of the manual	2.0	40%
						((7)) Diagnosis of soundness (As, Co, D, EXT)	2.3	47%	<20> Investigation of the cause of damage	3	60%
									<21> Ranking of damage level	2	40%
									<22> Storage and sharing of diagnostic records	2	40%
			(3) Repair and rehabilitation plan	2.4	49%	((8)) Pavement assets ledger/DB	3.0	60%	<23> Existence of pavement assets ledger/DB	3	60%
									<24> Use of pavement assets ledger/DB	3	60%
						((9)) Pavement management system	2.5	50%	<25> Existence of pavement management system	2	40%
									<26> Use of pavement management system	3	60%
						((10)) Development of the plan	2.2	44%	<27> Planning	2	40%
									<28> Scope of the plan	2	40%
									<29> Prediction of soundness	1	20%
									<30> Understanding of the cost of repairs and rehabilitation	4	80%
									<31> Preventive maintenance	2	40%
			(4) Daily maintenance and management	2.4	58%	((11)) System for daily maintenance and management	1.7	33%	<32> System	1.0	20%
									<33> Technical level of the person responsible for maintenance management	2	40%
									<34> Operation of maintenance work equipment (pavement)	2	40%
						((12)) Cleaning (road surface)	3.5	70%	<35> Cleaning range	4	80%
									<36> Frequency of cleaning	3	60%
						((13)) Emergency measures	2.5	70%	<37> Management of response to deformation and damage	2	40%
									<38> Small repair of deformations (temporary repair)	3	100%
									<39> Emergency restoration of failures, etc.	3	100%
									<40> Storage and sharing of emergency measure records	2	40%
			(5) Repair	2.5	60%	((14)) Repair system	2.5	50%	<41> System	2.5	50%
									<42> Technical level of repair	3	60%
									<43> Procurement of materials and equipment	2	40%
						((15)) Quality standards (As, Co, D, EXT)	3.0	73%	<44> Existence of quality standards	3	60%
									<45> Application of quality standards	3	100%
									<46> Quality control	3	60%
						((16)) Repair (Design) manual	2.4	63%	<47> Existence of repair (design) manual	2	40%
									<48> Use of repair (design) manual	3	100%
									<49> Technical level of the manual	2.2	49%
						((17)) Implementation of repairs	2.3	55%	<50> Construction planning and process management	2	40%
									<51> Repair (radical repair)	3	100%
									<52> Management of changes	2	40%
									<53> Storage and sharing of repair records	2	40%
			(6) Rehabilitations and reconstructions	2.1	45%	((18)) System for rehabilitations and reconstructions	2.5	50%	<54> System	2.5	50%
									<55> Level of technology for rehabilitations and reconstructions	3	60%
									<56> Procurement of materials and equipment	2	40%
						((19)) Implementation of rehabilitations and reconstructions	1.8	42%	<57> Implementation plan	1	20%
									<58> Rehabilitations and reconstructions	2	67%
									<59> Management of changes	2	40%
									<60> Storage and sharing of records of rehabilitations and reconstructions	2	40%

Figure 4.8 List of Road AM Evaluation Results in Bhutan【Pavement】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
2 Bridges	2.4	53.6%	(7) Inspection	2.4	55%	((20)) Inspection system	3.0	60%	<61> System	4.0	80%
									<62> Technical level of inspectors	3	60%
									<63> Use of inspection equipment	2	40%
						((21)) Inspection manual	2.0	51%	<64> Existence of daily inspection manual	1	20%
									<65> Use of daily inspection manual	1	33%
									<66> Existence of periodic inspection manual	3	60%
									<67> Periodic inspection manual operation	3	100%
									<68> Technical level of the manual	2.0	40%
						((22)) Implementation of daily inspections	1.0	24%	<69> Inspection range	1	20%
									<70> Frequency of inspections	1	33%
									<71> Storage and sharing of inspection records	1	20%
						((23)) Implementation of periodic inspections	3.7	87%	<72> Inspection range	5	100%
									<73> Frequency of inspections	3	100%
									<74> Storage and sharing of inspection records	3	60%
			(8) Diagnosis	2.3	50%	((24)) Diagnostic system	1.5	30%	<75> System	2.0	40%
									<76> Technical level of diagnosis	1	20%
						((25)) Diagnostic manual (M, Co, EXT)	2.6	60%	<77> Existence of diagnostic manual	3	60%
									<78> Use of diagnostic manual	2	67%
									<79> Technical level of the manual	2.7	53%
						((26)) Diagnosis of soundness(M, Co, EXT)	2.7	53%	<80> Investigation of the cause of damage	3	60%
									<81> Ranking of damage level	2	40%
									<82> Storage and sharing of diagnostic records	3	60%
			(9) Repair and rehabilitation plan	2.4	49%	((27)) Bridge assets ledger/DB	4.0	80%	<83> Existence of bridge assets ledger/DB	3	60%
									<84> Use of bridge assets	5	100%
						((28)) Bridge management system	2.0	40%	<85> Existence of bridge management system	3	60%
									<86> Use of bridge management system	1	20%
						((29)) Development of the plan	2.0	40%	<87> Planning	2	40%
									<88> Scope of the plan	2	40%
									<89> Prediction of soundness	1	20%
									<90> Understanding of the cost of repairs and rehabilitation	2	40%
									<91> Preventive maintenance	3	60%
			(10) Daily maintenance and management	2.2	52%	((30)) System for daily maintenance and management	1.0	20%	<92> System	1.0	20%
									<93> Technical level of the person responsible for maintenance and management	1	20%
									<94> Operation of maintenance and management work equipment (bridges)	1	20%
						((31)) Cleaning (road surface)	3.5	70%	<95> Cleaning range	4	80%
									<96> Frequency of cleaning	3	60%
						((32)) Emergency measures	2.5	67%	<97> Management of response to deformation and damage	3	60%
									<98> Small repair of deformation (temporary repair)	2	67%
									<99> Emergency restoration of failures, etc.	3	100%
									<100> Storage and sharing of emergency measure records	2	40%
			(11) Repair	2.5	57%	((33)) Repair system	2.7	53%	<101> System	3.0	60%
									<102> Technical level of repair	3	60%
									<103> Procurement of materials and equipment	2	40%
						((34)) Quality standards (M, Co, EXT)	2.3	56%	<104> Existence of quality standards	3	60%
									<105> Application of quality standards	2	67%
									<106> Quality control	2	40%
						((35)) Repair (Design) manual	2.4	59%	<107> Existence of repair (design) manuals	3	60%
									<108> Use of repair (design) manual	2	67%
									<109> Technical level of the manual	2.2	51%
						((36)) Implementation of repairs	2.5	60%	<110> Repair planning and process management	3	60%
									<111> Repair (radical repair)	3	100%
									<112> Management of changes	1	20%
									<113> Storage and sharing of repair records	3	60%
			(12) Rehabilitations and reconstructions	2.6	57%	((37)) System for rehabilitations and reconstructions	3.0	60%	<114> System	4.0	80%
									<115> Level of technology for rehabilitations and reconstructions	3	60%
									<116> Procurement of materials and equipment	2	40%
						((38)) Implementation of rehabilitations and reconstructions	2.3	55%	<117> Implementation plan	3	60%
									<118> Rehabilitation and reconstruction	3	100%
									<119> Management of changes	1	20%
									<120> Storage and sharing of records of rehabilitations and reconstructions	2	40%

Figure 4.9 List of Road AM Evaluation Results in Bhutan【Bridges】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
3 Earthworks(Slope)	2.2	49.0%	(13) Inspection	1.9	43%	((39)) Inspection system	1.7	33%	<121> System	1.0	20%
									<122> Technical level of inspectors	2	40%
									<123> Operation of inspection equipment	2	40%
						((40)) Inspection manual	1.1	27%	<124> Existence of daily inspection manual	1	20%
									<125> Use of daily inspection manual	1	33%
									<126> Existence of periodic inspection manual	1	20%
									<127> Use of periodic inspection manual	1	33%
									<128> Technical level of the manual	1.3	27%
						((41)) implementation of daily inspections	2.7	62%	<129> Inspection range	4	80%
									<130> Frequency of inspections	2	67%
									<131> Storage and sharing of inspection records	2	40%
						((42)) Implementation of periodic inspections	2.7	62%	<132> Inspection range	4	80%
									<133> Frequency of inspections	2	67%
									<134> Storage and sharing of inspection records	2	40%
			(14) Diagnosis	1.8	37%	((43)) Diagnostic system	2.3	45%	<135> System	2.5	50%
									<136> Technical level of diagnosis	2	40%
						((44)) Diagnostic manual (Slope, utility and drainage structures, retaining walls)	1.2	29%	<137> Existence of diagnostic manual	1	20%
									<138> Use of diagnostic manual	1	33%
									<139> Technical level of the manual	1.7	33%
						((45)) Diagnosis of soundness (Slope, utility and drainage structures, retaining walls)	2.0	40%	<140> Investigation of the cause of damage	3	60%
									<141> Ranking of damage level	1	20%
									<142> Storage and sharing of diagnostic records	2	40%
			(15) Repair and rehabilitation plan	2.3	46%	((46)) Earthwork assets ledger/DB	3.5	70%	<143> Existence of earthwork assets ledger/DB	3	60%
									<144> Use of earthwork assets ledger/DB	4	80%
						((47)) Development of the plan	1.8	36%	<145> Planning	1	20%
									<146> Scope of the plan	1	20%
									<147> Prediction of soundness	1	20%
									<148> Understanding of the cost of repairs and rehabilitations	4	80%
									<149> Preventive maintenance	2	40%
			(16) Daily maintenance and management	2.9	64%	((48)) System for daily maintenance and management	1.8	35%	<150> System	1.0	20%
									<151> Technical level of the person responsible for maintenance and management	2	40%
									<152> Operation of maintenance and management work equipment (earthworks)	2	40%
									<153> Operation of maintenance work equipment (accessories)	2	40%
						((49)) Mowing	4.0	80%	<154> Mowing area	5	100%
									<155> Frequency of mowing	3	60%
						((50)) Cleaning (waterways)	4.0	80%	<156> Cleaning range	5	100%
									<157> Frequency of cleaning	3	60%
						((51)) Cleaning (signs)	4.0	80%	<158> Cleaning range	5	100%
									<159> Frequency of cleaning	3	60%
						((52)) Emergency measures	2.5	70%	<160> Management of response to deformation and damage	2	40%
									<161> Small repair of deformation (temporary repair)	3	100%
									<162> Emergency restoration of failures, etc.	3	100%
									<163> Storage and sharing of emergency measure records	2	40%
			(17) Repair	2.2	51%	((53)) Repair system	2.3	47%	<164> System	2.0	40%
									<165> Technical level of repair	3	60%
									<166> Procurement of materials and equipment	2	40%
						((54)) Quality standards(Slope, retaining wall, drainage structure)	3.0	73%	<167> Existence of quality standards	3	60%
									<168> Application of quality standards	3	100%
									<169> Quality control	3	60%
						((55)) Repair (Design) manual	1.4	33%	<170> Existence of repair (design) manuals	1	20%
									<171> Use of repair (design) manual	1	33%
									<172> Technical level of the manual	2.1	45%
						((56)) Implementation of repairs	2.0	50%	<173> Construction planning and process management	1	20%
									<174> Repair (radical repair)	3	100%
									<175> Management of changes	2	40%
									<176> Storage and sharing of repair records	2	40%
			(18) Rehabilitations and reconstructions	2.0	44%	((57)) System for rehabilitation and reconstruction	2.3	47%	<177> System	2.0	40%
									<178> Level of technology for rehabilitations and reconstructions	3	60%
									<179> Procurement of materials and equipment	2	40%
						((58)) Implementation of rehabilitations and reconstructions	1.8	42%	<180> Implementation plan	1	20%
									<181> Rehabilitations and reconstructions	2	67%
									<182> Management of changes	2	40%
									<183> Storage and sharing of records of rehabilitations and reconstructions	2	40%

Figure 4.10 List of Road AM Evaluation Results in Bhutan【Earthworks (Slopes)】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Surveillance (monitoring)	3.1	67.5%	(19) Traffic conditions	3.8	85%	((59)) Traffic volume	3.8	85%	<184> Monitoring range	4	80%
									<185> Monitoring frequency	3	100%
									<186> Monitoring sites	3	60%
									<187> Information sharing and utilization of monitoring results	5	100%
			(20) Meteorology and disaster prevention	2.5	50%	((60)) Precipitation, temperature, wind	2.5	50%	<188> Monitoring range	2	40%
									<189> Monitoring frequency	3	60%
									<190> Monitoring sites	2	40%
									<191> Information sharing and utilization of monitoring results	3	60%
Organizational management	2.3	51.2%	(21) Organizational structure	2.3	49%	((61)) Asset management cycle	1.7	33%	<192> Setting management goals	3	60%
									<193> Conducting internal audits	1	20%
									<194> Implementation of management review	1	20%
						((62)) Organization	3.0	60%	<195> Role-sharing	3	60%
									<196> Manpower allocation	3	60%
						((63)) Control	2.7	67%	<197> Commitment from the top	3	100%
									<198> Influence of the organization	3	60%
									<199> Motivation and ability of counterpart	2	40%
						((64)) Business continuity	2.0	40%	<200> Responding to accidents	2	40%
									<201> Responding to rainfall	2	40%
									<202> Responding to earthquakes	2	40%
						((65)) Operational support facilities	2.5	50%	<203> Training facility	2	40%
									<204> Communication facilities	3	60%
			(22) Budget funding	3.0	70%	((66)) Budget	3.5	70%	<205> Budget planning	4	80%
									<206> Budgetary allocation	3	60%
						((67)) Raising funds	2.5	70%	<207> Short-term financing	3	100%
									<208> Long-term financing	2	40%
			(23) Bidding and contracting system	3.0	60%	((68)) Bidding and contracting system	3.0	60%	<209> Cost estimation standard	3	60%
									<210> Prevention of collusion	3	60%
									<211> Contract method	3	60%
									<212> Procurement process	3	60%
									<213> Contract change	3	60%
			(24) Technical training	1.3	36%	((69)) Pavement training	2.0	53%	<214> Training plan	2	67%
									<215> Contents of training	2	40%
						((70)) Bridge training	1.0	27%	<216> Training plan	1	33%
									<217> Contents of training	1	20%
						((71)) Earthwork training	1.0	27%	<218> Training plan	1	33%
									<219> Contents of training	1	20%

Figure 4.11 List of Road AM Evaluation Results in Bhutan【Surveillance (Monitoring), Organizational Management】

Chap.5 Current Status, Issues, and Support Plan for Road AM in Thailand

5.1 Target of the Chapter

The background of the tunnel project supervision capacity improvement project in Thailand, the outline of road maintenance and management, the outline of the technical cooperation project, construction, maintenance and management capability, and technical level will be investigated in this chapter. In addition, using the evaluation sheet of Road AM, we will confirm the maturity of Road AM in Thailand through interviews with technical cooperation project teams and their counterparts. In addition, we will identify issues and formulate support plans for establishing Road AM.

5.2 Overview

JICA aims to build a foundation for the project supervision of mountain tunnel construction projects in Thailand by supporting the establishment of an organization related to tunnel projects at the Department of Highways (hereinafter referred to as DOH) and with the aim of contributing to the promotion of national highway development in Thailand, the improvement of organizational and research design capabilities for project supervision, and the formation and supervision of the mountain road tunnel construction project by DOH, we have started the Project for Capacity Development on Tunnel Project Management during the construction period from December 2020 to November 2024.

In this survey, online interviews were conducted with the DOH. These were used to understand the general situation of DOH's construction and maintenance capability and technical levels and to evaluate the maturity of Road AM by DOH. Based on the results of this study, the current status and issues of asset management for pavement, bridges, and earthworks (slopes) in Thailand were identified and organized, and a support plan for establishing Road AM was formulated and proposed. The outline is as follows:

As for pavement, the DOH has sufficient technical capabilities and can respond. Revisions to inspections, diagnosis, and repair manuals that are easier to use at the site level can be managed in Japan by utilizing workshops.

As for bridges, the DOH has technical capabilities and can respond. However, although complex structures are to be implemented through outsourcing, it is necessary to formulate and implement periodic inspections and diagnostic plans after determining priorities according to the budget, since it is feared that they will not be consigned as planned due to restrictions on securing budgets which will lead to delays in responding to deterioration of structures.

As for earthworks, the DOH recognizes that earthworks are weak points, and it is necessary to raise the level of technical capabilities through human resource development and manual development. In the future, it is expected that the JICA technical cooperation projects will be introduced to improve technical capabilities.

Regarding surveillance (monitoring), it is necessary to promote the installation of necessary equipment to utilize weather and disaster prevention monitoring for traffic regulations. In addition, the idea is to transfer technology to the ongoing JICA Tunnel Technical Cooperation Project for landslide monitoring systems.

5.3 Background of the Technical Cooperation Project

Many road improvements in Thailand are conducted by the DOH and Department of Rural Roads (hereinafter referred to as DRR) within the Ministry of Transport (hereinafter referred to as MOT), and as of 2012, the first to third class national highways have been maintained for a total length of 51,610 km, which is the same total length of Japan's national highways. The first-class national highways connecting major cities are maintained as a high standard road with three lanes or more on one side divided depending on the direction, and it can be said that the level of maintenance is comparable to that of developed countries. On the other hand, in mountainous areas, even on class 1 national highways, there are many unseparated sections of one lane on each side with continuous sharp curves, leading to an increase in logistics costs and frequent accidents.

The Thai government has formulated the 12th National Economic and Social Development Plan (2017-2021) as a policy on economic and social development, and has set the development of local, urban, and special economic zones as one of its policies. Trucking accounts for 87.5% of Thailand's freight forwarding, and road infrastructure is one of the most important infrastructures in Thailand.
Therefore, to ensure smooth logistics to avoid traffic congestion and to suppress frequent traffic accidents, the 7th Road Improvement 7-Year Plan (2014-2022), which was formulated in July 2014, included a highway construction plan. Based on the plan, in 2015, a 20-year plan for the development of intercity expressways (motorways) was formulated, stating that “we will invest about 2 trillion baht (about 6.5 trillion yen) over the next 20 years to develop a 6,400 km nationwide access-controlled expressway network.” The project also includes a route connecting cities in the mountainous region, and to ensure good vertical alignment, several mountain roads tunnels, including a route between Turk and Masort on the East-West Economic Corridor, and the development of a tunnel with a length of more than 10 km is also included.

On the other hand, mountain tunnels in Thailand have been used for railway and waterway tunnels, but they yet to be used as road tunnels that require large cross sections and various equipment, and it is necessary to improve the DOH’s ability to investigate, plan, design, construct and implement project supervision and maintenance for the future maintenance of mountain road tunnels.

Considering this situation, the DOH requested JICA to implement technical cooperation projects related to capacity development regarding investigation, planning, design, construction, project supervision, maintenance, and management for mountain road tunnel maintenance.

5.4 Overview of Road Maintenance in Thailand

5.4.1 Road Maintenance and Management Extension

The total road length in Thailand is about 700,000 km, and it consists mainly of six types of roads as shown in Table 5.1, such as the general national highway managed by the DOH (about 50,000 km), the national highway managed by DRR (about 50,000 km), local government roads (about 600,000 km) managed by local government, and the expressway (about 225 km) managed by the Thai Expressway Authority of Thailand (hereinafter referred to as EXAT).

Table 5.1 Road Administrator and Classification[37]

Road Classification	Administrator	Extension (km)
National Highway	DOH	51,850.0
Motorway	DOH	291.6
Expressway	EXAT	224.6
Rural Road	DRR	48,031.4
Local Road	Bangkok Metropolitan Administration (BMA)	4,074.3
	Department of Local Administration (DLA)	597,667.0
Concession Road	DOH	20.9

5.4.1.1 National Highway

The National Highway is an important road connecting local and intercity areas throughout the whole country, and is under construction, management, and jurisdiction by the DOH. The pavement rate is about 100%, and the structural standards are shown in Table 5.2. As of 2017, the extension was approximately 51,850 km, equivalent to that of Japan's general national highway. The main national highway is equipped with more than three lanes on each side.

Table 5.2 Structural Standards for National Highways

Structural Standards	Overview	Route Number
Primary National Highway	Main roads connecting the regions	1 or 2 digits
Secondary National Highway	Main roads within each region	Three digits
Third-class National Highway	Roads connecting prefectural and metropolitan government offices, or between metropolitan government offices	Four digits

5.4.1.2 Motorway

It is a high-standard road built, managed, and controlled by the DOH and has controlled access. As of 2019, a total of 291.6 km has been used, including Lines 7 (between Bangkok and Chonburi) and No. 9 (Bangkok No. 2 Outer Ring Road).

Currently, the extension of Line 7 towards Rayong, Route 6 extending from Bangkok to the northeast (between Bang Pa-in and Nakhon Ratchasimah), and Route 81 (between Ban Yai and Kanchanaburi) extending from Bangkok to the west are under construction, aiming to be usable in 2020. In addition, Lines 82 (between Bankung Tian and Pak Tho) and 84 (Hart Yai-Malaysia border), which extend from Bangkok to the south, are under consideration with the aim of opening from 2023 to 2024. Most of these intercity expressways are operated, constructed, and managed as public-private partnerships (hereinafter referred to as PPP).

5.4.1.3 Expressway

The expressway is a toll highway mainly in Bangkok under the administration EXAT. As of 2019, the operating section is 224.6 km, with an average of about 1.8 million vehicles per day. EXAT, which was established in 1972 under the Ministry of Interior at the time, have been developed and operated for the

[37] Thailand Economic Overview (2018/2019) OTP Report Transport Infrastructure 2018, Transport Statistics, MOT (http://www.motoc.mot.go.th/stat/roadinfra.php)

purpose of easing the saturated road conditions in the city. Since the opening of the section in 1981, certain improvements have been confirmed in alleviating traffic congestion in cities.

Part of the Bangkok Metropolitan Expressway, which is under the jurisdiction of EXAT, is operated by a private company, BEM (Bangkok Expressway and Metro), as a BTO (Build-Transfer-Operate) type concesionear.

5.4.1.4 Rural Roads

Constructed, managed, and administered by DRR. The total length as of 2018 is about 48,000 km.

5.4.1.5 Local Roads

Local roads are constructed and managed by local governments including the Bangkok Metropolitan Administration (hereinafter referred to as BMA) and is administered by the Governor. In BMA, etc., they build and manage themselves, but DRR builds roads in municipalities other than major cities, and the management may be transferred to local governments.

5.4.1.6 Concession Roads

Although they are under the administrationn of DOH, they are public roads that the private sector constructs under a contract with DOH (BTO system) and collects construction funds by collecting fees from road users.

DOH is an administrative body under MOT and is responsible for the construction and management of Thailand's National Highway and intercity highways (Motorways).

The organizational structure is mainly composed of a headquarters and regional offices. The regional offices consist of 18 regional offices of highways, five road construction training centers and four bridge construction training centers. The regional bureau manages 104 highway district offices. The organizational structure of the DOH is shown in Figure 5.1.

The number of employees is 7,014 for Official employees, 3,784 for permanent employees, and 6,974 for government employees.

Figure 5.1 Organizational Structure of the DOH (Relationship Between the Main Office and Regional Offices)

5.4.2 Organizational Structure of the DRR

DRR is an administrative body under the jurisdiction of MOT and is responsible for the construction and management of rural roads in Thailand.

The organizational structure consists mainly of headquarters, 18 bureaus for rural roads and 76 rural road offices. The headquaters has three deputy directors general and three engineers under the directors general, and twelve bureaus, one center, and three offices. The construction and maintenance of roads and bridges in the Bangkok metropolitan area are operated by this bureau, and the local roads offices oversee the construction and maintenance throughout the 76 provinces, excluding Bangkok City. The organizational structure of DRR is shown in Figure 5.2.

The number of employees is 1,806 for Official, 739 for Permanent Employee, and 2,224 for Government Employee.

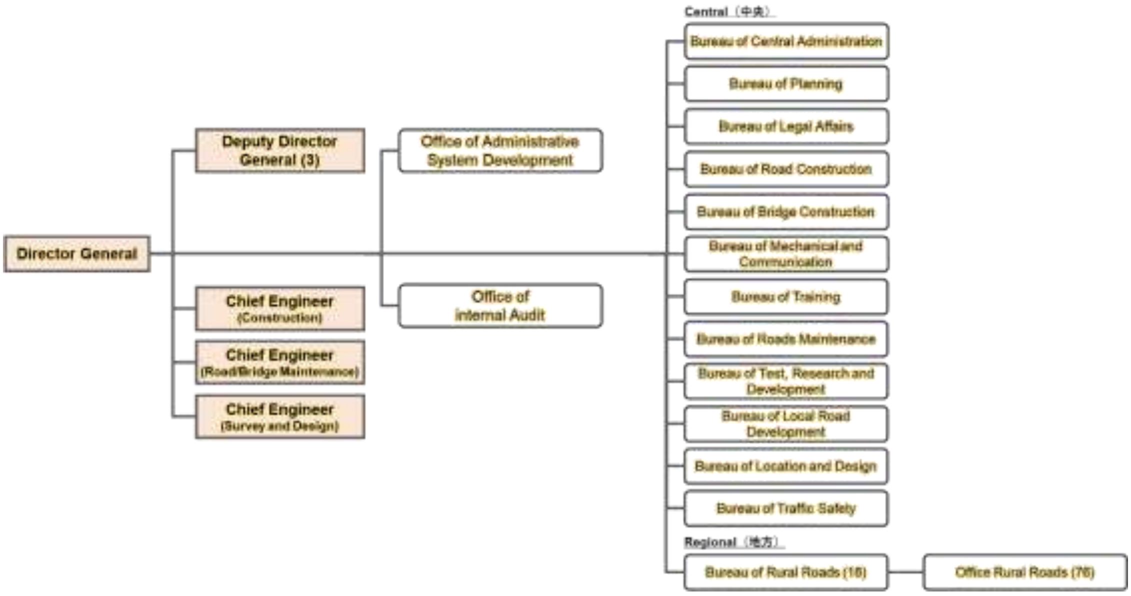


Figure 5.2 DRR Overall Organizational Structure[38]

5.4.3 Budget and Financial Situation

The annual budget of the DOH is shown in Table 5.3. The budget for fiscal year 2018 was THC 105.747 billion, and it was about 3.6% of the national budget ratio. The DOH's fiscal year 2018 budget is about twice as large as it was in fiscal year 2013. In addition, the ratio of the DOH budget to the national budget amount is also on an upward trend year by year.

Figure 5.3 shows the breakdown of DOH budgets for fiscal year 2017 and fiscal year 2018. The construction budget occupies the highest percentage of the total budget amount, and the maintenance budget is the highest after that.

[38] DRR Annual Report 2018.

Table 5.3 DOH Annual Budget[39]

Fiscal Year	Budget (Unit: million baht)		Ratio (b/a)
	National Budget (a)	DOH Budget (b)	
2018	2,900,000	105,747	3.6%
2017	2,733,000	91,280	3.3%
2016	2,720,000	77,510	2.8%
2015	2,575,000	60,334	2.3%
2014	2,525,000	52,759	2.1%
2013	2,400,000	52,966	2.2%

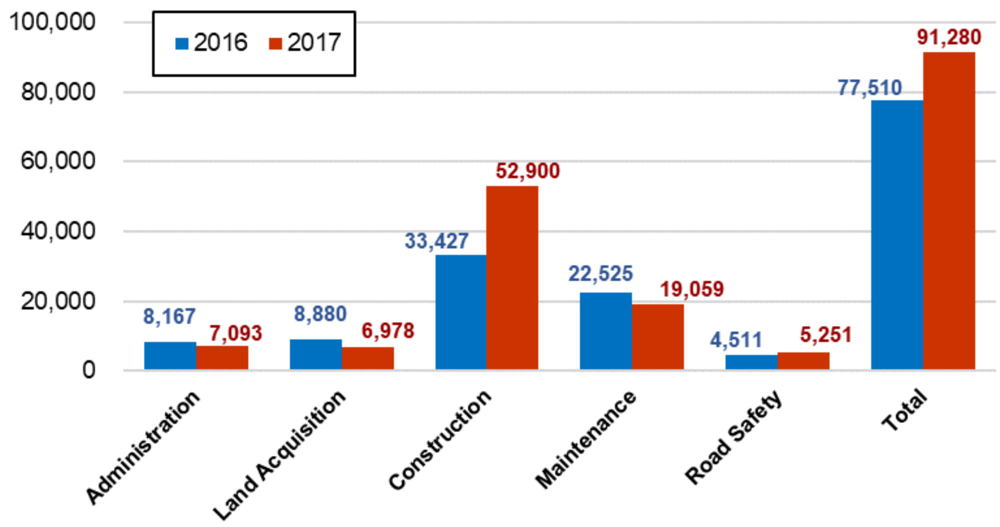


Figure 5.3 Breakdown of DOH Budget (2016/2017)[40]

5.4.4 Technical Capabilities, Human Resource Development, etc.

The DOH has jurisdiction of construction, management, and supervision for major highways in Thailand, including national highways and intercity highways, and the total length of the managed roads is approximately 52,000 km, which is equivalent to the length of highways in Japan. Many managed roads have more than three lanes on each side, and the pavement condition is maintained well, indicating that the development capacity of roads and bridges is high. On the other hand, there have been only two road tunnels built so far, and the capacity to construct and supervise road tunnels is insufficient. On the other hand, the DOH has a program to support PhD degrees in the ministry, and there are many staff who have obtained PhDs in the United States and Europe, and it is presumed that the individual staff are highly capable.

5.4.5 Support Status of Each Donor on Road AM

(1) JICA

Thailand's challenges are “strengthening industrial competitiveness,” “measures against aging,”

[39] DOH Annual Report 2018.
[40] Created a research team based on DOH Annual Report 2017.

"measures against environment and climate change," and "strengthening cooperation with neighboring countries," and Japan's priority areas for cooperation with neighboring countries are "continuous economic development and response to a mature society," "responding to common issues in the ASEAN region," and "third-country assistance to countries outside ASEAN."

The purpose of this survey is to contribute to the expansion of expressway networks in Thailand in the future by supporting the capacity development of mountain road tunnels in the DOH. Therefore, this research project is in line with Japan's assistance policy as it realizes the securing and strengthening of road traffic functions, which are essential for the economic development of Thailand and ASEAN.

The Thai government's full-fledged road improvement plan was initiated from the Seven-year Road Improvement Plan (1965-1971), which was developed in response to the First National Social Development Plan (1962-1966). In response, official development assistance from the Government of Japan began with technical cooperation in 1954, and in 1968 a paid financial cooperation project (yen loan project), and in 1970 a grant aid project, were started.

Since then, the roads developed through yen loan projects have been developed as many roads such as the Metropolitan Expressway in the Bangkok metropolitan area, the Chao Phraya River Bridge Construction Project, and main highway development, and these still function as important infrastructure developments that serve as the backbone of the city. For Thailand, Japan is exceptionally large in terms of both investment and aid, and for Japan, the country has become an important economic activity partner, such as through the expansion of many Japanese companies. Table 5.4 shows Japan's assistance to Thailand (in the transportation and transportation sector).

Table 5.4 Japan's Assistance to Thailand (Transport and Traffic Sector)[41]

Business Type	Period/Conclusion Date	Project Name
Technical Cooperation	April 2019 - March 2020	Project for Improving Traffic Congestion in Bangkok Metropolitan Administration through the Development of a Model Regional Traffic Control System
Technical Cooperation	October 2011 - July 2013	Bridge master plan development and bridge maintenance capacity project in rural areas
Technical Cooperation	April 2001 - March 2003	Railroad Training Center
Loan	Loan Agreement (L/A) Signing: September 2016	Bangkok Mass Transit Network Improvement Project (red line) (3)
Loan	Loan Agreement (L/A) Signing: June 2015	Bangkok Mass Transit Network Improvement Project (red line) (2)
Loan	Loan Agreement (L/A) Signing: September 2010	Nonthaburi 1 Road Chao Phraya River Bridge Construction Project
Loan	Loan Agreement (L/A) Signing: September 2010	Bangkok Mass Transit Network Improvement Project (purple line) (2)
Loan	Loan Agreement (L/A) Signing: May 2005	The Second Bangkok International Airport Construction Project (7)
Loan	Loan Agreement (L/A) Signing: April 2004	The Second Bangkok International Airport Construction Project (6)
Loan	Loan Agreement (L/A) Signing: September 2002	The Second Bangkok International Airport Construction Project (5)

[41] ODA Visualization Site (https://www.jica.go.jp/oda/index.html).

Business Type	Period/Conclusion Date	Project Name
Loan	Loan Agreement (L/A) Signing: December 2001	The Second Mekong International Bridge Project (Thailand)
Loan	Loan Agreement (L/A) Signing: September 2000	Bangkok Metro Construction Project (5)
Loan	Loan Agreement (L/A) Signing: September 2000	Local trunk road network improvement project (3)
Loan	Loan Agreement (L/A) Signing: September 2000	The Second Bangkok International Airport Construction Project (4)
Loan	Loan Agreement (L/A) Signing: September 1999	Bangkok Metro Construction Project (4)
Loan	Loan Agreement (L/A) Signing: September 1999	The Second Bangkok International Airport Construction Project (3)
Loan	Loan Agreement (L/A) Signing: September 1998	Bangkok Metro Construction Project (3)
Loan	Loan Agreement (L/A) Signing: September 1998	Transportation Planning and Management Sector Loan
Loan	Loan Agreement (L/A) Signing: September 1997	Bangkok Metro Construction Project (2)
Loan	Loan Agreement (L/A) Signing: September 1997	Pacquette Bridge and ancillary road construction project
Loan	Loan Agreement (L/A) Signing: September 1997	Industrial Ring Road Construction Project
Loan	Loan Agreement (L/A) Signing: September 1997	The Second Bangkok International Airport Construction Project (2)
Loan	Loan Agreement (L/A) Signing: September 1996	Bangkok Metro Construction Project
Loan	Loan Agreement (L/A) Signing: September 1996	Wat Nakhon in Bridge and ancillary road construction project (2)
Loan	Loan Agreement (L/A) Signing: September 1996	Japan National Railways Track Improvement Project (3)
Loan	Loan Agreement (L/A) Signing: September 1996	The Second Bangkok International Airport Construction Project (1)
Loan	Loan Agreement (L/A) Signing: September 1995	Wat Nakhon in Bridge and ancillary road construction project
Loan	Loan Agreement (L/A) Signing: September 1995	Local trunk road network improvement project (2)
Loan	Loan Agreement (L/A) Signing: September 1994	Japan National Railways Track Improvement Project (2)
Loan	Loan Agreement (L/A) Signing: September 1994	Local trunk road network improvement project
Loan	Loan Agreement (L/A) Signing: September 1993	Bangkok - Chonburi Road Construction Project (2)
Loan	Loan Agreement (L/A) Signing: January 1993	Japan National Railways Track Improvement Project
Grant	Grant Agreement (G/A): August 2012	Eastern Outer Ring Road (National Highway 9) Improvement Project

(2) The WB and ADB Support Status

The WB has not provided a loan to the Thai government in the last decade. The road widening project under DOH jurisdiction, which was implemented more than 10 years ago, was the last loan project in Thailand. In addition to the loans, we have supported the introduction of performance-based contracts (PBC) based on results and the construction of road databases, and we are continuing to provide opportunities for information exchange with Thai national ministries and agencies such as MOTs. The ADB is implementing the Greater Mekong Subregion Highway Expansion Project for several Southeast Asian countries, including Thailand, phase 1: Ending in January 2017, Phase 2: Starting in August 2018, scheduled to end in September 2022. Since both banks rate Thailand as a medium- to high-income country and sets loan rates above the market interest rate, it is unlikely that the two banks will conduct large-scale loan projects in the future.

Apart fromthe the WB and ADB, there are currently no donors who provide road infrastructure development support to the DOH.

5.4.6 Status of Technical Standards and Manuals

Table 5.5 shows the standards and manuals for design, construction, repair, and maintenance of the road sector (roads, bridges, etc.) in Thailand. These standards are mainly based on the American Association of State Highway and Transportation Officials and the Building of the American Concrete Institute (ACI) standards. It was created based on building code. In Thailand, each administrative organization owns its own standards and manuals, but they are not shared or unified between different organizations.

As can be seen from this table, road managers (DOH, etc.) in Thailand have established standards and manuals related to roads and bridges, but standards and manuals related to road tunnels have not been developed. The Bureau of Road Research and Development, within the Ministry of DOH, summarizes the introduction to the construction of mountain tunnels. The Basic Engineering Principles of Mountain Tunnel Construction (RD242) have been created, but this document contains a report from DOH staff member staff Dr. Attasit (Basic Engineering of Mountain Tunnel Tunnel Construction), which was independently prepared based on the experience and knowledge of studying in the United States, and it is not applied to actual tunnel work.

Table 5.5 Standards and Manuals for Roads, Bridges, etc

No.	Name of Standard/Manual	Date of Issue or Publication	Manager
1	Specifications for Highway Construction	2003	DOH
2	Bridge Strengthening Manual	2006.5	DOH
3	Bridge Inspection, Analysis and Evaluation Manual	2006.5	DOH
4	Bridge Repair and Maintenance Manual	2006.5	DOH
5	Work Instruction for Bridge and Box Culvert Construction	2006	DOH
6	Inspection Manual for Expressways	1990.3	EXAT
7	Manual for Inspection of the Rama IX Bridge	1990.3	EXAT
8	Procedure for Construction Management of RC Bridges and Condition Evaluation including Maintenance Method	2000.8	DRR
9	Manual for Construction and Maintenance of Road	2003	DRR
10	Project for Development of Management System for DRR's Road Network (Phase 1)-Manual for Bridge Inspection and Evaluation-	2007.2	DRR
11	Bridge Inspection and Improvement Manual	2007.9	DRR
12	The Industrial Ring Road Project -Inspection and Maintenance Manual-	2008.1	DRR
13	Study Project for Repair Method for Damages due to Material Deterioration and Service Life of Bridges in DRR's Road Network (Phase 2) -Final Report-	2009.9	DRR

No.	Name of Standard/Manual	Date of Issue or Publication	Manager
14	Project for Maintenance and Management System Development for DRR's Bridges -Manual for repair of RC bridge components due to deterioration of bridge structures and components	2009.12	DRR
15	Inspection and Evaluation Manual	2011.3	DRR
16	Formulation Manual for Long Term Maintenance Plans for Bridges	2011.3	DRR
17	Routine Maintenance Manual	2011.6	DRR
18	Inspection and Evaluation Manual	2013.7	DRR
19	Formulation Manual for Long Term Maintenance Plans for Bridges	2013.7	DRR
20	Manual for Flooding and Restoration	2013.7	DRR

5.5 Overview of Technical Cooperation Project

5.5.1 Basic Policy

The purpose of this project is to develop the DOH's supervising ability as an orderer for investigation, planning, design, construction, service, maintenance and management of mountain road tunnels.

According to an interview with the DOH, it was found that only mountain road tunnels are eligible for technical cooperation, and that they do not believe that road tunnels using open cutting and shielding methods in urban areas are targeted, and since most of the road projects are outsourced there are few directly managed projects.

In addition, according to interviews with several private geological survey companies, construction consultants, and contractors in Thailand, each company has received orders from the DOH for research, design, and construction work related to road business, and so far there have been no contractual problems such as unpaid commission fees. For this reason, even if the DOH entrusts the work related to the mountain road tunnel maintenance project to these private companies in a technical cooperation project, there is no fear that the progress of the project will be delayed.

Based on the results of these interviews, we concluded that it is appropriate for the DOH to acquire the ability to conduct surveys, planning and design related to mountain road tunnels.

5.5.2 Project Target Area

Since this project is related to all national highways managed by the DOH, the target area of the project is all of Thailand.

5.5.3 Goals and Outcomes of the Technical Cooperation Projects

(1) Overall Goals

The upper target is “as part of the national policy on the improvement of national highways and expressways, the mountain road tunnel construction project is formed and supervised by the DOH”, and the following items are set as indicators to evaluate the degree of achievement of the this goal.

1) The mountain road tunnel business plan list has been updated to continuously promote the tunnel business listed on the list.

2) The mountain road tunnel business reaches the stage of investigation, design and/or construction more than XX.

Since the project goal was to build a foundation for project supervision, the upper target was the formation and supervision of the mountain road tunnel construction business by creating a functioning the foundation. As indicators, two points were listed: continuous promotion of the business in the business plan list, which shows the promotion of the mountain road tunnel construction business, and the achievement of a specific stage in such business.

(2) Project Goals

The project goal is “the foundation for project supervision of the mountain road tunnel business is built in the DOH”, and the following items are set as indicators to evaluate the degree of project achievement.

1) DOH appoints more than XX staff in charge of tunnel construction.
2) Based on the standards and guidelines prepared by this project, more than XX mountain tunnel projects (investigations and designs) will be planned.

A baseline survey will be conducted within the first half of the project. In the past JICA technical cooperation projects aimed at strengthening and improving the capacity of implementing organizations, it was common to evaluate the current capabilities of the implementing organization at the start of the project in the baseline survey. This project is intended to strengthen its ability to tunnel mountain roads, which has not been well experienced in Thailand, and will start from practically zero base.

Therefore, in the baseline survey, one of the important issues is to propose the arrangement to make the activities of the project effective under the current resources, pinpoint what kind of Thai human resources, organizations, and funds are quantitatively and qualitatively accessible. Also, it is assumed that a concrete numerical value is set to XX which is in the index according to the result of the baseline investigation, and approval is obtained in JCC (the same is done for the upper target and the result).

5.5.4 Project Results (Output)

The project's achievements (outputs) are intermediate goals achieved by project activities in order to achieve them, and show how the project is trying to achieve the project goals. Table 5.6 shows the results.

Table 5.6 Project Outcomes (Output)

<u>Outcome 1</u>:→The personnel, organization, and duties under the authority of the DOH for the tunnel project will be established.
Indicator 1-1: A department in charge of the tunnel project is established in the DOH.
Indicator 1-2: Sufficient personnel will be assigned to the departments indicated in Indicator 1-1.
Indicator 1-3: The responsibilities of the departments listed in Indicator 1-1 will be clarified.

<u>Outcome 2</u>:→The DOH's understanding of the supervision cycle of mountain road tunnel projects will be enhanced.
Indicator 2-1: The supervision cycle for mountain road tunnel projects will be clarified at the DOH.
Indicator 2-2: A program for the mountain road tunnel project will be prepared by the DOH.
Indicator 2-3: Considering the project supervision cycle, a draft supervisory and inspection guideline for the construction and maintenance of mountain road tunnels will be prepared.

<u>Outcome 3</u>:→The DOH's survey capacity for mountain road tunnels will be improved.

Indicator 3-1: A draft survey manual for mountain road tunnels will be prepared by the DOH.
Indicator 3-2: The DOH will prepare a draft common specification for survey work on mountain road tunnels.
Indicator 3-3: A draft cost index for survey work on mountain road tunnels will be prepared by the DOH.
Indicator 3-4: The mountain road tunnel project in the investigation phase will be supervised with reference to the draft manual and the work instructions for the pilot study prepared for this project.

Outcome 4:→The design capacity of the DOH for mountain road tunnels will be improved.
Indicator 4-1: A draft design manual for mountain road tunnels will be prepared by the DOH.
Indicator 4-2: A draft common specification for the design work of mountain road tunnels will be prepared by the DOH.
Indicator 4-3: A draft cost index for the design work of mountain road tunnels will be prepared by the DOH.
Indicator 4-4: The mountain road tunnel project will be supervised during the design phase with reference to the draft manuals and work instructions for the pilot study prepared for this project.

Since the purpose of this project was to develop the ability to supervise investigations, plans, and designs related to mountain road tunnels, as an intermediate goal to achieve this, the establishment of personnel, organization and jurisdictional operations related to tunnel business (Result 1), understanding of the supervising cycle of mountain road tunnel business (Result 2), improvement of investigation ability (Result 3), and improvement of design capability (Result 4) were set.

Then, multiple indicators directly related to each result were set. In addition, since the DOH side stated that it was possible to respond relatively flexibly if a unit (Unit) or section (Section) was newly established at the lower level, even though the establishment of a department at the level of the section (Bureau) in the DOH was required, the organization and the department in the indicator 1-1 referred to the in Result 1 pointed to the level of the unit and section.

5.5.5 Project Activities

Each project activity has multiple activities for each outcome. Table 5.7 shows the activities of the project.

Table 5.7 Project Activities

Action 1-1: Review the current organizational structure and mandate of the DOH.
Action 1-2: Identify the most appropriate DOH department and necessary personnel to oversee supervision of the mountain road tunnel project.
Action 1-3: Identify the duties and responsibilities of the department in charge of supervision of the mountain road tunnel project.

Action 2-1: Identify the supervisory cycle for mountain road tunnels.
Action 2-2: Develop a program for mountain road tunnel maintenance as a supervisory cycle.
Action 2-3: Prepare a draft supervisory and inspection guideline for the construction and maintenance of mountain road tunnels, considering the project supervision cycle.

Action 3-1: Prepare a draft survey manual for mountain road tunnels.
Action 3-2: Prepare a draft of the common specifications for the survey work of mountain road tunnels.
Action 3-3: Prepare a draft cost index for survey work on mountain road tunnels.
Action 3-4: Select a pilot study site for the investigation of mountain road tunnels.
Action 3-5: Conduct a pilot study for the investigation of mountain road tunnels.

Action 4-1: Prepare a draft design manual for mountain road tunnels.
Action 4-2: Draft common specifications for the design work of mountain road tunnels will be prepared.
Action 4-3: Prepare a draft cost index for the design work of mountain road tunnels.

Action 4-4: Select a pilot study site for the design of a mountain road tunnel.
Action 4-5: Conduct a pilot study for the design of a mountain road tunnel.

Activities for outcome 1 were the review of the current situation as an organization building, the identification of the optimal existing departments and human resources, and the identification of the duties and responsibilities under the jurisdiction of the newly established department. Activities for Result 2 were the preparation of a supervisory inspection guideline (draft) pertaining to the identification, preparation, construction and maintenance of the supervision cycle of the mountain road tunnel business. Activities for Result 3 and Result 4 were the investigation of mountain road tunnels, preparation of manuals for design, and implementation of pilot studies.

5.6 Construction, Maintenance and Management Capabilities, Technical Standards

The DOH has jurisdiction over approximately 52,000 km of major highways, including national highways and intercity highways in Thailand, and is also responsible for new construction. In addition, under the headquarters of Bangkok, a system consisting of 18 regional offices and 104 road offices has been established, indicating that it has sufficient execution capabilities.

As a result of the hearing with the DOH, it was confirmed that the construction, maintenance ability, and technical level were high in pavement and bridges. In addition, various standards and manuals have been developed, and it was confirmed that there were no major issues in carrying out the business. On the other hand, as for earthworks (slopes), although geological experts, etc. are assigned to the headquarters, there are no engineers with specialized technical capabilities at the local offices, and sufficient ability to perform inspections and diagnoses is insufficient, and technical capabilities in planning for slope surface measures in the event of a disaster or special event are insufficient.

5.7 Road AM Maturity Level

5.7.1 How to Conduct Maturity Evaluation

The maturity evaluation was conducted by web interview with the participants and schedule shown in Table 5.8. The evaluation form was distributed in advance and the grading method was explained during the kick-off meeting. In the interview, we asked them to explain the reasons and background behind the low and high items that they graded. In addition, if the other party offered to revise the grade point during the hearing, the revision was made on the spot.

Table 5.8 Content of the Maturity Evaluation Hearing

Item	Date	Attendee	Contents
JICA Kick Off Meeting	6/8	JICA headquarters、JICA Thailand Office	Explanation of purpose
DOH Kick Off Meeting	6/29	Bridge Construction Department, Maintenance Management Department Mr. Pornchai Silarom (Acting Civil Engineer, Expert Level), Ms. Pattharin Sarutipand (Civil Engineer, Senior Professional Level), Mr. Wiboon Srikhom (Civil Engineer, Senior Professional Level), Ms. Ruttanawadee Phukham (Civil Engineer, Senior Professional Level), Mr. Wisit Rangsisuriyachai (Civil Engineer, Professional	Explanation of purpose, hearing date and time setting

Item	Date	Attendee	Contents
		Level), Mr. Naris Graisorn (Civil Engineer, Practitioner Level)	
Bridges, Monitoring/Organization	7/8	Bridge Construction Department Mr. Pornchai Silarom (Acting Civil Engineer, Expert Level), Mr. Wiboon Srikhom (Civil Engineer, Senior Professional Level), Mr. Naris Graisorn (Civil Engineer, Practitioner Level)	Evaluation sheet scoring
Bridges, Monitoring/Organization	7/13	Bridge Construction Department Mr. Pornchai Silarom (Acting Civil Engineer, Expert Level), Mr. Wiboon Srikhom (Civil Engineer, Senior Professional Level), Mr. Naris Graisorn (Civil Engineer, Practitioner Level)	Evaluation sheet scoring
Pavement and Earthworks (Check the evaluation sheet)	7/13	Maintenance Management Department Ms. Pattharin Sarutipand (Civil Engineer, Senior Professional Level), Ms. Ruttanawadee Phukham (Civil Engineer, Senior Professional Level), Mr. Wisit Rangsisuriyachai (Civil Engineer, Professional Level)	Evaluation sheet scoring
Draft Evaluation, Draft Support Plan (Exchange of opinions)	7/29	Bridge Construction Department, Maintenance Management Department Mr. Pornchai Silarom (Acting Civil Engineer, Expert Level), Ms. Pattharin Sarutipand (Civil Engineer, Senior Professional Level), Mr. Wiboon Srikhom (Civil Engineer, Senior Professional Level), Ms. Ruttanawadee Phukham (Civil Engineer, Senior Professional Level), Mr. Wisit Rangsisuriyachai, Mr. Naris Graisorn (Civil Engineer, Professional Level)	Overall summary
Report of survey results to JICA	8/19	JICA Thailand Office	Report on Survey Results
	8/24	JICA headquarters	

5.7.2 Maturity Evaluation Results

The major items radar chart (evaluation score) is shown in Figure 5.4.

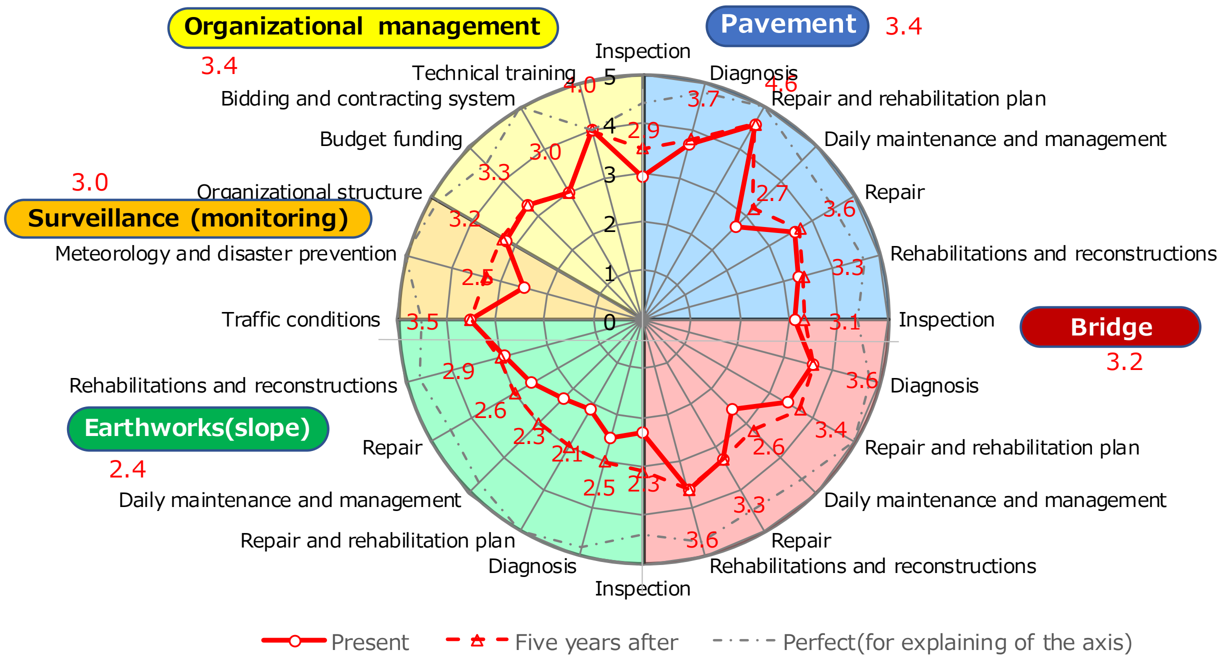


Figure 5.4 Radar Chart of Major Items (Level)

(1) Overall Evaluation

1) With the exception of "Earthworks", it is above level 3, and overall the rating is high.

2) "Pavement" is more than level 3 for most items and rated highly at level 3.4 for the overall.

3) The level of "Bridges" is 3 or more in most items, and the overall "Bridge" is highly rated at 3.2.

4) The overall level of "Earthworks" is low, with level 2.4.

5) The level of "Organizational Structure" is level3 or higher in all items and is highly rated at level 3.4 overall.

(2) Pavement (Evaluation Level 3.4)

1) Levels 2.9 and 3 of the "Inspection". This is due to insufficient content (process) of the inspection manual, differences in the technical level of engineers, and problems in the accuracy of inspection and diagnosis.

2) The level of "Daily Maintenance" is relatively low at 2.7. This is due to the lack of equipment required for the work.

3) The level of "Diagnosis" is 3.7, the level of "Repair and Rehabiritation" is 4.6, "Repair" level is 3.6, and the level of "Rehabilitation and Rehabilitation" is 3.3. This is due to the fact that a system supported by upper-level organizations has been built and a system to solve problems that are difficult

to respond to at the site level and the implementation of inspections and diagnosis is built, and the DOH has established a system to be directly managed in the implementation of construction, and has sufficient response capabilities, including when jobs are outsourced.

(3) Bridges (Evaluation Level 3.2)

1) The level of “Daily Maintenance” is low at 2.6. This includes factors such as the cleaning range being partial without a specialist engineer.
2) The level of “Diagnosis” is 3.6, the level of “Repair and Rehabilitation Plan” is 3.4, the level of “Repair” is 3.3, and the level of “Rehabilitation and Reconstruction” is 3.6. This is due to the fact that manuals are maintained for daily inspections and periodic inspections, and that complex bridges are outsourced, but the DOH has the ability to create standard bridges directly, and that the DOH has repair machinery and personnel at the bridge construction and maintenance center and has the ability to perform these jobs directly.

(4) Earthworks (Slope) (Evaluation Level 2.4)

1) The level of “Inspection” is as low as 2.3, which is due to the low technical level of the DOH technician, inability for proper inspection and diagnosis, and insufficient descriptions in the inspection manual (description of the process).
2) The level of “Diagnosis” is as low as 2.5. This is due to poor documentation (process description).
3) The level of “Repair and Rehabilitation Plan” is as low as 2.1, which is due to the lack of DB to record and preserve.
4) The level of “Maintenance” is as low as 2.3. This is because only partial mowing and waterway cleaning are executed.
5) The level of “Repair” is 2.6. This is due to insufficient quality standards.
6) “Rehabilitation and Reconstruction” is level 2.9. This is due to the fact that rehabilitation and reconstruction plans have not been carried out scientifically.

(5) Surveillance (Monitoring) (Evaluation Level 3.0)

1) The level of “Traffic Conditions” is highly evaluated as 3.5. This is due to the fact that traffic is monitored 24 hours a day on major roads with electronic devices.

(6) Organizational Management (Evaluation Level 3.4)

1) The level of “Organizational Structure” is as high as 3.2. This is because the responsibilities are clear, and the adequate personnel are assigned to the correct division.
2) The level of “Budget Funding” is as high as 3.3. This is due to the fact that a five-year budget has been planned, and the allocation of budgets required for roads is balanced.
3) The level of “Technical Training” is particularly high at 4.0. This is due to the fact that there are five road construction training centers in Japan that are used for training.

5.8 Current Status and Challenges of Road AM

5.8.1 Current Status and Challenges of Pavement AM

(1) Inspection and Diagnosis

1) A consultant is contracted to measure IRI, ruts, cracks, and slip resistance using a road surface measurement vehicle during periodic inspections.
2) In the daily inspections, the DOH conducts visual inspections.
3) There is a large difference in the technical level between DOH engineers, which makes for a difference in the accuracy of daily inspections.
4) The daily and periodic inspection manuals do not show the process and lack content for practical use.
5) Regular inspections are conducted and PMS data is updated based on the master plan.
6) There is a large difference in the diagnostic skills of the DOH technicians between generations. It is an issue to pass on the technology between generations.
7) A technical organizational hierarchy has been established (a system in which issues that cannot be addressed at the field level are supported by upper-level organizations). There is diversity in the technical level of engineers, and there are issues in the transmission of technology between generations.
8) For serious or critical damage, the Survey and Analysis Bureau will visit the site and conduct a detailed survey using a falling weight deflectometer (FWD).
9) The investigation and analysis bureaus have limited personnel and equipment, so they cannot make all the diagnoses.
10) There is a diagnostic manual. The DOH technicians use the diagnostic manual and only perform critical areas to determine the cause of damage.
11) Diagnosis results are updated in the database. It is not linked to PMS.

(2) Daily Maintenance Management

1) Regional offices do not have adequate equipment and sometimes the equipment is out of order.
2) In the event of emergency damage, a report will be made by the local office, evaluated according to the evaluation criteria, and budgets will be distributed as necessary.
3) Emergency event information is recorded, stored and shared in a database system; unlike the PMS, an emergency event management system is in operation.

(3) Repair

1) There is a repair manual, but it has not been updated for a long time.
2) Maintenance is basically outsourced.
3) The DOH has a directly managed construction unit, and in some cases, the DOH will carry out repairs that require a high level of technology or work in areas that are difficult to access.
4) Procurement of materials and equipment is possible in the market, but it takes time due to public procurement procedures.

(4) Rehabilitation, and Reconstruction

1)	Reconstruction and rehabilitation are basically outsourced.
2)	The DOH has a directly managed construction unit, and in some cases, the DOH will carry out repairs that require a high level of technology or work in areas that are difficult to access.
3)	Large-scale works are publicly procured in a manner determined by the Ministry of Finance (introduced two to three years ago).
4)	The change of the construction method is decided by the committee of DOH composed of the person who is familiar with the civil engineering technology.

5.8.2 Current Status and Challenges of Bridge AM

(1) Inspection and Diagnosis

1)	Daily and periodic inspections are conducted by the DOH. Manuals are prescribed.
2)	The inspection and diagnosis of long bridges and bridges with complicated structures are outsourced to consultants.
3)	Periodic inspections are conducted only about 50% of the time due to budget and human resource constraints.
4)	Records of periodic inspections are entered into the BMMS, but daily inspections are recorded on a paper basis.

(2) Repair and Rehabilitation Plan

1)	Very old bridges are not listed in the asset register.
2)	Health prediction is based on BMMS data.
3)	Only 50% of the respondents understand the cost of repair and rehabilitation.

(3) Daily Maintenance Management, Repair, Rehabilitation, and Reconstruction

1)	Daily maintenance is carried out by the DOH.
2)	The DOH has the capacity to carry out both repair and reconstruction/rehabilitation directly, as it has repair machines and personnel at the Bridge Construction and Maintenance Center.
3)	Special content is outsourced.
4)	Quality standards comply with the American Concrete Institute (ACI).
5)	Repair manuals are in place, but they are not continuously revised.

(4) Training and Research

1)	There is a shortage of bridge experts.

5.8.3 Current Status and Challenges of Earthworks (Slope) AM

(1) Inspection and Diagnosis

1)	The DOH technicians in the field office are not able to perform inspection and diagnostics. The role is to report events in the event of a disaster. Inspections of local roads have not been carried out.

2)	The inspection and diagnosis were conducted by geological experts with expertise in slope stability from the DOH's Bureau of Research and Analysis, and the level of technology is high.
3)	The design-build contractor may hire a geologist as a consultant to conduct the survey and design as one package.
4)	The inspection and diagnosis manual lacks practical content because it does not explain the process.
5)	The survey and analysis bureau records and stores the diagnosis results, but they are not shared.

(2) Repair and Rehabilitation Plan

1)	There is no DB.
2)	A comprehensive rehabilitation plan is launched last year. The evidence is based on hearings from regional offices and is not scientific. Preventive maintenance will still take time.
3)	The project plan is drawn up at the time of the budget request, but the scope of the countermeasure work is changed according to the budget, and the project plan is also revised if the local situation differs from that at the time of the budget request.

(3) Daily Maintenance Management, Repair, Rehabilitation, and Reconstruction

1)	Standards for design and construction have not been developed.
2)	The DOH regional office will secure traffic for initial response to slope failures. If they cannot handle the job, they will get help from a contractor.
3)	In the rainy season, waterway cleaning is carried out. However, it depends on the priority of the road.

(4) Training and Research

1)	There is a lack of experts on slope disaster prevention.

5.8.4 Current Status and Challenges of Monitoring and Organizational Management AM

(1) Surveillance (Monitoring)

1)	Traffic monitoring on major arterial roads is carried out 24 hours a day using electronic monitoring devices. For roads other than the main roads, this is done manually two to three times a year.
2)	Monitoring of meteorology and disaster prevention is not always carried out. Monitoring is carried out for bridges with structures that require monitoring.
3)	Monitoring results are not used for traffic control such as road closures.

(2) Organizational Management

1)	The budget is planned for 5 years.
2)	The budget allocation for roads is balanced.

5.8.5 Issues Requiring Research and Development

Among the issues extracted through Road AM evaluation, the issues that require research and development in repair technology, long life technology, and inspection technology are shown in Table 5.9.

Table 5.9 Issues Requiring Research and Development (Thailand)

	Target Issues	Remarks
Pavement	No specific themes	
Bridge	No specific themes	There is a shortage of engineers with expertise in bridge degradation mechanisms and response methods.
Earthworks	No specific themes	The DOH recognizes that there is a shortage of experts on slope disaster prevention, and that it is necessary to raise the level of its technical capabilities.

Table 5.10 Draft Research Plans and University Candidates for Extracted Subjects (Bridges)

<table>
<tr><td>Subject</td><td colspan="2">Study on deterioration mechanisms and correspondence methods of bridges</td></tr>
<tr><td>Background and Necessity</td><td colspan="2">There is a shortage of engineers with expertise in mechanisms and response methods for bridge degradation.</td></tr>
<tr><td>Research Plan</td><td colspan="2">Deflection and component distortion associated with vehicle traffic for deteriorated bridges is monitored and the soundness and deterioration mechanism of structures is verified using the obtained data. If a weak point is confirmed, measures will be examined.
The mechanism of deterioration is classified between steel bridges, concrete bridges, special bridges, etc., and countermeasures are examined according to their characteristics.
Research will be provided by Japan for materials and equipment and treatment methods necessary for monitoring, and inspections, measurements, analyses, and evaluations will be conducted in collaboration with research institutes and Japanese and local universities.</td></tr>
<tr><td>University Candidate Thailand</td><td colspan="2">■Chulalongkorn University
Located in the capital, Bangkok, it is established in 1917 as Thailand's first higher education school. Available fields include health science, architecture, art, contemporary art, dentistry, commerce and accounting, economics, education, engineering, law, medicine, nursing, pharmaceutical science, politics, psychology, agricultural resources, veterinary medicine, etc.</td></tr>
<tr><td rowspan="4">University Candidates Japan</td><td>The University of Tokyo</td><td>■Associate Professor Kohei Nagai
JICA international students (master's program) are accepted from Cambodia (utilization and analysis of bridge damage data).
His research interests include mature social infrastructure, and research on reinforced concrete and infrastructure maintenance.</td></tr>
<tr><td>Kanazawa Institute of Technology</td><td>■Professor Shinichi Miyazato
JICA international students (Ph.D. and master's programs) are accepted from Pakistan, Myanmar, and Kyrgyzstan.
The study focuses on the development of long-life reinforced concrete and resource recycling-type environmental materials.</td></tr>
<tr><td>Tohoku University</td><td>■Professor. Makoto Hisada, Associate Professor Hiroshi Minagawa
Industry, academia, and government from six prefectures in the Tohoku region collaborate on the development of information infrastructure and social implementation on the Tohoku Infrastructure Management Platform. Based on concrete and materials engineering, studies are focused on the maintenance, construction, and construction management of infrastructure.</td></tr>
<tr><td>Nagaoka University of Technology</td><td>■Tsuyoshi Miyashita, Associate Professor
A member of the Niigata City Bridge Asset Management Review Committee. Through measurement and data analysis of vibrations, development of measurement and control programs, development of monitoring equipment, structural analysis of framework and thin-walled structures such as bridges, structural experiments, etc.,</td></tr>
</table>

		research on bridge maintenance and management using structural health monitoring and repair and reinforcement of steel bridges using FRP will be promoted.

Table 5.11 Draft Research Plans and University Candidates for Extracted Subjects (Earthworks)

Subject	Measures to annotate slopes in the geology of Thailand	
Background and Necessity	There is a shortage of experts who are familiar with slope disaster prevention, which can analyze slope stability and plan appropriate countermeasures, because no database of slope surfaces has been constructed. In addition, the DOH is aware of its weaknesses in the slope sector, and it is necessary to raise the level of its technical capabilities, such as through human resource development and the development of manuals. Research in the field of maintenance and design will be promoted in collaboration with Japanese universities.	
Research Plan	Geological surveys will be conducted and design methods necessary for slope stabilization analysis. Materials and equipment and processing methods necessary for the investigation will be provided from Japan as necessary, and on-site surveys, tests, analysis, and evaluation will be conducted in collaboration with Japanese universities and local universities and junior colleges.	
University Candidate Thailand	■Chulalongkorn University Located in the capital, Bangkok, it is established in 1917 as Thailand's first higher education school. Available fields include health science, architecture, art, contemporary art, dentistry, commerce and accounting, economics, education, engineering, law, medicine, nursing, pharmaceutical science, politics, psychology, agricultural resources, veterinary medicine, etc.	
University Candidates Japan	Slope stability based on disaster prevention has been studied at many universities, and it is considered that it can be managed if international students can be accepted at universities that can research stable analysis based on soil tests. Standards such as standard gradients have been formulated under the leadership of the Ministry of Land, Infrastructure, Transport and Tourism (Civil Engineering Research Institute) and expressway companies (NEXCO Research Institute), and collaboration with such research institutes is also possible. In the research from the viewpoint of Road AM and human resource development, the following universities are candidates.	
	Kyoto University	■Associate Professor Pipatpongsa Thirapong Graduated from Chulalongkhon University, Thailand, Department of Civil Engineering. From the research of slope stability analysis by numerical geomechanics and granular body model, research is conducted on physical model experiments, ground composition rules, numerical calculation methods, and on-site applications, including material property experiments aimed at improving accuracy and efficiency improvement to predict the behavior of ground and soil structures.
	University of Tsukuba	■Professor Wataru Matsushima With the aim of predicting deformation, destruction, or flow phenomena of ground and various granular materials from particle-level mechanics, basic theories are constructed, and various experimental and analytical methods are developed along with applied research.

5.9 Support Plan for Establishing Road AM

5.9.1 Support Plan for Pavement AM

5.9.1.1 Inspection and Diagnosis, Daily Maintenance Management, Repair

In the paving department, the DOH has sufficient technical capabilities and is able to respond to Road AM in the pavement department. On the other hand, regarding the level of diagnostic technology of engineers, although there are engineers with expertise within the DOH, there is a big gap between the senior generation and the young generation, and there is a difference in technical capabilities. The DOH recognizes the problem that it is necessary to pass on knowledge from the skilled engineers to the younger engineers regarding this. It seems to be a problem which can be handled in Thailand in the future.

There were problems such as the lack of sufficient equipment necessary for daily maintenance and management of local offices and the failure of equipment to prevent operation. In order to prevent damage to road vehicles in such cases, it is necessary to establish a system and have emergency recovery materials in place so that quick response in an emergency can be made, and also to introduce a quick recovery method in the event of an emergency or disaster. This is considered to be a problem that can be handled in Thailand.

In addition, there is a problem that periodic revisions were not made on inspection, diagnosis, and repair manuals. In order to carry out business more smoothly, it is necessary to continuously revise the content to be easy to use at the site level. This is an issue that must be addressed in Thailand by utilizing workshops and other means. It is also a good idea to provide technical support for the preparation of highly effective manuals through workshops. The aforementioned support plan is summarized in Table 5.12.

Table 5.12 Support Plan for Pavement AM

<table>
<tr><th></th><th>Issues</th><th>Contents</th><th>Support Plan</th></tr>
<tr><td>1</td><td>Eliminate technical level differences between DOH technicians and make appropriate inspections and diagnoses</td><td>Be initiative-taking in transferring technical knowledge from skilled technicians to younger technicians.</td><td rowspan="5">Supported by DOH

Manual revision work is managed through workshops (supported by JICA)</td></tr>
<tr><td>2</td><td>Use of daily/periodic inspection manuals that establish inspection and diagnostic procedures.</td><td>Review the inspection and diagnosis manual to make it more practical.</td></tr>
<tr><td>3</td><td>Budget for outsourcing diagnostics is secured.</td><td>Develop a priority periodic inspection and diagnosis plan according to the budget.</td></tr>
<tr><td>4</td><td>Prepare equipment necessary for daily maintenance.</td><td>Establish a system for rapid response in case of emergencies and keep emergency recovery materials on hand.</td></tr>
<tr><td>5</td><td>Quickly respond to emergency pothole situations to prevent damage to road vehicles.</td><td>Implement quick recovery methods in case of emergency or disaster.</td></tr>
<tr><td>6</td><td>Periodically revise the repair manual as necessary to ensure that it can be operated properly.</td><td>Review the repair manual to make it practical and make the revision process routine.</td><td></td></tr>
</table>

5.9.2 Support Plan for Bridge AM

5.9.2.1 Inspection and Diagnosis, Repair and Rehabilitation Plan, Daily Maintenance Management Repair, Rehabilitation, and Reconstruction

In the bridge division, the DOH has technical capabilities and is able to respond to Road AM in the bridge division. However, complex structures and long-span bridges are technically difficult to oversee directly, so they have decided to outsource, but consignment as planned may not be possible due to restrictions on securing budgets. It is necessary to respond in a timely and appropriate manner to the deterioration of structures that are progressing every day, and there are concerns that delaying response will lead to unforeseen circumstances such as damage to third parties. Therefore, it is necessary to formulate an effective periodic inspection and diagnosis plan after determining priorities according to the budget, and to carry out inspection, diagnosis, repairs, rehabilitation and reconstruction based on the plan. These measures are expected to be available in Thailand, but in some cases, it is possible to improve maintenance and management capabilities by utilizing the JICA Technical Cooperation Projects.

By incorporating new technologies and construction methods for rehabilitation and reconstruction projects, the organization will lead to efficient execution of the overall business and reduction of business costs. Regarding this, it is thought that it will be possible to respond in Thailand, but it is also a good idea to transfer the know-how of the reconstruction projects currently underway on Japanese expressways by utilizing the JICA technical cooperation projects.

In addition, for issues that lack experts with specialized knowledge on bridge deterioration, it is expected that collaboration with Japanese universities and research institutes will lead to the acquisition of technical capabilities related to bridge deterioration mechanisms and response methods and the development of experts. The aforementioned support plan is summarized in Table 5.13.

Table 5.13 Support Plan for Bridge AM

	Issues	Contents	Support Plan
1	Ensure that the number of personnel is adequate for the number of bridges to conduct appropriate inspections and diagnosis.	Secure human resources for the DOH commensurate with the volume of business and acquire technical skills through training, etc.	Supported by DOH Manual revision work is managed through workshops (supported by JICA)
2	Secure appropriate budget for outsourcing of inspection and diagnosis	Formulate a periodic inspection and diagnosis plan after determining the priorities according to the budget and conduct inspection and diagnosis based on the plan.	
3	Register old bridge records in the asset register.	Develop and implement a plan to register old bridges in the asset register. A system will also be established for this purpose.	
4	Identify repair and rehabilitation costs for all bridges.	Identify repair and rehabilitation costs, develop a medium-term construction plan, and secure a budget.	
5	Ensure that adequate funds are available to secure materials and equipment, and damaged areas are appropriately repaired.	For rehabilitation and reconstruction projects, modern technologies and construction methods will be incorporated to ensure efficient execution of the overall project and to reduce project costs.	
6	Periodic revision of the repair manual is implemented.	Revise the repair manual.	
7	Fill the required number of bridge specialists.	Experts with technical capabilities will be trained on bridge deterioration mechanisms and response methods. Collaborate with local universities and research institutions.	JICA training Invitation, Acceptance of international students to Japanese universities.

5.9.3 Support Plan for Earthworks (Slope) AM

5.9.3.1 Inspection and Diagnosis, Repair and Rehabilitation Plan, Daily Maintenance Management Repair, Rehabilitation, and Reconstruction

In this survey, the earthworks (slope) section is the least highly rated. In this regard, the DOH recognizes that the earthworks (slope) division is a weak point, and it is necessary to raise the level of technical capabilities by developing human resources and developing manuals. The DOH also intends to promote research in collaboration with Japanese universities in the field of maintenance and design.

In the future, it is considered that it will be effective for engineers in the field to prepare easy-to-use and highly effective inspection and diagnosis manuals in line with the actual situation in Thailand, and to improve the maintenance and management ability. In addition, since the design and construction manuals for the slope surface have not been prepared, local engineers have not been able to select surface measures in a timely manner, including when an emergency event occurs. Therefore, by preparing manuals, it is thought that it will lead to the improvement of the technical capabilities of engineers involved in design and construction, including the DOH engineers stationed at the local offices, and the promotion of efficient projects. This can be achieved by introducing th JICA technical cooperation projects. In addition, a plan is to use workshops to create a practical manual.

Because the database of the slope surface is not built, there can be no planning of an appropriate repair and rehabilitation plan. Therefore, it is necessary to construct a database and develop and operate a system that can share data in the central and local offices. In order to do so, it is also a good idea to introduce JICA Technical Cooperation Projects.

For issues that lack experts on slope disaster prevention that can analyze the slope stably and formulate appropriate measures, it is expected that the DOH staff will be accepted as trainees to Japanese universities and research institutes, etc., leading to the development of engineers for slope disaster prevention and improvement of maintenance and management capabilities. The aforementioned support plan is summarized in Table 5.14.

Table 5.14 Support Plan for Earthworks (Slopes) AM

	Issues	Contents	Support Plan
1	Inspection and diagnosis of the slopes at the field offices	We will train experts with technical capabilities on the mechanism and response method of slope disaster prevention.	JICA Technical Cooperation Project
2	Daily inspection procedures established /Use of periodic inspection manuals	Develop a manual that is practical for field office inspectors.	
3	Utilize technically skilled consultants in a timely manner	Establish a regular inspection system, including subcontracting.	
4	Share diagnostic results	Build a DB to share the diagnosis results.	
5	Share repair and rehabilitation history	Establish a DB to share the repair and diagnosis history.	
6	Allocate necessary budget for repair and rehabilitation	Develop a comprehensive rehabilitation plan based on scientific evidence.	

	Issues	Contents	Support Plan
7	Develop standards for design and construction of slopes	Develop design and construction manuals for slopes.	
8	Enough experts in slope disaster prevention	We will train experts with technical capabilities on the mechanism and response method of slope disaster prevention. Collaborate with local universities and research institutions.	JICA training Invitation, Acceptance of international students to Japanese universities

5.9.4 Support Plan for Surveillance (Monitoring) and Organizational Management AM

5.9.4.1 Monitoring, Organizational Management

With regard to landslide monitoring systems, the DOH has just begun monitoring slopes, including installing sensors to monitor slope movement in projects in northern Thailand. The DOH recognizes that it is necessary to monitor slopes in the future, but in most cases it is necessary to obtain the cooperation of consultants and contractors because it does not own the equipment and equipment, so we believe that this is a challenge. In addition, the DOH does not have the knowledge and experience about what kind of system and what equipment is optimal for each event.

The DOH is beginning efforts to attach cameras to surveillance vehicles in the event of an emergency or disaster. It also buys drones and uses them to monitor landslides, bridge collapses, holiday traffic conditions, etc., but hopes to transfer technology on effective and appropriate utilization methods.

It is also a good idea to incorporate these into the ongoing JICA tunnel technical cooperation projects and transfer technology. The support plan is summarized in Table 5.15.

Table 5.15 Monitoring and Support Plans for Organizational AM

	Issues	Contents	Support Plan
1	Monitoring of traffic conditions and volumes on required roads	Installation of equipment such as CCTV and traffic counters, as well as expansion of the system to implement centralized monitoring and information sharing.	Can be managed in own country (In some cases, the JICA technical cooperation projects are utilized.)
2	Monitoring of weather and disaster prevention, and decisions on road closures and traffic control are made appropriately without delay.	Install air temperature gauges, road surface temperature gauges, wind speed gauges, and other data acquisition devices at necessary locations, and implement road closures and traffic control measures appropriately.	

5.10 List of Road AM Evaluation Results in Thailand

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
1 Pavement	3.4	75.4%	(1) Inspection	2.9	67%	((1)) Inspection system	3.0	60%	<1> System	4.0	80%
									<2> Technical level of inspectors	3	60%
									<3> Use of inspection equipment	2	40%
						((2)) Inspection manual	2.0	51%	<4> Existence of daily inspection manual	2	40%
									<5> Use of daily inspection manual	2	67%
									<6> Existence of periodic inspection manual	2	40%
									<7> Use of periodic inspection manual	2	67%
									<8> Technical level of the manual	2.0	40%
						((3)) Implementation of daily inspections	3.0	69%	<9> Inspection range	2	40%
									<10> Frequency of inspections	2	67%
									<11> Storage and sharing of inspection records	5	100%
						((4)) Implementation of periodic inspections	4.3	100%	<12> Inspection range	5	100%
									<13> Frequency of inspections	3	100%
									<14> Storage and sharing of inspection records	5	100%
			(2) Diagnosis	3.7	79%	((5)) Diagnostic system	3.5	70%	<15> System	2.0	40%
									<16> Technical level of diagnosis	5	100%
						((6)) Diagnostic manual (As, Co, D, EXT)	3.2	78%	<17> Existence of diagnostic manual	3	60%
									<18> Use of diagnostic manual	3	100%
									<19> Technical level of the manual	3.7	73%
						((7)) Diagnosis of soundness (As, Co, D, EXT)	4.3	87%	<20> Investigation of the cause of damage	3	60%
									<21> Ranking of damage level	5	100%
									<22> Storage and sharing of diagnostic records	5	100%
			(3) Repair and rehabilitation plan	4.6	91%	((8)) Pavement assets ledger/DB	5.0	100%	<23> Existence of pavement assets ledger/DB	5	100%
									<24> Use of pavement assets ledger/DB	5	100%
						((9)) Pavement management system	5.0	100%	<25> Existence of pavement management system	5	100%
									<26> Use of pavement management system	5	100%
						((10)) Development of the plan	4.2	84%	<27> Planning	3	60%
									<28> Scope of the plan	5	100%
									<29> Prediction of soundness	5	100%
									<30> Understanding of the cost of repairs and rehabilitation	5	100%
									<31> Preventive maintenance	3	60%
			(4) Daily maintenance and management	2.7	62%	((11)) System for daily maintenance and management	2.0	40%	<32> System	2.0	40%
									<33> Technical level of the person responsible for maintenance management	2	40%
									<34> Operation of maintenance work equipment (pavement)	2	40%
						((12)) Cleaning (road surface)	2.0	40%	<35> Cleaning range	2	40%
									<36> Frequency of cleaning	2	40%
						((13)) Emergency measures	3.5	90%	<37> Management of response to deformation and damage	3	60%
									<38> Small repair of deformations (temporary repair)	3	100%
									<39> Emergency restoration of failures, etc.	3	100%
									<40> Storage and sharing of emergency measure records	5	100%
			(5) Repair	3.6	83%	((14)) Repair system	3.5	70%	<41> System	3.5	70%
									<42> Technical level of repair	3	60%
									<43> Procurement of materials and equipment	4	80%
						((15)) Quality standards (As, Co, D, EXT)	3.0	73%	<44> Existence of quality standards	3	60%
									<45> Application of quality standards	3	100%
									<46> Quality control	3	60%
						((16)) Repair (Design) manual	3.3	81%	<47> Existence of repair (design) manual	3	60%
									<48> Use of repair (design) manual	3	100%
									<49> Technical level of the manual	3.9	82%
						((17)) Implementation of repairs	4.5	100%	<50> Construction planning and process management	5	100%
									<51> Repair (radical repair)	3	100%
									<52> Management of changes	5	100%
									<53> Storage and sharing of repair records	5	100%
			(6) Rehabilitations and reconstructions	3.3	71%	((18)) System for rehabilitations and reconstructions	3.0	60%	<54> System	4.0	80%
									<55> Level of technology for rehabilitations and reconstructions	3	60%
									<56> Procurement of materials and equipment	2	40%
						((19)) Implementation of rehabilitations and reconstructions	3.5	80%	<57> Implementation plan	5	100%
									<58> Rehabilitations and reconstructions	3	100%
									<59> Management of changes	3	60%
									<60> Storage and sharing of records of rehabilitations and reconstructions	3	60%

Figure 5.5 List of Road AM Evaluation Results in Thailand【Pavement】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
2 Bridges	3.2	71.5%	(7) Inspection	3.1	73%	((20)) Inspection system	3.7	73%	<61> System	3.0	60%
									<62> Technical level of inspectors	3	60%
									<63> Use of inspection equipment	5	100%
						((21)) Inspection manual	3.1	79%	<64> Existence of daily inspection manual	3	60%
									<65> Use of daily inspection manual	3	100%
									<66> Existence of periodic inspection manual	3	60%
									<67> Periodic inspection manual operation	3	100%
									<68> Technical level of the manual	3.7	73%
						((22)) Implementation of daily inspections	2.0	49%	<69> Inspection range	2	40%
									<70> Frequency of inspections	2	67%
									<71> Storage and sharing of inspection records	2	40%
						((23)) Implementation of periodic inspections	3.7	87%	<72> Inspection range	3	60%
									<73> Frequency of inspections	3	100%
									<74> Storage and sharing of inspection records	5	100%
			(8) Diagnosis	3.6	77%	((24)) Diagnostic system	3.0	60%	<75> System	3.0	60%
									<76> Technical level of diagnosis	3	60%
						((25)) Diagnostic manual (M, Co, EXT)	3.2	78%	<77> Existence of diagnostic manual	3	60%
									<78> Use of diagnostic manual	3	100%
									<79> Technical level of the manual	3.7	73%
						((26)) Diagnosis of soundness(M, Co, EXT)	4.3	87%	<80> Investigation of the cause of damage	4	80%
									<81> Ranking of damage level	4	80%
									<82> Storage and sharing of diagnostic records	5	100%
			(9) Repair and rehabilitation plan	3.4	69%	((27)) Bridge assets ledger/DB	3.0	60%	<83> Existence of bridge assets ledger/DB	2	40%
									<84> Use of bridge assets	4	80%
						((28)) Bridge management system	4.5	90%	<85> Existence of bridge management system	5	100%
									<86> Use of bridge management system	4	80%
						((29)) Development of the plan	3.2	64%	<87> Planning	4	80%
									<88> Scope of the plan	2	40%
									<89> Prediction of soundness	4	80%
									<90> Understanding of the cost of repairs and rehabilitation	3	60%
									<91> Preventive maintenance	3	60%
			(10) Daily maintenance and management	2.6	59%	((30)) System for daily maintenance and management	2.0	40%	<92> System	2.0	40%
									<93> Technical level of the person responsible for maintenance and management	1	20%
									<94> Operation of maintenance and management work equipment (bridges)	3	60%
						((31)) Cleaning (road surface)	2.0	40%	<95> Cleaning range	2	40%
									<96> Frequency of cleaning	2	40%
						((32)) Emergency measures	3.3	82%	<97> Management of response to deformation and damage	3	60%
									<98> Small repair of deformation (temporary repair)	2	67%
									<99> Emergency restoration of failures, etc.	3	100%
									<100> Storage and sharing of emergency measure records	5	100%
			(11) Repair	3.3	75%	((33)) Repair system	3.0	60%	<101> System	3.0	60%
									<102> Technical level of repair	3	60%
									<103> Procurement of materials and equipment	3	60%
						((34)) Quality standards (M, Co, EXT)	3.7	87%	<104> Existence of quality standards	5	100%
									<105> Application of quality standards	3	100%
									<106> Quality control	3	60%
						((35)) Repair (Design) manual	3.1	77%	<107> Existence of repair (design) manuals	3	60%
									<108> Use of repair (design) manual	3	100%
									<109> Technical level of the manual	3.3	71%
						((36)) Implementation of repairs	3.3	75%	<110> Repair planning and process management	3	60%
									<111> Repair (radical repair)	3	100%
									<112> Management of changes	3	60%
									<113> Storage and sharing of repair records	4	80%
			(12) Rehabilitations and reconstructions	3.6	77%	((37)) System for rehabilitations and reconstructions	3.3	67%	<114> System	4.0	80%
									<115> Level of technology for rehabilitations and reconstructions	3	60%
									<116> Procurement of materials and equipment	3	60%
						((38)) Implementation of rehabilitations and reconstructions	3.8	85%	<117> Implementation plan	5	100%
									<118> Rehabilitation and reconstruction	3	100%
									<119> Management of changes	3	60%
									<120> Storage and sharing of records of rehabilitations and reconstructions	4	80%

Figure 5.6 List of Road AM Evaluation Results in Thailand【Bridge】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
3 Earthworks(Slope)	2.4	54.3%	(13) Inspection	2.3	54%	((39)) Inspection system	3.2	63%	<121> System	2.5	50%
									<122> Technical level of inspectors	5	100%
									<123> Operation of inspection equipment	2	40%
						((40)) Inspection manual	2.0	51%	<124> Existence of daily inspection manual	2	40%
									<125> Use of daily inspection manual	2	67%
									<126> Existence of periodic inspection manual	2	40%
									<127> Use of periodic inspection manual	2	67%
									<128> Technical level of the manual	2.0	40%
						((41)) implementation of daily inspections	2.0	49%	<129> Inspection range	2	40%
									<130> Frequency of inspections	2	67%
									<131> Storage and sharing of inspection records	2	40%
						((42)) Implementation of periodic inspections	2.3	56%	<132> Inspection range	2	40%
									<133> Frequency of inspections	2	67%
									<134> Storage and sharing of inspection records	3	60%
			(14) Diagnosis	2.5	53%	((43)) Diagnostic system	2.5	50%	<135> System	2.0	40%
									<136> Technical level of diagnosis	3	60%
						((44)) Diagnostic manual (Slope, utility and drainage structures, retaining walls)	2.2	53%	<137> Existence of diagnostic manual	2	40%
									<138> Use of diagnostic manual	2	67%
									<139> Technical level of the manual	2.7	53%
						((45)) Diagnosis of soundness (Slope, utility and drainage structures, retaining walls)	2.7	53%	<140> Investigation of the cause of damage	3	60%
									<141> Ranking of damage level	3	60%
									<142> Storage and sharing of diagnostic records	2	40%
			(15) Repair and rehabilitation plan	2.1	43%	((46)) Earthwork assets ledger/DB	2.5	50%	<143> Existence of earthwork assets ledger/DB	3	60%
									<144> Use of earthwork assets ledger/DB	2	40%
						((47)) Development of the plan	2.0	40%	<145> Planning	2	40%
									<146> Scope of the plan	1	20%
									<147> Prediction of soundness	2	40%
									<148> Understanding of the cost of repairs and rehabilitations	2	40%
									<149> Preventive maintenance	3	60%
			(16) Daily maintenance and management	2.3	51%	((48)) System for daily maintenance and management	2.0	40%	<150> System	2.0	40%
									<151> Technical level of the person responsible for maintenance and management	2	40%
									<152> Operation of maintenance and management work equipment (earthworks)	2	40%
									<153> Operation of maintenance work equipment (accessories)	2	40%
						((49)) Mowing	2.0	40%	<154> Mowing area	2	40%
									<155> Frequency of mowing	2	40%
						((50)) Cleaning (waterways)	2.0	40%	<156> Cleaning range	2	40%
									<157> Frequency of cleaning	2	40%
						((51)) Cleaning (signs)	2.0	40%	<158> Cleaning range	2	40%
									<159> Frequency of cleaning	2	40%
						((52)) Emergency measures	3.0	80%	<160> Management of response to deformation and damage	3	60%
									<161> Small repair of deformation (temporary repair)	3	100%
									<162> Emergency restoration of failures, etc.	3	100%
									<163> Storage and sharing of emergency measure records	3	60%
			(17) Repair	2.6	61%	((53)) Repair system	2.7	53%	<164> System	2.0	40%
									<165> Technical level of repair	3	60%
									<166> Procurement of materials and equipment	3	60%
						((54)) Quality standards(Slope, retaining wall, drainage structure)	2.7	67%	<167> Existence of quality standards	2	40%
									<168> Application of quality standards	3	100%
									<169> Quality control	3	60%
						((55)) Repair (Design) manual	2.6	62%	<170> Existence of repair (design) manuals	3	60%
									<171> Use of repair (design) manual	2	67%
									<172> Technical level of the manual	2.8	60%
						((56)) Implementation of repairs	2.5	60%	<173> Construction planning and process management	3	60%
									<174> Repair (radical repair)	3	100%
									<175> Management of changes	2	40%
									<176> Storage and sharing of repair records	2	40%
			(18) Rehabilitations and reconstructions	2.9	63%	((57)) System for rehabilitation and reconstruction	2.7	53%	<177> System	2.0	40%
									<178> Level of technology for rehabilitations and reconstructions	3	60%
									<179> Procurement of materials and equipment	3	60%
						((58)) Implementation of rehabilitations and reconstructions	3.0	70%	<180> Implementation plan	3	60%
									<181> Rehabilitations and reconstructions	3	100%
									<182> Management of changes	3	60%
									<183> Storage and sharing of records of rehabilitations and reconstructions	3	60%

Figure 5.7 List of Road AM Evaluation Results in Thailand【Earthworks (Slopes)】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
4 Surveillance (monitoring)	3.0	65.0%	(19) Traffic conditions	3.5	80%	((59)) Traffic volume	3.5	80%	<184> Monitoring range	4	80%
									<185> Monitoring frequency	3	100%
									<186> Monitoring sites	3	60%
									<187> Information sharing and utilization of monitoring results	4	80%
			(20) Meteorology and disaster prevention	2.5	50%	((60)) Precipitation, temperature, wind	2.5	50%	<188> Monitoring range	2	40%
									<189> Monitoring frequency	2	40%
									<190> Monitoring sites	2	40%
									<191> Information sharing and utilization of monitoring results	4	80%
5 Organizational management	3.4	74.3%	(21) Organizational structure	3.2	68%	((61)) Asset management cycle	4.0	80%	<192> Setting management goals	4	80%
									<193> Conducting internal audits	4	80%
									<194> Implementation of management review	4	80%
						((62)) Organization	3.0	60%	<195> Role-sharing	3	60%
									<196> Manpower allocation	3	60%
						((63)) Control	2.7	67%	<197> Commitment from the top	3	100%
									<198> Influence of the organization	2	40%
									<199> Motivation and ability of counterpart	3	60%
						((64)) Business continuity	3.0	60%	<200> Responding to accidents	3	60%
									<201> Responding to rainfall	3	60%
									<202> Responding to earthquakes	3	60%
						((65)) Operational support facilities	3.5	70%	<203> Training facility	4	80%
									<204> Communication facilities	3	60%
			(22) Budget funding	3.3	75%	((66)) Budget	3.5	70%	<205> Budget planning	4	80%
									<206> Budgetary allocation	3	60%
						((67)) Raising funds	3.0	80%	<207> Short-term financing	3	100%
									<208> Long-term financing	3	60%
			(23) Bidding and contracting system	3.0	60%	((68)) Bidding and contracting system	3.0	60%	<209> Cost estimation standard	3	60%
									<210> Prevention of collusion	3	60%
									<211> Contract method	3	60%
									<212> Procurement process	3	60%
									<213> Contract change	3	60%
			(24) Technical training	4.0	100%	((69)) Pavement training	4.0	100%	<214> Training plan	3	100%
									<215> Contents of training	5	100%
						((70)) Bridge training	4.0	100%	<216> Training plan	3	100%
									<217> Contents of training	5	100%
						((71)) Earthwork training	4.0	100%	<218> Training plan	3	100%
									<219> Contents of training	5	100%

Figure 5.8 List of Road AM Evaluation Results in Thailand【Surveillance (Monitoring), Organizational Management】

Chap.6 Current Status, Issues, and Support Plan for Road AM in Zambia

6.1 Target of the Chapter

Interviews were conducted online with counterparts in the partner country and people involved in the technical cooperation project regarding road AM in Zambia, and issues for establishing road AM were identified by referring to materials available on the web. Based on the issues identified, a draft support plan for after the completion of the technical cooperation project is formulated.

6.2 Overview

JICA implemented the Bridge Maintenance Capacity Enhancement Project (Phase I) during the period from February 2015 to August 2017, and achieved the following objectives as the initial stage of bridge maintenance for the Road Development Agency (RDA) of Zambia: development of daily maintenance management guidelines, bridge inspections The project achieved the following objectives: development of the daily maintenance management guidelines, bridge inspection guidelines, and repair guidebook; acquisition of basic knowledge and skills on the maintenance management cycle process through on-the-job training; and acquisition of contract management skills through the daily maintenance management pilot project.

As a successor to Phase I, the Bridge Maintenance Management Capacity Improvement Project (Phase II) is being implemented with a construction period from February 2019 to February 2023, with the aim of improving bridge maintenance management operations by strengthening daily operations, inspections, and repair techniques related to bridge maintenance management. The results of this study revealed the following.

As for pavements, RDA will purchase IRI measurement equipment at the end of 2020, which will provide accurate and detailed information on road damage and be used to formulate repair plans. In addition to the conventional management based only on IRI indicators, it is considered necessary to consider incorporating indicators that preserve the pavement structure, such as cracks, into the management indicators. It is also important to reduce the life cycle cost by enhancing the repair of small potholes and other damages from the initial stage.

With regard to bridges, it is important to promote direct inspections and cleaning of bridges within a limited budget, and to expand routine maintenance and repair work to other regions based on the implementation of pilot projects supported by the technical cooperation project. In addition, it is necessary to promote the results of the bridge engineer training program being implemented in cooperation between Gifu University and the University of Zambia, and to ensure that bridge maintenance and management are steadily carried out.

With earthwork, it is important to move from post-disaster response to disaster prevention based on inspections and repair planning. As for financing, which is the biggest issue, it is necessary to strengthen the functions of the Road Fund, which is in charge of financing and budget distribution, in cooperation with the WB.

6.3 Background of the Teachnical Coorporation Project

The Zambian government has been implementing the Road Sector Investment Plan (ROADSIP) since 1998, based on the recognition that road development promotes poverty reduction and economic development. The Road Sector Investment Plan (ROADSIP) has been implemented since 1998.

Most of the bridges were built in the 1970s or earlier and have not been systematically maintained, resulting in the aging of bridge structures. In 2011, the Road Development Agency (RDA), the main road administrator, commissioned an inspection and damage evaluation of the bridges, and determined that about 15% of the bridges needed urgent repair work. Based on these results, in 2013, RDA established the Bridge and Emergency Rehabilitation Section in the Maintenance Department to promote the strengthening of the systematic bridge maintenance and management field, and decided to start bridge inspections and rehabilitation. Since the organization has just been established, there are only a few bridge engineers and they do not have know-how on operations from planning to operations management, so it is a challenge to improve the bridge maintenance management capacity of RDA staff.

Phase II of the Bridge Maintenance Capacity Improvement Project was requested by the Japanese government as a successor to the Bridge Maintenance Capacity Improvement Project (hereinafter referred to as "Phase I"), which was implemented under these circumstances (February 2015 to August 2017).

In Phase I, as the initial stage of bridge maintenance management, the following objectives were generally achieved: development of "Daily Routine Maintenance Manual," "Bridge Inspection Manual," and "Repair Manual," acquisition of basic knowledge and skills on the process of maintenance cycle through on-the-job training, and acquisition of contract supervision through daily maintenance pilot works. However, it is necessary to continue to strengthen the knowledge and skills needed to comprehensively understand the entire process from inspections to repairs and to continue business operations. In order to develop a maintenance system for bridges, it is necessary to establish a series of maintenance cycles such as inspections, diagnosis, repair planning, and repair. However, although the RDA prepared a "Repair Manual" in Phase I, RDA staff do not have practical experience, and special bridge maintenance management across national borders has not yet been implemented.

In addition, with regard to routine maintenance, it is essential to improve the skills of local engineers in order to properly carry out bridge maintenance management nationwide, and it is necessary to steadily disseminate the guidelines and guidebooks prepared in Phase I. With the above background, RDA requested the Japanese government to implement Phase II with the aim of improving bridge maintenance operations by strengthening daily operations, inspections and repair techniques related to bridge maintenance.

6.4 Overview of Road Maintenance in Zambia

6.4.1 Road Maintenance and Management Extension

Figure 6.1 Shows a Location Map of the Major National Highways and 10 Regions in Zambia.

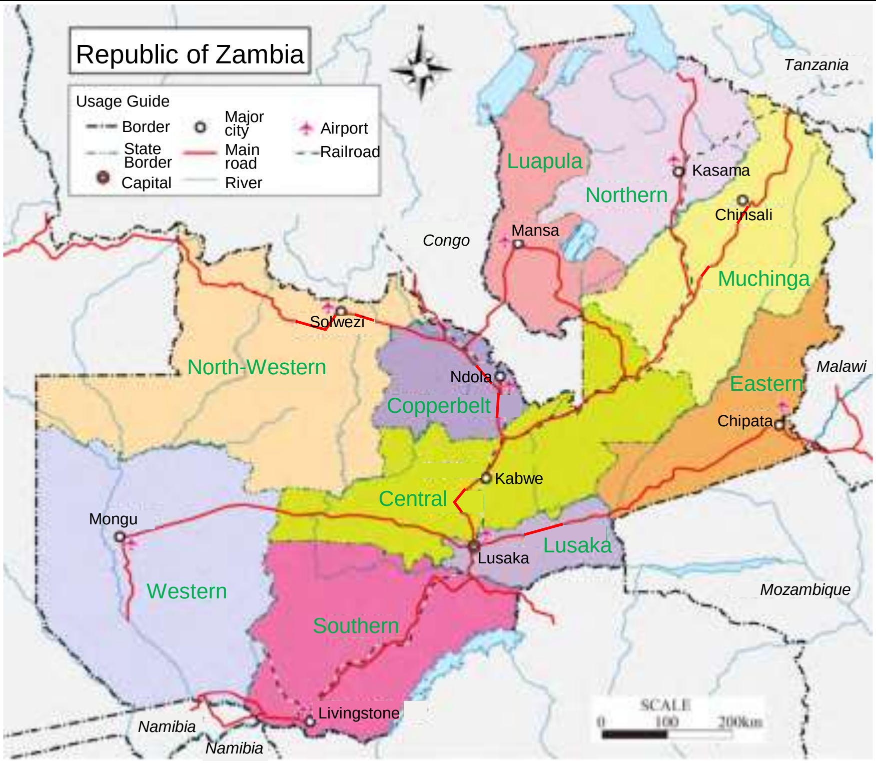


Figure 6.1 Location of Zambia's Main Trunk Roads and 10 Regions[42]

Table 6.1 shows the road extension in Zambia; the paving rate of Trunk and Main roads is high at 97% and 78%, respectively, while that of District and Primary Feeder roads, which account for most of the extension, is low at 15.4% and 0.2%.

Table 6.1 Road Length by Road Type/Road Manager (2019)[43]

		Length (km)	Pavement length (km)	Pavement rate (%)	Road administrator
Core Road Network					
	Trunk (T)	3,116	3,024	97.1%	RDA
	Main (M)	3,701	2,885	78.0%	RDA
	District (D)	13,707	2,111	15.4%	RDA
	Urban	5,597	2,055	36.7%	RDA
	Primary Feeder Roads	14,333	32	0.2%	RDA/LRAs
	Subtotal	40,454	10,107	25.0%	RDA/LRAs
Non-Core Road Network					
	Secondary Feeder Roads	10,060			RDA/LRAs
	Tertiary Feeder Roads	4,424			RDA/LRAs
	Park Roads	6,607			RDA/DNPW
	Community Roads	5,000			RDA/LRAs
	Other Roads	1,126			RDA/LRAs
	Subtotal	27,217			
Total		67,671	10,107		

Remarks: RDA (Road Development Agency), LRAs(Local Road Authorities), DNPW(Department of National Parks and Wildlife)

42 Zambia Bridge Maintenance Technical Cooperation Project Phase II Work Plan 2019.3
43 RDA [2020], 2019 Annual Report

According to the interviews, there are 483 bridges directly managed by RDAs. The breakdown is 19% concrete bridges, 32% composite bridges, 28% concrete hollow slab bridges, 3% concrete box girder bridges, 6% truss bridges, 1% suspension bridges and 11% wooden bridges.

6.4.2 Organizational Structure of the RDA

6.4.2.1 Ministry of Housing and Infrastructure Development

The Ministry of Housing and Infrastructure Development was established in 2016 by merging the Housing and Infrastructure Division of the former Ministry of Local Government and Housing and the Public Infrastructure Division of the Ministry of Public Works and Supply. The ministry's vision is “to create a nation with quality, modern, resilient, and affordable housing and public infrastructure for inclusive and sustainable socioeconomic development” and its goal is “to develop the necessary public infrastructure and affordable housing throughout the country to accelerate socioeconomic development.” The following is a list of the ministry's issues as listed on the website of the Ministry of Housing and Infrastructure Development.

1) The Ministry of Housing and Infrastructure Development distributed only 48% of the originally approved 2019 budget. Furthermore, the budget distribution from the Ministry of Finance was unstable and it was not possible to predict when and how much would be distributed.
2) The procurement process was time-consuming, and in many cases, project implementation was delayed.
3) Vacant posts in the ministry and lack of necessary human resources affected the implementation and supervision of the project.
4) Lack of progress in developing/amending laws such as the Road Act and the National Construction Companies Act (NCC Act) to promote infrastructure development.
5) There is a need to promote infrastructure development in response to climate change.

6.4.2.2 RDA

The RDA was established under the Public Roads Act No. 12. of 2002 and has been in operation since 2006.The RDA has 432 employees as of 2019 as shown in Table 6.2.

Table 6.2 Number of Staff in RDA (2019)[44]

	Men	Women	Total
Management	10	1	11
Executives	85	24	109
General employees	241	71	312
Total	336	96	432

The headquarters organization of the RDA is shown in Figure 6.2. As far as road AM operations are concerned, the Planning & Design Department oversees survey and design to construction order, while the Maintenance Department oversees implementation and supervision of construction. The Planning & Design Department oversees survey, design, and ordering, while the Maintenance Department oversees

[44] RDA [2020], 2019 Annual Report

implementation and supervision.

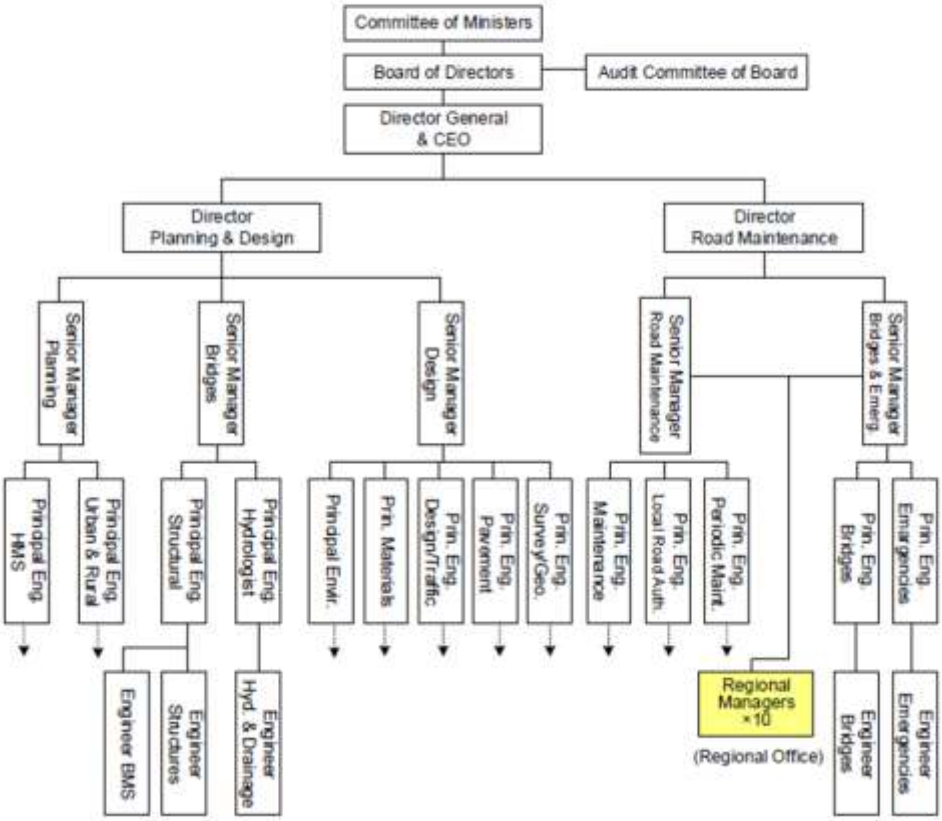


Figure 6.2 Organization of RDA Headquarters[45]

Figure 6.3 shows a typical example of the organization of one of the ten regional offices throughout Zambia. Usually, there are only about four technical staff, including the office manager, and about three technicians. In addition, there are many offices where RDAs are understaffed and the staff in charge is vacant.

45 JICA [2019], Project proposal for technical cooperation on bridge maintenance in Zambia, Phase II

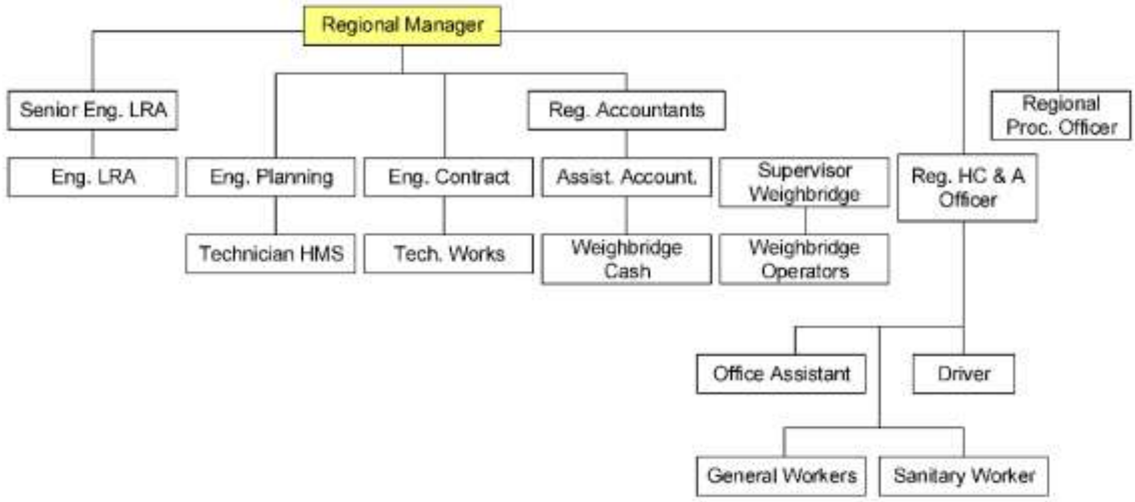


Figure 6.3 Example of RDA Regional Office Organization[46]

In 2014, RDA formulated the Maintenance strategy 2015-2024, which sets out a 10-year long-term maintenance strategy. In 2014, RDA formulated the Maintenance strategy 2015-2024, which sets out a 10-year long-term maintenance strategy.[47]

1) Routine maintenance is to be carried out in areas where the rating is Good or Fair in order to preserve the road condition. Basically, it is to be carried out under Performance Based Contracts for three years.
2) Periodic maintenance is to be carried out periodically, for example, once every five years.
3) Emergencies works will be carried out where emergency measures are required. For example, washing of bridges and culverts due to extreme rainfall.
4) Primary feeder roads are basically improved by Output Performance Road Contract (OPRC) for about one year and then maintained by performance specifications for about fiv

The following RDA issues are listed on the RDA website.

1) Delays in payment for all projects is a problem.
2) Progress on maintenance projects is slow. There is a concern that if periodic maintenance is delayed, rehabilitation will have to be done which will cost four times more.

6.4.3 Road Maintenance Budget

6.4.3.1 National Road Fund Agency (NRFA)

The NRFA was established under the National Road Fund Act[48] of 2002 to manage the road fund. Road funding mainly consists of fuel tax, registration tax, border tax, and tolls, and is used for road construction, road maintenance, and traffic safety measures.Table 6.3 shows the revenue breakdown of the Road Fund in 2019.

[46] JICA [2019], Capacity building for bridge maintenance and management project phase II: detailed planning study
[47] RDA [2017], Presentation by Senior Manager Road Maintenance
[48] The national road fund act, 2002

Table 6.3 Revenue Breakdown of the Road Fund in 2019[49]

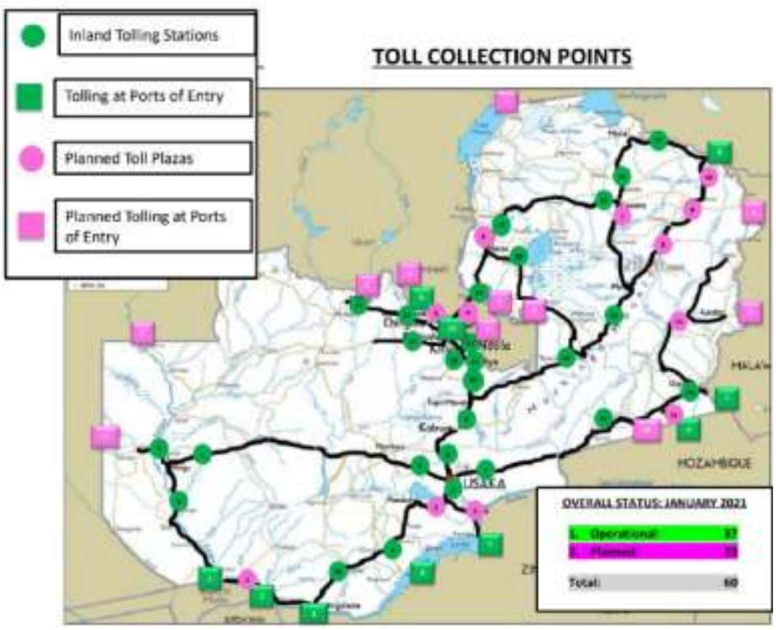
		Revenue 2019	
		K million	One hundred million yen
Domestic	Fuel tax	711.3	40.5
	Collection at the toll booth	537.4	30.6
	Collection at the border toll booth	669.5	38 .2
	Road tax, license tax	510.6	29.1
	Vehicle weight tax	20.7	1.2
	others	254.8	14.5
	Fuel tax	977.6	55.8
Subtotal		3,681.9	209.9
Overseas	Domestic debt	4,603.8	262.4
Total		8,285.7	472.2

Remarks: Calculated at 1K = 5.7 yen

6.4.3.2 Toll Collection on Public Roads

The National Road Tolling Program (NRTP) was established and the Tolls Act enacted in 2011 made RDAs collect road tolls from heavy vehicles at vehicle weigh stations from 2013. Then, in January 2016, mainline toll booths were set up sequentially, and toll collection began for all vehicles, including general vehicles. As of 2021, there are 27 mainline toll booths and 10 border toll booths, but in the future, there are plans to increase the number of mainline toll booths to 39 and border toll booths to 21 (see Figure 6.4).

Payments to contractors have been delayed every year, and although there was sufficient revenue for the budgeted amount in 2019, in some cases it has become difficult to pay for ongoing projects in order to make payments from the previous year .[50]



[49] RDA [2020], 2019 Annual Report
[50] NRFA [2020], Annual report 2019

Remarks: 1K = 5.7 yen

Figure 6.4 Location map of mainline and border toll booths and toll table for mainline toll booths[51]

6.4.3.3 Road-Related Budget Breakdown

The road-related budget for Zambia in 2021 is shown in Table 6.4. In the budget breakdown, "debt repayment" accounts for 16% of the budget amount, amounting to 1,021mK, and is increasing every year (2020: 762mK, 2019: 481mK). In addition, outstanding payments to contractors from the previous year are also to be paid from the following budget. In addition, foreign funds (foreign donors) account for a large share of "Rehabiritation" and "Reconstruction".

Table 6.4 Breakdown of Road-Related Budget (2021)[52]

	Domestic funds (Million K)	Foreign funds (Million K)	PPP, etc. (Million K)	Total (Million K)
Bridge (new)	133	150		283
Capital	320			320
Debt repayment	1,021			1,021
Maintenance	416	27		443
Construction supervision	150			150
Rehabilitation (pavement overlay)	281	2,320		2,601
Research and Design	55	71		126
Toll booth	241			241
Update (mainly paved gravel road → pavement)	61	435	525	1,021
Other	225	121		346
Total	2,903	3,124		6,552

For reference：Calculated at 1K=5.7 yen, "Bridge" includes only the new cost, and the bridge maintenance cost is included in "maintenance". "Capital" includes building, machinery, land acquisition expenses such as RDA, etc., and "toll booth" includes new construction fee and operation fee. Foreign funds are supported by foreign donors. Debt repayment is a repayment of borrowings from a city bank. Figure 6.5 shows the distribution of road-related budget and its percentage in 2015.

51 NRFA [2020], Annual report 2019
52 RDA [2016], 2015 Annual Report

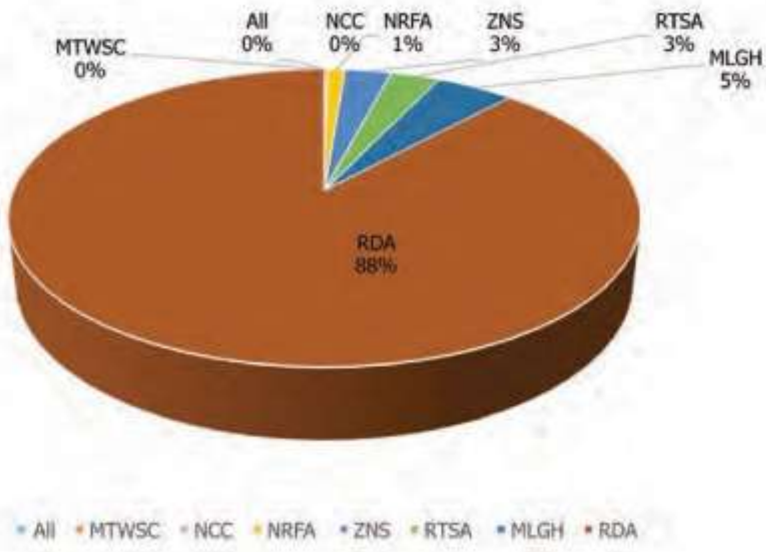
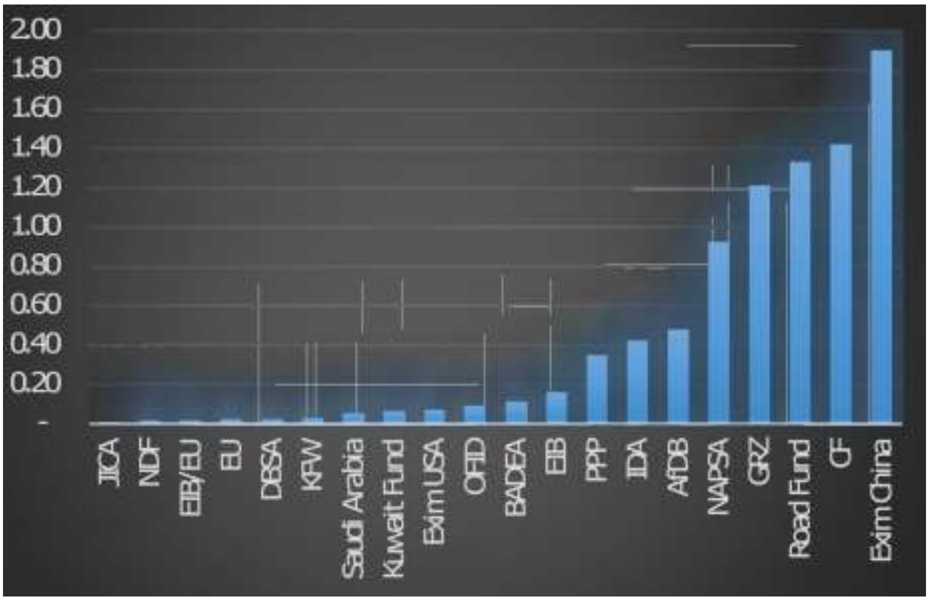


Figure 6.5 Road Budget Distribution Agencies (2015)[53]

Figure 6.6 shows the sources of road-related funding in 2018. The Export-Import Bank of China (Exim China) accounts for the largest amount of investment from foreign donors, followed by the African Development Bank (AfDB) and the WB.



Unit: Billion K (1 billion K is 5.7 billion yen)

Remarks: Exim China stands for Export-Import Bank of China, CF stands for Contractor Facilitated Initiative and is similar to PPP, GRZ stands for Government of Zambia, NAPS stands for National Pensions Scheme Authority.

Figure 6.6 Breakdown of sources of investment in the road-related budget (2018)[54]

53 RDA [2016], 2015 Annual Report
54 RDA Annual Report 2018

6.4.4 Road Conditions

The pavement condition survey was conducted almost every year from 2006 to 2015, and the condition of paved TMD (Trunk, Main, and District) roads is shown in Figure 6.7 and Figure 6.8. Since 2016, due to budget constraints, a nationwide pavement condition survey has not been conducted, and it is only partially conducted on a project basis. The pavement condition is measured by the flatness index (Figure 6.7).

The pavement condition is assessed by the Index of Flatness (IRI), which is based on the criteria set in Road SHIP II. 2013-2015 was measured by a JV between Messes HIMS (New Zealand) and SATRA Infrastructure Management Services (India). (New Zealand) and SATRA Infrastructure Management Services (India). The measurement results are entered into the Highway Management System (HMS) and are used to make decisions on the implementation of repairs and are also stored as inventory information.

The RDA changed its pavement management standards in 2008. The RDA seems to have lowered the thresholds of Good, Fair, and Poor for paved roads from IRI<3, 3<IRI<6, and IRI>6 to IRI<4.5, 4.5<IRI<8, and IRI>9.[55] It is likely that the ratio of Fair to Good has increased since 2011 due to the change in thresholds and progress in road improvement.

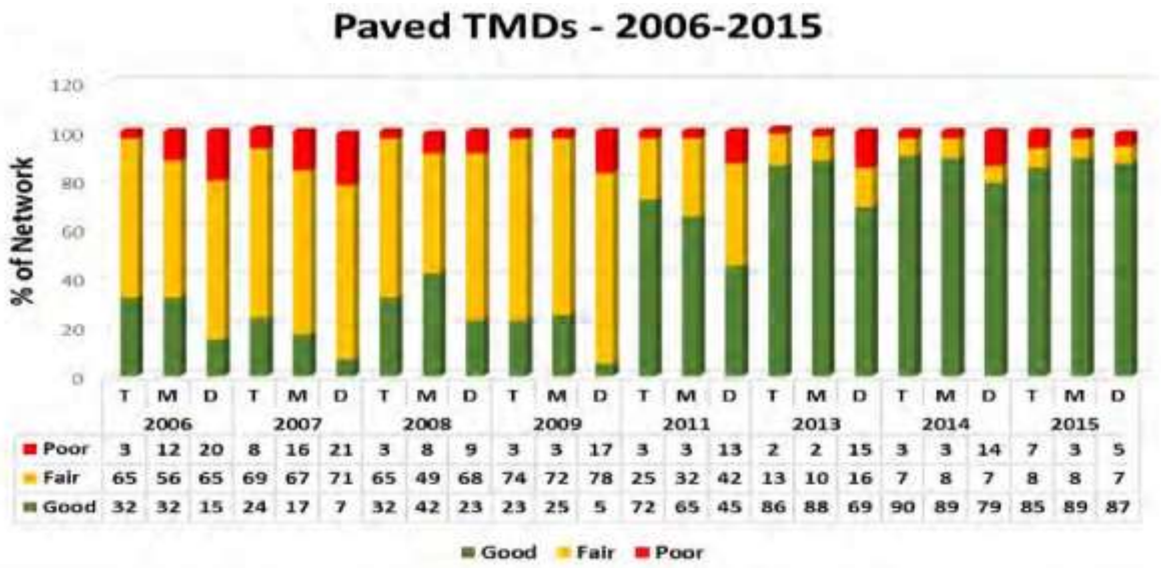


Figure 6.7 Condition of Paved Trunk, Main, and District Roads[56]

[55] The WB [2012], The crisis in the Zambian Road Sector
[56] RDA [2018], 2017 Annual Report

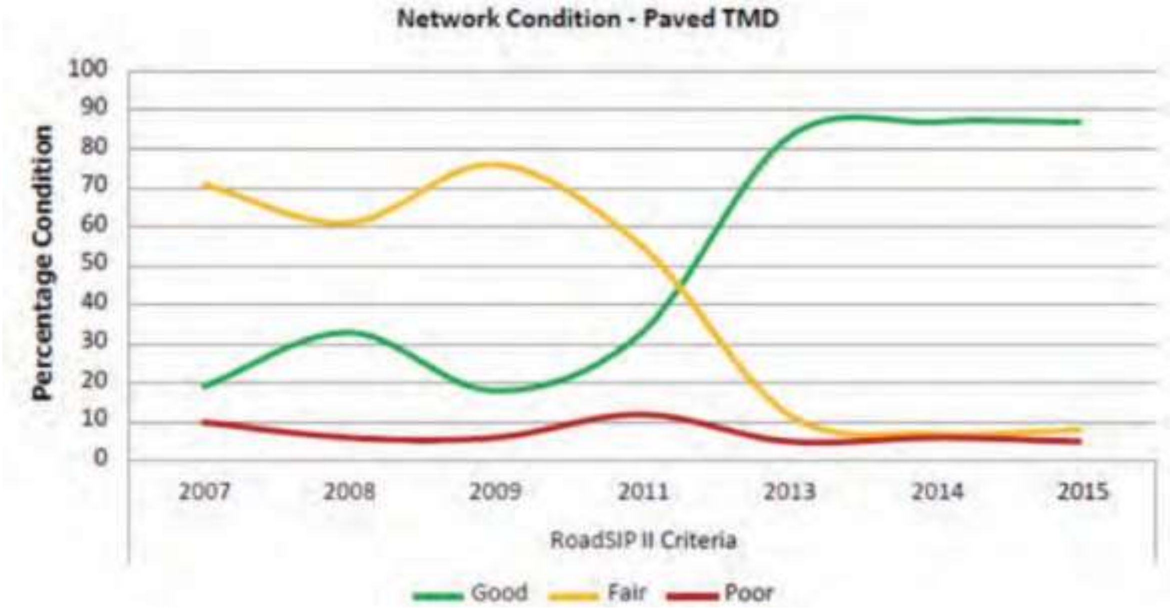


Figure 6.8 Condition of Paved Trunk, Main, and District Roads[57]

Next, the condition of the unpaved TMD is shown in Figure 6.9 and Figure 6.10. Unlike paved roads, the percentage of poor roads is high, peaking between 2008 and 2009 and increasing between 2013 and 2015. Eighty percent of the roads were in poor condition in 2015, and less than 5% were in good condition.

[57] RDA [2016], 2015 Annual Report

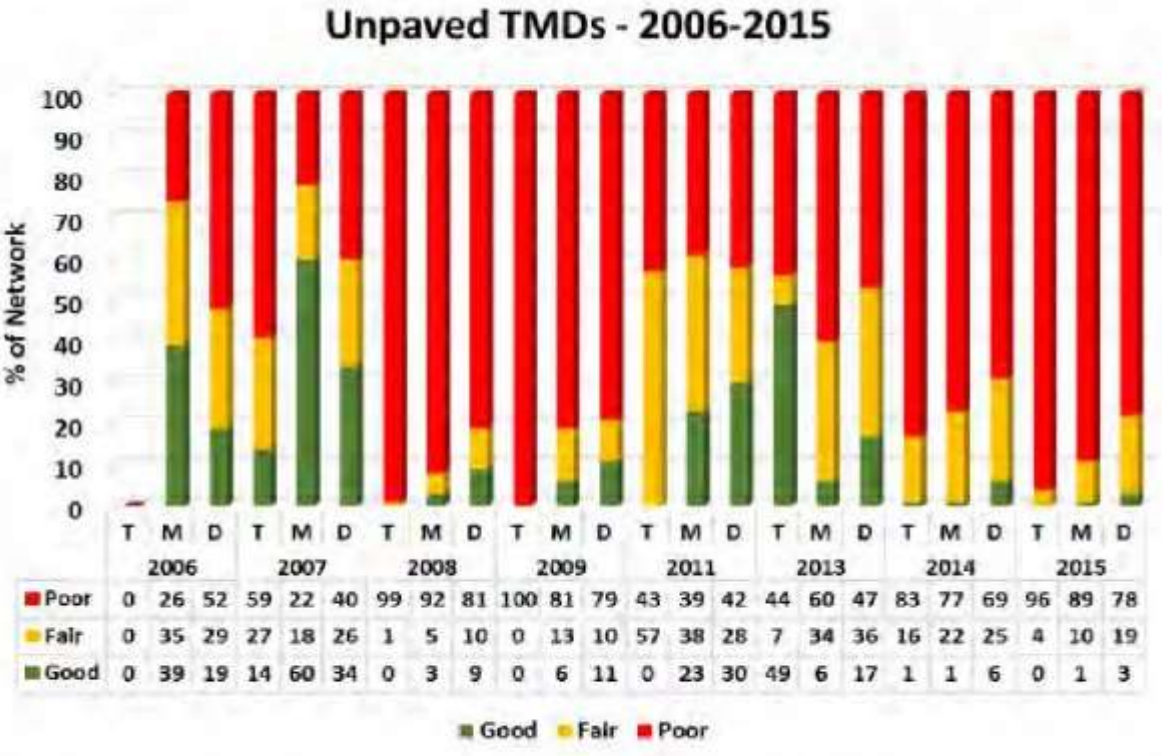


Figure 6.9 Unpaved Trunk, Main, and District Road Conditions [58]

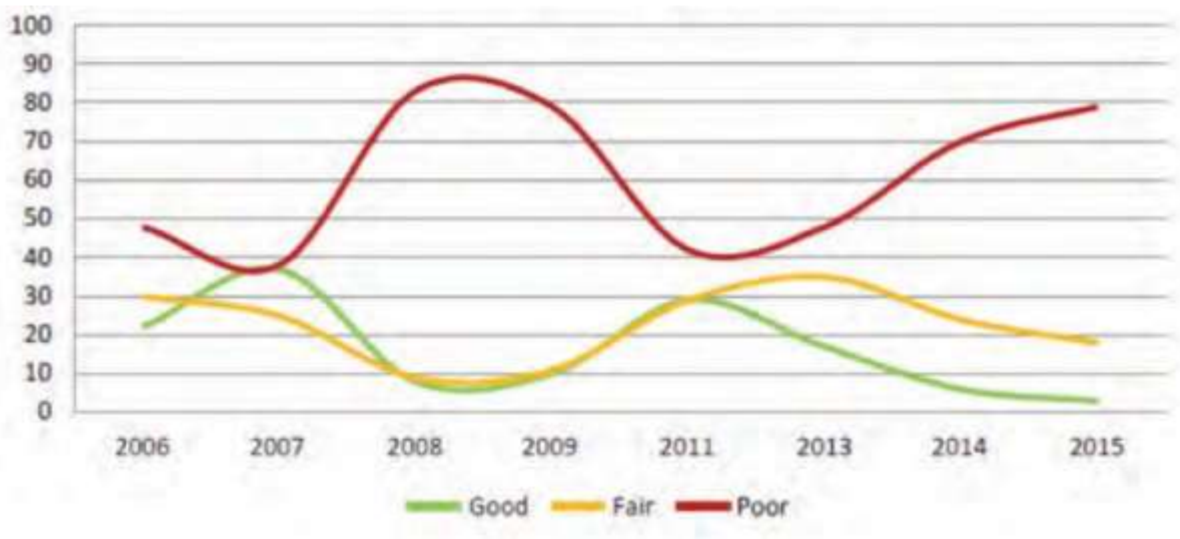


Figure 6.10 Condition of Unpaved Trunk, Main, and District Roads.[59]

Figure 6.11 shows the change in road condition of Primary Feeder Roads, showing that from 2011 to 2015, the condition of Poor roads has worsened from 77% to 82%, and the condition of Good roads has worsened from 9% to 3%.

[58] RDA [2018], 2017 Annual Report

[59] RDA [2016], 2015 Annual Report

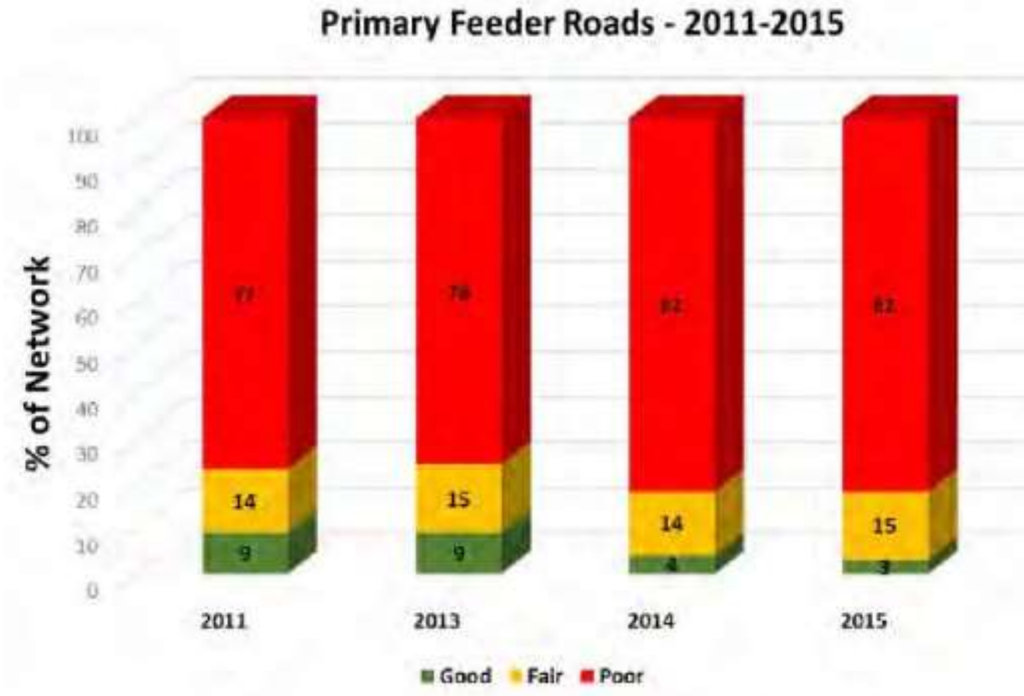


Figure 6.11 Road Condition of Primary Feeder Roads[60]

6.4.5 Support Status of Each Donor on Road AM

6.4.5.1 The WB

Table 6.5 shows the projects related to road AM supported by the WB. In the past, support to trunk roads was the focus, but in recent years the emphasis has shifted to support to feeder roads and other local roads.

Table 6.5 Road AM Related Support Provided by the WB[61]

Subject	Project cost	Completion time	Business content
Road SIP I	500USD	1997-2002	Upgrade, Rehabilitation, Periodic, and Routine maintenance of 3,500 km roads were conducted to gradually reduce the proportion of road networks in a poor state.
Road SIP II	1,624USD	2004-2013	Periodic & Routine Maintenance of Good and Fair roads was conducted with an emphasis on the core network, and roads in poor condition were repaired. In addition, maintenance of the road repaired by Road SIP I was conducted.
Road Network Improvement Project	200USD	2018-2022	Repair and maintenance of Feeder roads that could not be covered by Road SIPI and II were conducted using the Output Performance Road Contract (OPRC). At the same time, capacity building of government agencies will be conducted.

60 RDA [2018], 2017 Annual Report
61 The WB [2012], The crisis in the Zambian Road Sector

(1) Projects Currently Being Implemented

1) Rural Network Improvement Project

a) Implementation Period (Project Cost) January 2018 - December 2022 (US$200million)
b) Donor The WB, etc.
c) Purpose and background of the project

The road condition in Zambia (2014 data) is shown in Figure 6.12. The condition of trunk roads such as Trunk and Main in Zambia is getting better, but more than 80% of Primary Feeder roads are in "Poor" condition. The poor condition of Primary Feeder roads is affecting the accessibility of rural roads. The accessibility of local roads is linked to the development of local agriculture and poverty in the region. If accessibility is poor, fewer crops are shipped to the market. There is a significant link between access to local roads and agricultural development and poverty.

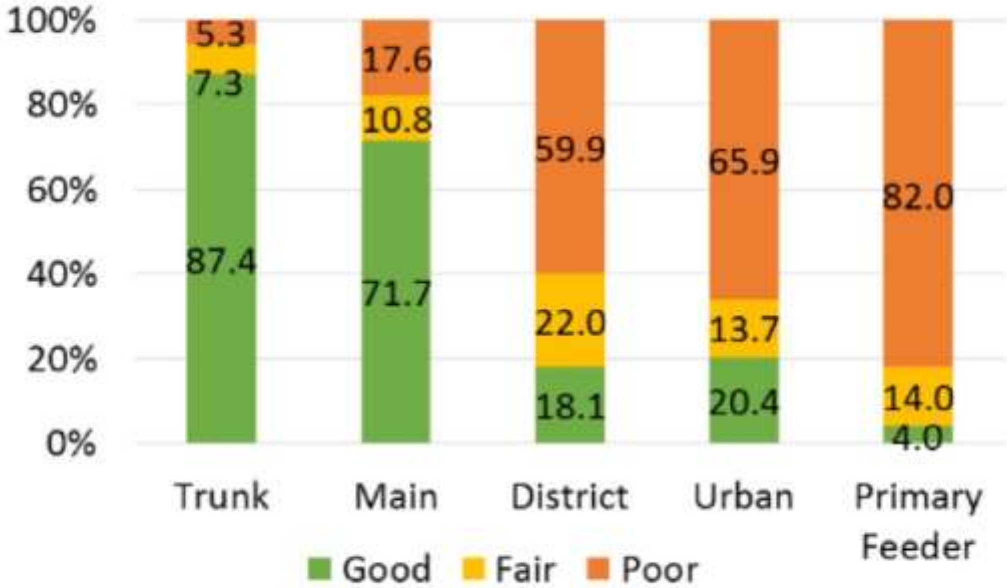


Figure 6.12 Road Conditions in Zambia (2014 Data)[62]

(2) Implementation Plan

1) Improvement of Feeder Roads (US$180 million)

4,300 km of feeder roads in six regions of Zambia (Central, Eastern, Northern, Luapula, Southern and Muchinga) will be upgraded from earthen to gravel roads, using the Output Performance Road Contract (OPRC). The contract is an Output Performance Road Contract (OPRC), which has a five-year construction period. In the first year, improvement work will be conducted, and in the remaining four years, the road will be maintained and managed.[63] Areas with a daily traffic volume of 50 to 100 vehicles or more after

[62] The WB [2017], Zambia: Improved rural connectivity project appraisal document
[63] The WB [2017], Output and Performance-Based Road Contracts and Agricultural Production Evidence from Zambia

10 years will be upgraded to low-cost asphalt-sealed pavement. In addition, climate change adaptation measures to be considered in future studies shall be added.

2) Support for Project Implementation (US$14.3 million)

The project will support the implementation of the project, including implementation of the OPRC FS and design, resettlement support, and construction management.

3) Support for Capacity Building of Road Agencies (US$9.0 million)

Establishment of a materials testing laboratory, technical assistance on transportation policy, strengthening of the organizational capacity of the Road Fund, development of a maintenance strategy for local roads, etc. will be implemented.

6.4.5.2 JICA

Table 6.6 shows the projects implemented and under implementation by JICA. In the field of road AM, support related to bridges is the focus.

Table 6.6 Road AM-Studies and the Technical Cooperation Projects by JICA

Subject	Completion time	Contractor	Business content
Bridge maintenance capacity improvement project detailed plan formulation survey	2015～2017	Nippon Engineering Consultants Co, Ltd.	Collection of basic information for project implementation and examination of project cooperation contents
Bridge maintenance capacity improvement project	2015～2017	Nippon Engineering Consultants Co, Ltd.、West Nippon Expressway Co, Ltd	Formulation of bridge daily maintenance guidebook, implementation of bridge daily maintenance pilot project, formulation of bridge repair guidebook
Bridge maintenance capacity improvement project Phase II	2019～2023	Nippon Engineering Consultants Co, Ltd.、Japan Overseas Consultants Co, Ltd、Central Nippon Expressway Co, Ltd、Pacific Consultants Co., Ltd.	Development of daily maintenance and management of bridges in rural areas, implementation of pilot projects for repair work
Basic survey on bridge repair using epoxy resin	2020	Alpha industry Co, Ltd.	Survey on the possibility of deploying concrete repair technology in Zambia

6.5 Overview of Bridge Maintenance Capacity Improvement Project (Phase II)

6.5.1 Goals and Project Objectives and Performance Indicators

(1) Overall Goals

The overall objective is “the condition of bridges under the jurisdiction of the RDA will improve” and the following items have been set as indicators to evaluate the achievement of the overriding objective.

1) Bridge maintenance work will be explicitly included in the RDA's annual activity plan.
2) Regular inspections of bridges will be conducted in each region.

(2) Project Goals

The project goal is to “improve bridge maintenance operations at RDA headquarters and regional offices”, and the following indicators have been set to evaluate the achievement of the project goal.

1) Number of bridges routinely maintained in each region according to the guidelines and guidebooks developed by the project (xx or more).
2) Bridge maintenance cycle is established in each region.
3) Number of bridges routinely maintained based on project guidelines, guidebooks, etc.

Table 6.7 Project Outcome Objectives and Performance Indicators

Achievement Goals	Outcome indicators
Outcome one The ability of engineers involved in daily bridge maintenance will be improved at the RDA headquarters and region offices.	1) Working groups will be convened more than once to review the guidelines for daily bridge maintenance and will be revised, as necessary. 2) Bridge daily maintenance seminar / OJT participants' comprehension (xx% or more of the participants reached a certain level in the comprehension test) 3) Based on the established technical specifications, daily bridge maintenance will be conducted on the planned schedule.
Outcome two Improve the capabilities of technicians involved in bridge repair at RDA headquarters and region offices.	1) Working groups will be convened more than once to review the bridge repair guidebook and will be revised, as necessary. 2) Bridge repair seminar / OJT participants' comprehension (xx% or more of the participants reached a certain level in the comprehension test) 3) The bridge will be repaired according to the planned schedule based on the specified technical specifications.
Outcome three Improve the capabilities of technicians involved in bridge inspections at RDA headquarters and region offices.	1) Working groups will be convened more than once to review the bridge inspection guidebook and will be revised, as necessary. 2) Bridge inspection seminar / OJT participants' comprehension (xx% or more of the participants meet a certain level in the comprehension test)

6.5.2 Manuals Introduced in the Project

In the project, the manuals listed in Table 6.8 are planned to be prepared.

Table 6.8 Manuals to be Introduced

Document name	Overview
Special bridge inspection guidebook	Inspect methods for special bridges such as suspension bridges, cable-stayed bridges, and PC box girder bridges will be summarized and added to the inspection guidebook.
Daily maintenance method for special bridges	Add daily maintenance methods for special bridges to the daily maintenance guidelines for bridges.
Review of Bridge Inspection Guidebook	Review the “Bridge Inspection Guidebook” prepared in Phase I and revise it, as necessary.
Review of bridge daily maintenance guidelines	Review the “Bridge Daily Maintenance Guidelines” prepared in Phase I and revise them, as necessary.
Review of bridge repair guidebook	Review the “Bridge Repair Guidebook” prepared in Phase I through the pilot project and revise it, as necessary.

The manuals already prepared for the technical cooperation project Phase I are shown in Table 6.9.

Table 6.9 Manuals Prepared in Phase I of the Bridge Technical Cooperation Project

Document name	Overview
Bridge daily maintenance guidelines	This is a summary of work contents, work frequency, and work range such as daily inspections, cleaning, planting, and minor repairs of bridges.
Bridge repair guidelines	This is a summary of repair methods according to damage. The materials applied to each repair method are also summarized.
Bridge inspection guidebook	This is a summary of the method of performing periodic bridge inspections, the frequency of implementation, the scope of implementation, the recording method, and the method of determining the degree of damage.

6.5.3 Project Progress

The project started in early 2019, but was temporarily interrupted due to the corona, but has partially resumed project field deployment in 2021. Note that the above manuals have not yet been developed yet.

6.6 Construction, Maintenance and Management Capabilities, Technical Standards

As shown in Figure 6.13, 87% of the construction companies in Zambia are local construction companies in terms of the number of contracts, but 20% are local construction companies in terms of the contract amount, and 71% are Chinese companies. The reality is that Chinese companies conduct rehabilitation and upgrade projects with large contract amounts, while local construction companies receive smaller maintenance contracts and subcontracts from Chinese companies.

In Routine maintenance, manual construction is recommended from the government's employment security measures. Even in places where weeding machines can be used, it is done manually with a sickle, which is extremely inefficient. The reality is that mechanization is hindering the improvement of maintenance and management capabilities in the name of employment promotion. In addition, regarding pavement repair, cutting overlays are not actively adopted due to the problem of the ability of contractors, in addition to economic reasons, and construction by overlays is the main method.

Regarding technical standards, Zambia does not have its own standards, but applies standards such as BS（British Standard）, SABS（South African Bureau of Standards）, and SATCC（Southern Africa Transport and Communications Commission） mutatis mutandis, and does not have standards based on the construction standards of its own country.

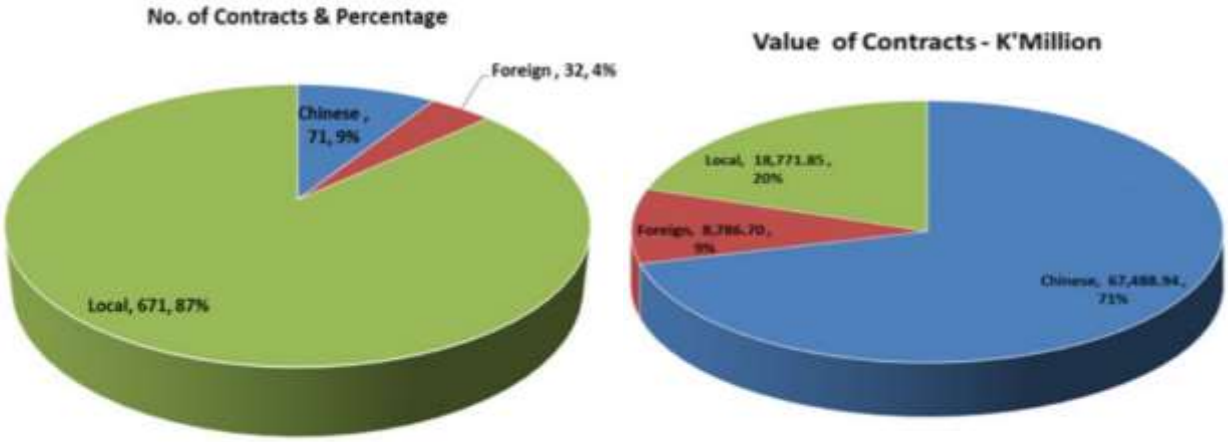


Figure 6.13 Breakdown of Construction Companies by Number of Contracts[64] and Contract Amount[65]

6.7 Road AM Maturity Level

6.7.1 How to Conduct Maturity Evaluation

The maturity evaluation was conducted through web interviews with the participants and dates shown in Table 6.10. An evaluation sheet was distributed in advance, and the grading process was explained at the kick-off meeting. In the hearing, the participants were asked to explain the points they graded and the reasons for their grades, and to confirm the background of the items with low or high self-grading results. If the other party suggested a change in the grading during the hearing, the change was made on the spot. In addition, for items that needed to be confirmed by obtaining documents, we asked them to send us the documents after the hearing.

Table 6.10 Details of the Hearings

Item	Date	Attendees	Contents
JICA kick off	5/18	JICA Headquarters、JICA Zambia office	Explanation of purpose
RDA kick off	6/8	Maintenance Department Senior manager Eng. Kapinda Planning and Design Department Senior manager Eng. Yobe	Explanation of purpose, hearing date and time setting
Bridges, monitoring / organization	6/15	Maintenance Department Senior manager Eng. Kapinda	Evaluation sheet scoring
Pavement, earthwork	6/17	Planning and Design Department Senior manager Eng. Yobe	Evaluation sheet scoring
Bridges, monitoring / organization	6/21	Maintenance Department Senior manager Eng. Kapinda	Additional hearings
Pavement, earthwork	6/25	Planning and Design Department Senior manager Eng. Yobe	Evaluation sheet scoring
Bridges, monitoring / organization	7/15	Maintenance Department Senior manager Eng. Kapinda	Overall summary
Pavement, earthwork	7/16	Planning and Design Department Senior manager Eng. Yobe	Additional hearings

[64] National Road Fund Agency [2020], 2019 Annual Report
[65] National Road Fund Agency [2020], 2019 Annual Report

Item	Date	Attendees	Contents
Pavement, earthwork	7/28	Planning and Design Department Senior manager Eng. Yobe	Overall summary
Report of survey results to JICA	8/11	JICA Headquarters	Report on Survey Results

To obtain supplementary information, a web-based hearing was conducted with the technical cooperation project team as shown in Table 6.11.

Table 6.11 Details of the Supplementary Hearing

Hearing target	Date	Attendees	Contents
Nippon Engineering Consultants Co, Ltd.	4/16 5/7 7/13	Zambia National Bridge Technical Cooperation Project II Project Manager	Hearing about bridge AM

6.7.2 Maturity Evaluation Results

Figure 6.14 shows the radar chart of major items (evaluation scores).

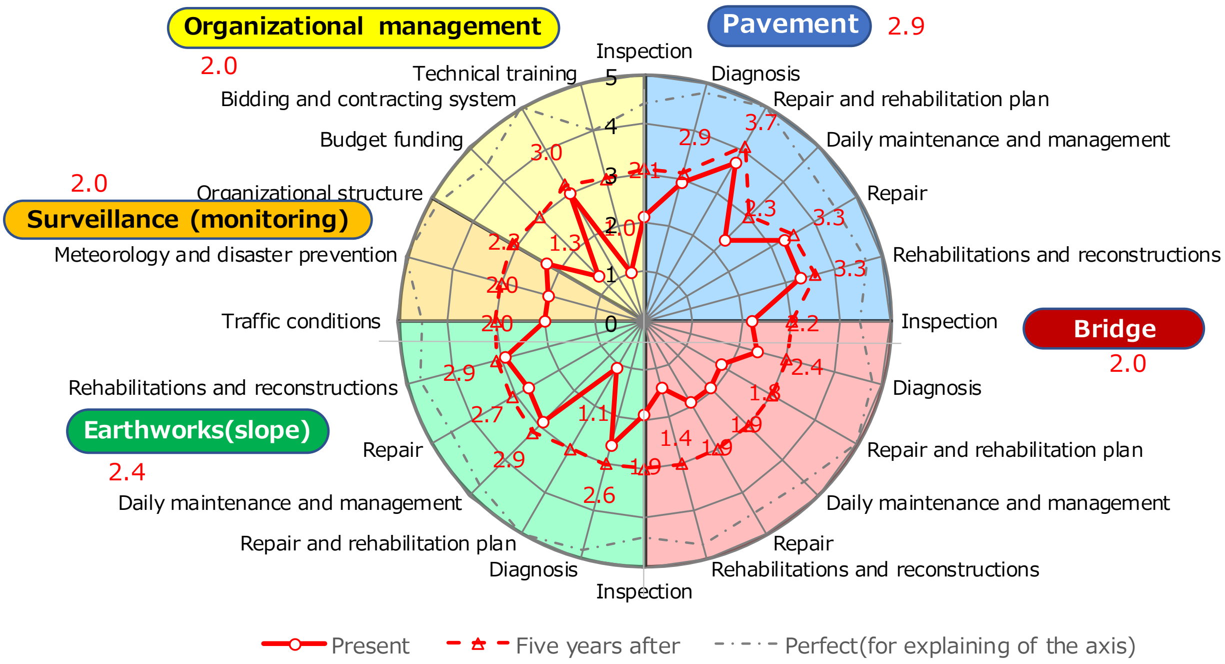


Figure 6.14 Radar Chart of Major Items (Level)

(1) Overall Evaluation

1) The maturity level of bridge-related projects has been low. Due to lack of funds, routine maintenance work has not been expanded to other regions. Periodic inspection data has not been updated in time, with the most recent data being from 2011, and repair plans have not been formulated. And repair works and reconstruction/reconstruction works have not been started yet.

(2) Pavements (Evaluation Level 2.9)

1) The level of "Repair/Rehabilitation Plan" is high at 3.7; the pavement ledger DB has been developed for all lines with the support of the WB in 2015; the PMS was developed in 1997 and has been upgraded

several times since then. The PMS was developed in 1997 and has been upgraded several times since then. In addition, a 10-year long-term plan for pavements was developed in 2015, and annual repairs are conducted based on this plan.

2) The level of “Rehabilitation and Reconstruction” is 3.3. This is because the RDA checks and monitors the entire process based on the construction plan prepared by the contractor. This is because the RDA checks and monitors the entire process based on the construction plan prepared by the contractor, and a repair manual is prepared, and quality control is conducted throughout the entire process.

(3) Bridges (Evaluation Level 2.0)

1) The level of “Rehabilitation and Reconstruction” is low at 1.4. The level of “Rehabilitation and Reconstruction” is low at 1.4, which is since there are bridges that need to be reconstructed or renewed but have not yet been tackled.

(4) Earthwork (Slopes) (Evaluation Level 2.4)

1) The level of “Inspection” is low at 1.9, which is since daily inspections have not yet been conducted, and periodic inspections are conducted on a limited number of routes with paper-based records and information is not shared.
2) The level of “Daily Maintenance Management” is 2.9. This is since in 40% of the routes under the RDA's jurisdiction, road maintenance is outsourced according to performance standards, cleaning and planting work is carried out on a regular basis, and the RDA conducts monthly inspections to continuously evaluate the contractor's work.
3) The level of “Rehabilitation and Reconstruction” is 2.9. This is since the RDA checks and monitors the entire process based on the construction plan, and that the necessary materials and equipment are available, and the specifications and performance of the work are satisfactory.
4) The level of the “Repair and Reconstruction Plan” is low at 1.1. This is because there is no ledger database for earthworks and no repair plan has been formulated. This is since most of the work is done after the disaster has occurred.

(5) Monitoring (Evaluation Level 2.0)

1) Meteorological observation and traffic volume measurement are conducted only on some routes, and the frequency of observation and measurement is irregular, resulting in a low rating.

(6) Organizational Management (Evaluation Level 2.0)

1) The level of “Bidding and Contracting System” is 3.0, and the contracting system itself is well established.
2) The level of “Budget Financing” is low at 1.3. This is because the Zambian government defaulted on its debt in November 2010, making it difficult to raise funds, and payment for contracted work has been delayed.
3) The level of “Technical Training” is low at 1.0 since the RDA did not have a specific training plan. (The University of Zambia is in the process of developing a bridge training program).

6.8 Current Status and Challenges of Road AM

6.8.1 Current Status and Challenges of Pavement AM

In December 2020, RDA purchased a road surface condition measuring vehicle that can measure IRI, cracks, potholes, etc., with the support of the WB, and started regular inspections, which had not been conducted since 2016, under the direct management of RDA from 2021. The pavement condition is evaluated in three levels according to the IRI measurement value: IRI<3=Good, 4<IRI<5=Fair, and IRI>6=Bad. Newly measured vehicles are also capable of measuring cracks and ruts, and it is necessary to consider how to incorporate these indicators into the evaluation criteria.

The RDA lacks engineers who are familiar with measurement and diagnosis, and there is a need for training and development of engineers for pavement inspection, diagnosis, and repair planning. There is a need to train and develop engineers.

PMS was developed by RDA in 1997 and has been upgraded several times since then. IRI measurements were manually entered into the PMS system in the past, but now it is linked to the database and the data can be transferred. A 10-year long term plan was established in 2015. In 2015, a 10-year long term plan was developed; however, it was developed using data up to 2015, and no data was entered after 2016, and the plan has not been revised.

Routine maintenance work under performance regulations is outsourced for 40% of the routes under RDA jurisdiction. Pothole treatment is to be managed by the contractor based on the instructions of the RDA, but due to budget constraints, this is done only after the pothole becomes large. Although many of the repair materials must be imported and procured, most of the materials are readily available.

1) RDA has purchased a vehicle at the end of 2020 that can also measure cracks and ruts, but only IRI is still used to determine pavement management standards.
2) Road surface condition surveys were conducted every year from 2006 to 2015 but have not been conducted since 2016 due to budget shortage. As a result, the latest road surface condition has not been grasped and the areas that need to be repaired on a priority basis have not been identified.
3) In the past, inspection and diagnoses have been outsourced, so there are few staff with the necessary skills. In the future, it will be necessary to provide opportunities to receive the necessary training to proceed with inspection under direct management.
4) Potholes and cracks are treated in bulk after they have grown to a certain degree. In the meantime, there is a possibility that the strength of the lower layer will be reduced due to rainwater infiltration.

6.8.2 Current Status and Challenges of Bridge AM

There is a basic set of bridge inspection machines and equipment including bridge inspection vehicles. In Phase I of the technical cooperation project, a manual for general bridge inspections, daily maintenance management and repair has been prepared, and a manual for special inspections, for long-span bridges, will be prepared in Phase II.

As for the daily maintenance of bridges, a pilot project for Lusaka region was conducted in Phase I of the technical cooperation project. Subsequently, as part of the roll-out program, routine maintenance work was ordered in three regions, but partial payment of advance payments was not made due to lack of funds from RDA. Therefore, after the work started, daily inspections and some minor repairs were conducted, but the work has been suspended due to lack of funds from the contractor.

As for the BMS, a South African system called Truman was introduced in 2017 and is ready for operation, but the routine inspections that had been outsourced was suspended due to lack of budget. The RDA introduced a US BMS called BMI in 2011, and the JICA technical cooperation project Phase II is working with the data from this system. As soon as the funding is secured, regular inspections will be resumed, and the data will be entered into Truman to enable the BMS to operate. However, the evaluation criteria for the inspection results in Truman is slightly different from the inspection manual created in Phase I. In addition, Truman is a system that can be applied only to concrete bridges. The reason for this is that South Africa has almost no steel bridges.

As for the repair work, the technical cooperation project Phase I has been conducted up to the preparation of the repair guidebook, and the pilot work is scheduled to be ordered by RDA with the support of the technical cooperation project Phase II. As for bridge repair materials, polymer cement and epoxy resin are imported from South Africa and Japan, but if they could be procured domestically, it would not only be more cost effective but also easier to procure and use in construction.

1) Due to budget shortage, the regular inspections of bridges have been suspended, and the inspection data of 2011 is the latest. Therefore, the degree of damage in the current state has not been confirmed.
2) The BMS has been installed, but as shown above, the inspection data has not been input yet, and the repair plan has not been formulated.
3) In 2019, routine maintenance work was ordered in three areas, but only a part of the advance payment was made due to lack of funds from the RDA, so only routine inspections and some minor repairs were conducted. In 2019, daily maintenance work was ordered in three areas, but only partial payment was made due to lack of RDA funding, so only daily inspections and some minor repairs were conducted.
4) In response to the recommendation of JICA's technical cooperation project team, a plan is currently underway to divide the work into direct management and outsourcing.
5) Zambia has no experience in conducting repair work. Therefore, even if damage is found during inspections, it cannot be repaired. It has not been possible to halt the progress of damage by implementing appropriate repairs at the right time.
6) In Phase I of the technical cooperation project, the guidebook for repair was prepared, but it did not lead to the implementation of repair work. In Phase II, technical assistance will be provided in a pilot project ordered by RDA.

6.8.3 Current Status and Challenges of Earthworks AM

About earthworks, there is no basic periodic inspection manual or database ledger, and inspection results are recorded on a paper basis, which is for emergency response to disasters. In addition, a medium- to long-term repair plan has not been formulated.

1) Daily inspections are not conducted, and periodic inspections are only conducted on some routes.
2) There is a shortage of staff who can inspect slopes.
3) Inspection results are stored in paper form, and information is not shared.
4) The database ledger for earthworks is not maintained.
5) Medium- and long-term repair plans have not been formulated.
6) Recovery measures are being taken in the event of a disaster.
7) Repair and rehabilitation work is outsourced.

6.8.4 Current Status and Challenges of Organizational Management AM

The Zambian government defaulted on its debt in November 2020, making it difficult to raise funds. This is especially true in bridges, where the budget is small. The bridge inspections ordered in 2017 and the routine maintenance work in three regions ordered in 2019 have been suspended since the start of work due to the inability to pay the full number of advance payments.

This is due to the small budget distributed by the government and the unpredictability and instability of the amount distributed, but also due to the lack of coordination between the Road Fund, which oversees payments, and the RDA, which oversees contracts, and the fact that the contracts were made without any guarantee of financing. In this regard, the Road Fund and RDAs are likely to set up a system from 2021 where contracts will not be awarded without funding checks. However, considering the situation where such rudimentary checks are finally being introduced, it can be inferred that there are many areas for improvement regarding the operation of the Road Fund.

1) Contracted for periodic bridge inspections and daily bridge maintenance work, but unable to make advance payments due to lack of RDA funds, and thus unable to start surveys and construction (from RDA interview)
2) Lack of coordination between the Road Fund, which oversees payments, and the RDA, which oversees construction contracts (from the Road Fund Annual Report).
3) In addition to the low budget distribution from the government, it is impossible to predict when and how much will be distributed. This has caused a major hindrance in the execution of projects (from the Annual Report of the Ministry of Public Works and Resettlement).
4) Due to unpaid debts from the previous fiscal year, payment for the work scheduled for the relevant fiscal year has been delayed (from the Road Fund Annual Report).

6.8.5 Issues Requiring Research and Development

Among the issues extracted through Road AM evaluation, the issues that require research and development of repair technology, long life technology, and inspection technology are shown in Table 6.12.

Table 6.12 Issues Requiring Research and Development (Zambia)

	Target Issues	Remarks
Pavement	No specific themes	
Bridge	Tight budget constraints on bridge maintenance	We need to take measures to maintain and manage bridges in an extremely limited budget.
Earth work	Measures to stabilize slopes	No database of slopes or geological surveys, no experts on slope countermeasures

Table 6.13 Draft Research Plans and University Candidates for Extracted Subjects (Bridges)

<table>
<tr><td>Subject</td><td colspan="2">A study on the countermeasure priority determination method of existing bridges</td></tr>
<tr><td>Background and Necessity</td><td colspan="2">Manuals on bridge maintenance and repair are being developed by the technical cooperation projects, but the number of bridges that can be implemented for financial reasons is extremely limited. Therefore, how to prioritize repairs for bridges in similar damage situations is a challenge.</td></tr>
<tr><td>Research Plan</td><td colspan="2">Considering “soundness” as the main factor of the new priority determination method, the “importance” possessed by each bridge that considers the location conditions and environmental conditions of bridges closely related to the local community is also set as an evaluation axis. The soundness is evaluated by weighting the soundness diagnosis result of the entire bridge and the degree of damage for each member.
In addition, in view of the location conditions and regionality, for example, (1) the importance of the route, (2) the use status of the bridge, (3) the presence or absence of a lifeline sub-rack, (4) the road down condition of the bridge, (5) the designation of the school road, (6) the presence or absence of circuits, (7) the possibility of isolated villages, etc. Finally, we construct a method using “evaluation based on comprehensive judgment of soundness and importance” by adding points of “evaluation on soundness” and “evaluation on importance”. In Zambia, where this method is strongly constrained by financial constraints, it is possible to rationally select the bridges that need the most countermeasures.</td></tr>
<tr><td>University Candidates Zambia</td><td colspan="2">■University of Zambia
Established in 1966, it is a comprehensive university located in Lusaka City. It is the oldest and largest university in Zambia. The number of students is about 30,000. The Faculty of Engineering was established in 1969 and has the Department of Civil Engineering, the Department of Electrical and Electronic Engineering, the Department of Mechanical Engineering, and the Department of Agricultural Engineering
■Copperbelt University
It is a comprehensive university established in 1987 and is in Copperbelt. The number of students is about 11,000. The Faculty of Engineering has the largest engineering department in Zambia, with the Department of Civil Engineering, the Department of Construction Management, the Department of Electrical Engineering, the Department of Mechanical Engineering, the Department of Mechatronics Engineering, the Department of Aeronautical Engineering, and the Department of Communication Engineering.</td></tr>
<tr><td rowspan="2">University Candidates Japan</td><td>Gifu University</td><td>■Associate Professor Koji Kinoshita, Professor Emeritus Keitetsu Rokugo
Gifu University concluded an inter-faculty agreement with the University of Zambia's Graduate School of Engineering in January 2019 and has established a system to train maintenance experts who are engineers who can perform appropriate diagnosis and treatment for existing infrastructure facilities. His research interests are widely conducted on fatigue of steel structures, nondestructive inspections, and earthquake resistance of bridge structures.</td></tr>
<tr><td>Nagasaki University</td><td>■Professor Seizo Nakamura
JICA international students (master's program) are accepted from Laos (bridge inspections and evaluation method for asset management).</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

		■Associate Professor Takafumi Nishikawa JICA international students (master's program) are accepted from Laos (research on maintenance model that contributes to extending the life of steel bridges). We are conducting research that contributes to the appropriate maintenance and management of structures, such as prediction methods for structural deterioration, correlation between corrosive environment and corrosion situation, and durability evaluation of various anticorrosion methods.
	Niigata University	■Professor Tatsuhiko Saeki He oversees the secretariat of the Niigata Regional Council for The Development of Infrastructure Revitalization Engineers and conducts lectures and practical training in infrastructure maintenance seminars, as well as conducting “ME Niigata” certification tests. They are studying the construction of a series of methods to evaluate the performance of concrete from the properties of individual hydrates by considering concrete as a collection of various hydrates.

Table 6.14 Draft Research Plans and University Candidates for Extracted Subjects (Earthworks)

Subject	Study on extraction of necessary parts for roadside stability measures	
Background and Necessity	Zambia does not have a DB of slopes geological conditions, and there are no regular inspections, and the post-action is repeated to recover every time a disaster occurs. In the event of a disaster, the main road is cut off and it becomes difficult to transport daily necessitation, and how to prevent disasters is a problem.	
Research Plan	By analyzing the relationship between rainfall patterns, geology, road conditions (pavement/ dirt, road drainage facilities, etc.) and disaster occurrence with respect to slope disasters caused by abnormal rainfall, they analyze the probability of disaster occurrence in what cases. By setting the degree of impact of a disaster on the region in conjunction with the probability of a disaster, the probability of regional impact due to the disaster is calculated, and the priority location selection logic to be prioritized among the whole of Zambia is constructed. By conducting this research, it is possible to identify places where emergency measures are implemented without waiting for the construction of a database of roadsides and periodic inspections throughout Zambia, leading to the prevention of disasters.	
University Candidates Zambia	■University of Zambia Established in 1966, it is a comprehensive university located in Lusaka City. It is the oldest and largest university in Zambia. The number of students is about 30,000. The Faculty of Engineering was established in 1969 and has the Department of Civil Engineering, the Department of Electrical and Electronic Engineering, the Department of Mechanical Engineering, and the Department of Agricultural Engineering. ■Copperbelt University It is a comprehensive university established in 1987 and is in Copperbelt. The number of students is about 11,000. The Faculty of Engineering has the largest engineering department in Zambia, with the Department of Civil Engineering, the Department of Construction Management, the Department of Electrical Engineering, the Department of Mechanical Engineering, the Department of Mechatronics Engineering, the Department of Aeronautical Engineering, and the Department of Communication Engineering.	
University Candidates Japan	Gifu University	■Professor. Atsushi Yashima, Associate Professor Koji Kinoshita Gifu University concluded an inter-faculty agreement with the University of Zambia's Graduate School of Engineering in January 2019, and has established a disaster prevention course in the Department of Social Infrastructure Engineering to elucidate the mechanism of various disasters, examine methodologies to mitigate damage, and develop a system for local residents to cooperate to prepare for disasters, and are conducting research aimed at forming a safe and secure society from both hardware and software. Prof. Yashima is studying geotechnical engineering, earthquake engineering, geo-disaster prevention engineering, etc.
	Tohoku University	■Professor Makoto Hisada, Associate Professor Hiroshi Minagawa Industry, academia, and government from six prefectures in Tohoku collaborate on the development of information infrastructure and social implementation on the Tohoku Infrastructure Management Platform. Based on concrete and

		materials engineering, I am studying the maintenance, construction, and construction management of infrastructure.
	Kyoto University	■Professor. Ryosuke Uzuoka (National Research Institute for Disaster Risk Reduction) In response to problems in disaster prevention engineering, we are working from all angles, such as upgrading vulnerability diagnosis technology and risk evaluation technology, constructing wide-area ground model using GIS and urban information database, and reproduction model experiment of ground disaster. ■Professor. Ryo Kimura (Geodynamics) We elucidate the complex interaction between ground and structure for various structures and study the interaction between ground and structure using experiments and numerical analysis.

6.9 Support Plan for Establishing Road AM

6.9.1 Support Plan for Pavement AM

The support plan is shown in Table 6.15 based on the issues. However, about pavement AM, it is necessary to proceed in collaboration with the WBs that have provided support in the past.

Table 6.15 Draft Support Plan for Pavement AM in Zambia

	Challenge Item	Contents	Support Measures
1	Formulation of medium- to long-term plans using measurement data from road surface condition measurement vehicles	The management level, which was conventionally determined only by IRI, will be considered from the viewpoint of the durability of the pavement structure, and indicators such as cracks and potholes will be added to formulate an effective repair plan. In addition, when adding a crack or rut index, it is necessary to predict the degree of the effect in advance and then consider whether to change the conventional method.	JICA Technical Cooperation Project (Pavement)
2	Potholes and cracks in the initial stages	By repairing small potholes and cracks at an early stage, the spread of damage is prevented, and the life cycle cost is reduced. For example, we will consider the introduction of early pothole treatment using room temperature aggregate in the performance regulation maintenance contract introduced on 40% of routes (RDA can import room temperature mixture from South Africa and the Middle East.)	
3	Direct pavement inspection/diagnosis by RDA staff	To directly manage the measurement / diagnosis work, which was previously outsourced, the staff will be required to take training to improve their technical capabilities.	Improve basic knowledge ability by utilizing task-based training

6.9.2 Support Plan for Bridge AM

The support plan is shown in Table 6.16 based on the bridge issues. However, the full-scale implementation of the Bridge Technical Cooperation Project Phase II is about to begin, and some of the issues will be addressed in that phase.

Table 6.16 Future Support Plan for Bridge AM in Zambia

	Challenge Item	Contents	Support Measures
1	Conducting daily maintenance and regular inspections in consideration of lack of funds	To enable RDA staff to conduct daily inspections and cleaning work that can be managed directly in daily maintenance as a response to the constant shortage of funds (under consideration in Technical Cooperation Project Phase II). Consider conducting regular inspections directly. Based on the data obtained by the periodic inspections, BMS will be used to formulate a medium- to long-term plan.	Due to the unstable budget distribution, the technical cooperation project supports the direct management of daily maintenance and regular inspections in one.
2	Development of daily maintenance work	The daily maintenance conducted in the Lusaka region in the technical cooperation project phase I will be expanded to other regions (scheduled to be conducted in the technical cooperation project phase II). Routine maintenance work will be conducted separately for direct management and outsourcing, and the budget will be streamlined so that daily maintenance work can be conducted continuously. Securing personnel for local offices.	
3	Development of repair work	Using the created repair manual, pilot work will be conducted in Phase II of the technical cooperation project, and after understanding the issues and points for improvement, the repair work will be expanded to other regions.	
4	Supporting the activities of Gifu University / University of Zambia	We will enhance the bridge technology development program currently being undertaken by Gifu University and the University of Zambia to train bridge engineers in Zambia. In implementing the support 1 to 3 above, we will promote the development of engineers in cooperation with the courses at the University of Zambia.	Support for the operation of bridge management courses at the University of Zambia

6.9.3 Support Plan for Earthwork AM

The support plan is shown in Table 6.17 based on the earthwork issues.

Table 6.17 Future Support Plan for Earthwork AM in Zambia

	Challenge Item	Contents	Support Measures
1	Formulation of repair plan based on inspection/diagnosis results	Develop a DB so that information on inspection results can be shared. In addition, it will be possible to formulate a medium- to long-term repair plan based on the inspection results.	JICA Technical Cooperation Project (Earthwork)
2	Implementation of repair work		
3	Direct management and diagnosis by RDA staff	Since the staff has little knowledge about slope inspections, etc., take training etc. to improve their technical skills.	Improve basic knowledge ability by utilizing task-based training

6.9.4 Support Plan for Organizational Management AM

Based on the issues, the support plan is shown in Table 6.18. It is necessary for the Road Fund and RDAs to establish a system where contracts cannot be signed if there is no prospect of funding. Stable funding by the Road Fund is an essential element for the efficient implementation of road projects. Therefore, in addition to the above, support will be provided to improve the operational efficiency of the Road Fund. In addition, the WB is currently supporting the "Road network improvement project", which includes strengthening the organizational capacity of the Road Fund as a menu item. The support needs to be implemented in coordination with the WB.

Table 6.18 Support Plan for Operational Efficiency of the Road Fund

	Challenge Item	Contents	Support Measures
1	Improving the efficiency of road fund operations	Strengthen the cooperation between the road fund, which oversees payments to contractors, and RDA, which oversees contracts, and prevent the situation where advance payments are difficult to pay after the contract is concluded. Consider measures to provide stable funding to road enforcement agencies.	Consider support plans in collaboration with the WB

6.10 List of Road AM Evaluation Results in Zambia

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
1 Pavement	2.9	62.8%	(1) Inspection	2.1	48%	((1)) Inspection system	2.5	50%	<1> System	2.5	50%
									<2> Technical level of inspectors	2	40%
									<3> Use of inspection equipment	3	60%
						((2)) Inspection manual	1.6	40%	<4> Existence of daily inspection manual	1	20%
									<5> Use of daily inspection manual	1	33%
									<6> Existence of periodic inspection manual	2	40%
									<7> Use of periodic inspection manual	2	67%
									<8> Technical level of the manual	2.0	40%
						((3)) Implementation of daily inspections	2.0	44%	<9> Inspection range	1	20%
									<10> Frequency of inspections	1	33%
									<11> Storage and sharing of inspection records	4	80%
						((4)) Implementation of periodic inspections	2.7	62%	<12> Inspection range	2	40%
									<13> Frequency of inspections	2	67%
									<14> Storage and sharing of inspection records	4	80%
			(2) Diagnosis	2.9	61%	((5)) Diagnostic system	2.5	50%	<15> System	3.0	60%
									<16> Technical level of diagnosis	2	40%
						((6)) Diagnostic manual (As, Co, D, EXT)	2.7	62%	<17> Existence of diagnostic manual	3	60%
									<18> Use of diagnostic manual	2	67%
									<19> Technical level of the manual	3.0	60%
						((7)) Diagnosis of soundness (As, Co, D, EXT)	3.3	67%	<20> Investigation of the cause of damage	3	60%
									<21> Ranking of damage level	3	60%
									<22> Storage and sharing of diagnostic records	4	80%
			(3) Repair and rehabilitation plan	3.7	73%	((8)) Pavement assets ledger/DB	4.0	80%	<23> Existence of pavement assets ledger/DB	3	60%
									<24> Use of pavement assets ledger/DB	5	100%
						((9)) Pavement management system	3.0	60%	<25> Existence of pavement management system	5	100%
									<26> Use of pavement management system	1	20%
						((10)) Development of the plan	3.8	76%	<27> Planning	5	100%
									<28> Scope of the plan	5	100%
									<29> Prediction of soundness	2	40%
									<30> Understanding of the cost of repairs and rehabilitation	5	100%
									<31> Preventive maintenance	2	40%
			(4) Daily maintenance and management	2.3	56%	((11)) System for daily maintenance and management	2.3	47%	<32> System	2.0	40%
									<33> Technical level of the person responsible for maintenance management	3	60%
									<34> Operation of maintenance work equipment (pavement)	2	40%
						((12)) Cleaning (road surface)	1.0	20%	<35> Cleaning range	1	20%
									<36> Frequency of cleaning	1	20%
						((13)) Emergency measures	3.0	80%	<37> Management of response to deformation and damage	3	60%
									<38> Small repair of deformations (temporary repair)	3	100%
									<39> Emergency restoration of failures, etc.	3	100%
									<40> Storage and sharing of emergency measure records	3	60%
			(5) Repair	3.3	74%	((14)) Repair system	3.0	60%	<41> System	2.0	40%
									<42> Technical level of repair	4	80%
									<43> Procurement of materials and equipment	3	60%
						((15)) Quality standards (As, Co, D, EXT)	2.7	67%	<44> Existence of quality standards	3	60%
									<45> Application of quality standards	3	100%
									<46> Quality control	2	40%
						((16)) Repair (Design) manual	3.2	79%	<47> Existence of repair (design) manual	3	60%
									<48> Use of repair (design) manual	3	100%
									<49> Technical level of the manual	3.7	76%
						((17)) Implementation of repairs	4.0	87%	<50> Construction planning and process management	5	100%
									<51> Repair (radical repair)	2	67%
									<52> Management of changes	5	100%
									<53> Storage and sharing of repair records	4	80%
			(6) Rehabilitations and reconstructions	3.3	70%	((18)) System for rehabilitations and reconstructions	2.7	50%	<54> System	2.0	40%
									<55> Level of technology for rehabilitations and reconstructions	3	60%
									<56> Procurement of materials and equipment	3	60%
						((19)) Implementation of rehabilitations and reconstructions	3.8	82%	<57> Implementation plan	4	80%
									<58> Rehabilitations and reconstructions	2	67%
									<59> Management of changes	5	100%
									<60> Storage and sharing of records of rehabilitations and reconstructions	4	80%

Figure 6.15 List of Road AM Evaluation Results in Zambia【Pavement】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Bridges	2.0	44.0%	(7) Inspection	2.2	52%	((20)) Inspection system	2.2	43%	<61> System	1.5	30%
									<62> Technical level of inspectors	2	40%
									<63> Use of inspection equipment	3	60%
						((21)) Inspection manual	2.1	52%	<64> Existence of daily inspection manual	2	40%
									<65> Use of daily inspection manual	2	67%
									<66> Existence of periodic inspection manual	2	40%
									<67> Periodic inspection manual operation	2	67%
									<68> Technical level of the manual	2.3	47%
						((22)) Implementation of daily inspections	2.3	56%	<69> Inspection range	2	40%
									<70> Frequency of inspections	2	67%
									<71> Storage and sharing of inspection records	3	60%
						((23)) Implementation of periodic inspections	2.3	56%	<72> Inspection range	2	40%
									<73> Frequency of inspections	2	67%
									<74> Storage and sharing of inspection records	3	60%
			(8) Diagnosis	2.4	52%	((24)) Diagnostic system	1.8	35%	<75> System	1.5	30%
									<76> Technical level of diagnosis	2	40%
						((25)) Diagnostic manual (M, Co, EXT)	2.7	62%	<77> Existence of diagnostic manual	3	60%
									<78> Use of diagnostic manual	2	67%
									<79> Technical level of the manual	3.0	60%
						((26)) Diagnosis of soundness(M, Co, EXT)	2.7	53%	<80> Investigation of the cause of damage	3	60%
									<81> Ranking of damage level	3	60%
									<82> Storage and sharing of diagnostic records	2	40%
			(9) Repair and rehabilitation plan	1.8	36%	((27)) Bridge assets ledger/DB	1.5	30%	<83> Existence of bridge assets ledger/DB	2	40%
									<84> Use of bridge assets	1	20%
						((28)) Bridge management system	2.0	40%	<85> Existence of bridge management system	3	60%
									<86> Use of bridge management system	1	20%
						((29)) Development of the plan	1.8	36%	<87> Planning	2	40%
									<88> Scope of the plan	2	40%
									<89> Prediction of soundness	1	20%
									<90> Understanding of the cost of repairs and rehabilitation	1	20%
									<91> Preventive maintenance	3	60%
			(10) Daily maintenance and management	1.9	45%	((30)) System for daily maintenance and management	1.8	37%	<92> System	1.5	30%
									<93> Technical level of the person responsible for maintenance and management	2	40%
									<94> Operation of maintenance and management work equipment (bridges)	2	40%
						((31)) Cleaning (road surface)	2.0	40%	<95> Cleaning range	2	40%
									<96> Frequency of cleaning	2	40%
						((32)) Emergency measures	2.0	53%	<97> Management of response to deformation and damage	2	40%
									<98> Small repair of deformation (temporary repair)	1	33%
									<99> Emergency restoration of failures, etc.	3	100%
									<100> Storage and sharing of emergency measure records	2	40%
			(11) Repair	1.9	44%	((33)) Repair system	1.8	37%	<101> System	1.5	30%
									<102> Technical level of repair	2	40%
									<103> Procurement of materials and equipment	2	40%
						((34)) Quality standards (M, Co, EXT)	2.3	56%	<104> Existence of quality standards	3	60%
									<105> Application of quality standards	2	67%
									<106> Quality control	2	40%
						((35)) Repair (Design) manual	2.3	55%	<107> Existence of repair (design) manuals	3	60%
									<108> Use of repair (design) manual	2	67%
									<109> Technical level of the manual	1.8	40%
						((36)) Implementation of repairs	1.5	33%	<110> Repair planning and process management	2	40%
									<111> Repair (radical repair)	1	33%
									<112> Management of changes	1	20%
									<113> Storage and sharing of repair records	2	40%
			(12) Rehabilitations and reconstructions	1.4	29%	((37)) System for rehabilitations and reconstructions	1.5	30%	<114> System	1.5	30%
									<115> Level of technology for rehabilitations and reconstructions	1	20%
									<116> Procurement of materials and equipment	2	40%
						((38)) Implementation of rehabilitations and reconstructions	1.3	28%	<117> Implementation plan	1	20%
									<118> Rehabilitation and reconstruction	1	33%
									<119> Management of changes	1	20%
									<120> Storage and sharing of records of rehabilitations and reconstructions	2	40%

Figure 6.16 List of Road AM Evaluation Results in Zambia【Bridges】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
3 Earthworks(Slope)	2.4	52.7%	(13) Inspection	1.9	44%	((39)) Inspection system	2.7	53%	<121> System	3.0	60%
									<122> Technical level of inspectors	3	60%
									<123> Operation of inspection equipment	2	40%
						((40)) Inspection manual	1.8	44%	<124> Existence of daily inspection manual	1	20%
									<125> Use of daily inspection manual	1	33%
									<126> Existence of periodic inspection manual	3	60%
									<127> Use of periodic inspection manual	2	67%
									<128> Technical level of the manual	2.0	40%
						((41)) implementation of daily inspections	1.0	24%	<129> Inspection range	1	20%
									<130> Frequency of inspections	1	33%
									<131> Storage and sharing of inspection records	1	20%
						((42)) Implementation of periodic inspections	2.3	56%	<132> Inspection range	2	40%
									<133> Frequency of inspections	2	67%
									<134> Storage and sharing of inspection records	3	60%
			(14) Diagnosis	2.6	55%	((43)) Diagnostic system	2.5	50%	<135> System	3.0	60%
									<136> Technical level of diagnosis	2	40%
						((44)) Diagnostic manual (Slope, utility and drainage structures, retaining walls)	2.6	60%	<137> Existence of diagnostic manual	3	60%
									<138> Use of diagnostic manual	2	67%
									<139> Technical level of the manual	2.7	53%
						((45)) Diagnosis of soundness (Slope, utility and drainage structures, retaining walls)	2.7	53%	<140> Investigation of the cause of damage	2	40%
									<141> Ranking of damage level	3	60%
									<142> Storage and sharing of diagnostic records	3	60%
			(15) Repair and rehabilitation plan	1.1	23%	((46)) Earthwork assets ledger/DB	1.0	20%	<143> Existence of earthwork assets ledger/DB	1	20%
									<144> Use of earthwork assets ledger/DB	1	20%
						((47)) Development of the plan	1.2	24%	<145> Planning	1	20%
									<146> Scope of the plan	1	20%
									<147> Prediction of soundness	1	20%
									<148> Understanding of the cost of repairs and rehabilitations	1	20%
									<149> Preventive maintenance	2	40%
			(16) Daily maintenance and management	2.9	62%	((48)) System for daily maintenance and management	2.5	50%	<150> System	3.0	60%
									<151> Technical level of the person responsible for maintenance and management	3	60%
									<152> Operation of maintenance and management work equipment (earthworks)	2	40%
									<153> Operation of maintenance work equipment (accessories)	2	40%
						((49)) Mowing	3.5	70%	<154> Mowing area	3	60%
									<155> Frequency of mowing	4	80%
						((50)) Cleaning (waterways)	3.5	70%	<156> Cleaning range	3	60%
									<157> Frequency of cleaning	4	80%
						((51)) Cleaning (signs)	3.5	70%	<158> Cleaning range	3	60%
									<159> Frequency of cleaning	4	80%
						((52)) Emergency measures	2.5	63%	<160> Management of response to deformation and damage	3	60%
									<161> Small repair of deformation (temporary repair)	2	67%
									<162> Emergency restoration of failures, etc.	2	67%
									<163> Storage and sharing of emergency measure records	3	60%
			(17) Repair	2.7	62%	((53)) Repair system	2.7	53%	<164> System	3.0	60%
									<165> Technical level of repair	3	60%
									<166> Procurement of materials and equipment	2	40%
						((54)) Quality standards(Slope, retaining wall, drainage structure)	2.7	62%	<167> Existence of quality standards	3	60%
									<168> Application of quality standards	2	67%
									<169> Quality control	3	60%
						((55)) Repair (Design) manual	2.7	69%	<170> Existence of repair (design) manuals	3	60%
									<171> Use of repair (design) manual	3	100%
									<172> Technical level of the manual	2.2	47%
						((56)) Implementation of repairs	2.8	62%	<173> Construction planning and process management	4	80%
									<174> Repair (radical repair)	2	67%
									<175> Management of changes	2	40%
									<176> Storage and sharing of repair records	3	60%
			(18) Rehabilitations and reconstructions	2.9	61%	((57)) System for rehabilitation and reconstruction	3.0	60%	<177> System	3.0	60%
									<178> Level of technology for rehabilitations and reconstructions	3	60%
									<179> Procurement of materials and equipment	3	60%
						((58)) Implementation of rehabilitations and reconstructions	2.8	62%	<180> Implementation plan	4	80%
									<181> Rehabilitations and reconstructions	2	67%
									<182> Management of changes	2	40%
									<183> Storage and sharing of records of rehabilitations and reconstructions	3	60%

Figure 6.17 List of Road AM Evaluation Results in Zambia【Earthworks (Slopes)】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Surveillance (monitoring)	2.0	43.3%	(19) Traffic conditions	2.0	47%	((59)) Traffic volume	2.0	47%	<184> Monitoring range	2	40%
									<185> Monitoring frequency	2	67%
									<186> Monitoring sites	2	40%
									<187> Information sharing and utilization of monitoring results	2	40%
			(20) Meteorology and disaster prevention	2.0	40%	((60)) Precipitation, temperature, wind	2.0	40%	<188> Monitoring range	2	40%
									<189> Monitoring frequency	2	40%
									<190> Monitoring sites	2	40%
									<191> Information sharing and utilization of monitoring results	2	40%
Organizational management	2.0	42.9%	(21) Organizational structure	2.3	48%	((61)) Asset management cycle	2.3	47%	<192> Setting management goals	3	60%
									<193> Conducting internal audits	2	40%
									<194> Implementation of management review	2	40%
						((62)) Organization	2.5	50%	<195> Role-sharing	3	60%
									<196> Manpower allocation	2	40%
						((63)) Control	2.7	62%	<197> Commitment from the top	2	67%
									<198> Influence of the organization	2	40%
									<199> Motivation and ability of counterpart	4	80%
						((64)) Business continuity	1.7	33%	<200> Responding to accidents	1	20%
									<201> Responding to rainfall	3	60%
									<202> Responding to earthquakes	1	20%
						((65)) Operational support facilities	2.5	50%	<203> Training facility	3	60%
									<204> Communication facilities	2	40%
			(22) Budget funding	1.3	28%	((66)) Budget	1.5	30%	<205> Budget planning	2	40%
									<206> Budgetary allocation	1	20%
						((67)) Raising funds	1.0	27%	<207> Short-term financing	1	33%
									<208> Long-term financing	1	20%
			(23) Bidding and contracting system	3.0	60%	((68)) Bidding and contracting system	3.0	60%	<209> Cost estimation standard	4	80%
									<210> Prevention of collusion	2	40%
									<211> Contract method	3	60%
									<212> Procurement process	3	60%
									<213> Contract change	3	60%
			(24) Technical training	1.0	27%	((69)) Pavement training	1.0	27%	<214> Training plan	1	33%
									<215> Contents of training	1	20%
						((70)) Bridge training	1.0	27%	<216> Training plan	1	33%
									<217> Contents of training	1	20%
						((71)) Earthwork training	1.0	27%	<218> Training plan	1	33%
									<219> Contents of training	1	20%

Figure 6.18 List of Road AM Evaluation Results in Zambia【Surveillance (Monitoring), Organizational Management】

Chap.7 Initiatives on Road AM in Japan

7.1 Target of the Chapter

We will compile seven examples of initiatives and technologies that can be used as reference in developing countries by analyzing literature and exchanging opinions with related parties on the status of initiatives and technologies introduced by road managers of local governments in Japan to establish Road AM Interviews with local government road managers in Niigata City and Yamagata Prefecture will be conducted to compile the case studies. In addition, we will compile ten case studies of research and development technologies and technologies owned by universities, research institutions, and private companies that are expected to be utilized in developing countries.

7.2 Overview

The outline of the results on the survey policy, survey outlines of previous years (2018 and 2019), 2020 survey outline and recommendations for the following years regarding the initiatives on Road AM in Japan are as listed below.

Survey Policy		In Japan, various efforts are being made in the maintenance management cycle, and this report summarizes the efforts and technologies that are useful for resolving issues from the three perspectives (budget, technology, and lack of human resources) in developing countries and rural areas. The survey method is to organize and analyze literature and published materials. For initiatives and technologies that are particularly useful, an exchange of opinions or hearings will be conducted.
Survey Outlines of Previous Years	2018	Regarding the organization of documents and published materials, we conducted a questionnaire to local governments who are connected to university professors based on information gathering results obtained at various seminars and technical exhibitions. We exchanged opinions with four universities (The University of Tokyo, Tohoku University, Gifu University, and Nagasaki University) that are conducting research on SIP area implementation, Yokohama National Road Office, and toll road management companies.
	2019	Regarding the organization of documents and publications, the first round of inspections, infrastructure maintenance, and a national conference on inspection support technology (image measurement, nondestructive inspections) were conducted by MLIT. These are summarized in this outline. Exchange of opinions with organizations such as NEXCO West Japan, Honshu Shikoku Bridge Expressway, Hokuriku SIP Team (Kanazawa Institute of Technology, Kanazawa University, and University of Fukui), and University of the Ryukyus, Kanto Maintenance Center, Omiya National Highway Office, Civil Engineering Research Institute, Toyama City were conducted.
2020 Survey Outline		Regarding the organization of documents and publications, we collected information on the status of the second inspection cycle (first year) compiled by MLIT, the activities of the National Council for Infrastructure Maintenance, and various seminars held by the newly established General Committee for Infrastructure Maintenance of the Japan Society of Civil Engineers (JSCE). (1) image measurement, (2) non-destructive inspections, and (3) measurement monitoring, among the modern technologies listed in the "Inspection Support Skills Performance Catalogue (Draft), June 2020" published by MLIT, and compiled an outline of the technologies.

	We exchanged opinions with Niigata City, the Niigata Branch Office of NEXCO East Japan, Yamagata Prefecture, the Niigata City Bridge Asset Management Committee (Niigata University and Nagaoka University of Technology), and the Saitama Bridge Maintenance Study Group (Resilient Society Research Center, Saitama University).

7.2.1 List of Survey Results

An outline of initiatives with the organizations that conducted literature surveys and exchanged opinions in 2018-2020 are shown in Table 7.1, Table 7.2 and Table 7.3.In addition, the status of efforts and technologies used for exchanging opinions, hearings, and literature surveys are organized in individual survey sheets as reference materials.

Table 7.1 List of Survey/Hearing Results (2018)

No.	Institution / Company	Title of Research / Outline of Initiatives	Applicability and Effective Technology	Technology Field(s)	Field(s) Applied
■Cutting-Edge Initiatives by Expressway Companies					
	E-NEXCO	Advanced expressway AM through ICT utilization and mechanization	Recording Efficiency Improvement	Survey Inspection	Pavements
	Metropolitan Expressway Co Ltd.	Infrastructure maintenance management and society implementation of disaster prevention system using advanced technology （i-DREAMs）	Recording Efficiency Improvement	Survey Inspection	Pavements
	Metropolitan Expressway Co Ltd.	Maintenance management support system using GIS and 3D point cloud data (Infra Doctor)	Recording Efficiency Improvement	Survey Inspection	Pavements
	Metropolitan Expressway Co Ltd.	Patrol inspection system using high-performance drive recorder (infrastructure Patrol)	Inspection Efficiency Improvement	Survey Inspection	Pavements
	West Nippon Expressway Engineering Shikoku Co Ltd.	Road surface survey with a small vehicle adopting a simple system (Smart Eagle)	Inspection Efficiency Improvement	Survey Inspection	Pavements
	Shutoko Engineering Co Ltd.	Structural inspection equipment in high places and/or narrow areas	Inspection Efficiency Improvement	Survey Inspection	Structures
	Shutoko Engineering Co Ltd.	Lateral-tightening PC grout filling investigation with elastic wave method	Inspection Efficiency Improvement	Survey Inspection	Structures
■Initiatives on National Roads, Prefectures and Municipalities					
	Yokohama National Road Office / Kanto Regional Development Bureau/ MLIT	Approach to Road Maintenance Meeting, etc.	Technical Support	Road AM	Others
■Trends in Research and Development of Technologies and Systems at Universities and Research Institutes					

No.	Institution / Company	Title of Research / Outline of Initiatives	Applicability and Effective Technology	Technology Field(s)	Field(s) Applied
	National institute for Infrastructure Management / MLIT	Maintenance and Utilization of road space data	Road Management	Road AM	Others
	The University of Tokyo /Associate Prof. Nagai	Approach of Niigata City Bridge Asset Management Review Committee	Technical Support	Road AM	Others
	Gifu University /Prof. Kunieda, et al.	Infra-Museum as Technical Educator	Training Facilities	Road AM	Structures
	Gifu University /Prof. Rokugo, et al.	Efficiency and advancement of regular bridge inspection by robot technology and shortening traffic regulation	Inspection Efficiency Improvement	Robots	Structures
	Tohoku University /Prof. Hisada	Construction and Bridge maintenance integrated database system and introduction support to local governments by industry-academia-government collaboration	Recording Efficiency Improvement	Road AM	Structures
■Development Trends of Inspection and Maintenance Technology etc. which are Implementable Overseas by Private Companies					
	TRION Corporation	All-road surrounding view information – “All Road Around View Information” (CV-RAVI)	Recording Efficiency Improvement	Information Communication	Others
	TSUTAI	Hammering inspection system (T.T. Car)	Inspection Efficiency Improvement	Survey Inspection	Pavements
	Institute of System Planning Co. Ltd. /ISP	Crack detection engine with AI/Deep Learning	Inspection Efficiency Improvement	Survey Inspection	Structures
	Nippon Engineering Consultants Co. Ltd.	Multicopter for bridge inspection (MARCO)	Inspection Efficiency Improvement	Survey Inspection	Structures
	Toshiba Infrastructure Systems and Solutions Co. Ltd.	Road pavement crack analysis service	Inspection Efficiency Improvement	Survey Inspection	Pavements
	Kurabo Industries Ltd.	Road surface inspection compact-unit-PG-4	Inspection Efficiency Improvement	Survey Inspection	Pavements
	Nichireki Co. Ltd.	Romencatcher VPW	Inspection Efficiency Improvement	Survey Inspection	Pavements
	Asia Air Survey Co. Ltd.	Road surface profile measurement system (Road Profiling System)	Inspection Efficiency Improvement	Survey Inspection	Pavements
	FUJIFILM Holdings Corporation	Social infrastructure imaging diagnosis service (HIBIMIKKE)	Inspection Efficiency Improvement	Survey Inspection	Structures

No.	Institution / Company	Title of Research / Outline of Initiatives	Applicability and Effective Technology	Technology Field(s)	Field(s) Applied
	JIP Techno Science Corporation	Road surface inspection system using Smartphone (DRIMS)	Inspection Efficiency Improvement	Survey Inspection	Pavements
	Sumitomo Mitsui Construction Co Ltd.	Bridge-inspection robot camera	Inspection Efficiency Improvement	Survey Inspection	Structures
	IKEE Co. Ltd.	Spread and Verification regarding Manufacturing of Cold Patch (Excel) and Daily Road Maintenance Management Operation	Example of Overseas Development	Road AM	Pavements
	Shiraito Highland Way / GAEART Corporation	Maintenance and Operation of Toll roads and acquisition of ISO 55001 by road pavement companies	Road AM	Road AM	Pavements
	Hakone Turnpike / C-NEXCO	Maintenance and operation of toll roads by expressway related companies	Road AM	Road AM	Pavements
■Initiatives on Establishment of Road AM by Local Government and Universities					
	Gifu University	Maintenance Expert System	Human Resource Development	Road AM	Others
	Nagasaki University	Michimori System	Human Resource Development	Road AM	Others
	Tohoku University	Approach to Tohoku Infrastructures Management Platform	Technology Sharing	Road AM	Others
	Nihon University	Establishment and Practice of "Bridge self-maintenance; Fukushima Model"	Inspection Efficiency Improvement	Survey Inspection	Structures

Table 7.2 List of Survey/Hearing Results (2019)

No.	Institution / Company	Title of Research / Outline of Initiatives	Applicability and Effective Technology	Technology Field(s)	Field(s) Applied
■Cutting-Edge Initiatives by Expressway Companies					
1.	W-NEXCO	Improvement in asset management by building internal system and external collaboration systems	Road AM	Road AM	Others
2.	Honshu-Shikoku Bridge Expressway Co. Ltd.	Maintenance technology for long bridge (Corrosion prevention technology)	Longer life	Materials Repairs	Structures
3.	Honshu-Shikoku Bridge Expressway Co. Ltd.	Maintenance technology for long bridge (Inspection efficiency improvement)	Inspection Efficiency Improvement	Robots	Structures

No.	Institution / Company	Title of Research / Outline of Initiatives	Applicability and Effective Technology	Technology Field(s)	Field(s) Applied
4.	West Nippon Expressway Engineering Shikoku Co. Ltd.	Total support system for infrared survey (J-SYSTEM)	Inspection Efficiency Improvement	Survey Inspection	Structures
■Initiatives on National Roads, Prefectures, and Municipalities					
5.	Kanto Regional Maintenance Center / Kanto Regional Development Bureau / MLIT	Technical support for local governments, technical training for inspections	Local Government Support	Road AM	Others
6.	Omiya National Road Office / Kanto Regional Development Bureau / MLIT	Saitama Prefecture Road Maintenance Meeting Collaboration with Saitama University	Collaboration with Universities	Road AM	Others
7.	Toyama City	Evaluation system for human resource development and repair technology	Human Resource Development Evaluation System	Road AM	Others
8.	Kimitsu City	Drone inspection by city staff	Inspection Efficiency Improvement	Robots	Structures
■Initiatives on Research Institute					
9.	Public Works Research Institute	Technical evaluation, standard revision	Evaluation system	Road AM	Others
■Development Trend of Inspection and Maintenance Technology etc. which are Implementable Overseas by Private Companies					
10.	Luce Search Co. Ltd. CTI Engineering Co. Ltd.	Structure inspection robot system “SPIDER”	Inspection Efficiency Improvement	Survey Inspection	Structures
11.	Sanshin Construction Materials Co. Ltd. Autonomous Control System Laboratory Ltd.	Close-up visual inspection support technology using non-GPS environment-friendly drone	Inspection Efficiency Improvement	Survey Inspection	Structures
12.	Musokagaku Ltd.	Close-up photography by multi-copter and two-dimensional measurement of abnormal places	Inspection Efficiency Improvement	Survey Inspection	Structures
13.	Kawada Technologies, Inc. Nippon Engineering Consultants Co. Ltd.	Bridge inspection system using multi-copter	Inspection Efficiency Improvement	Survey Inspection	Structures
14.	Zivil investigation design Ltd. INTES University of Fukui	Assistance/complementary technology for close-range visual inspection and tapping sound survey by “looking and examining bridge inspection camera systems”	Inspection Efficiency Improvement	Survey Inspection	Structures

No.	Institution / Company	Title of Research / Outline of Initiatives	Applicability and Effective Technology	Technology Field(s)	Field(s) Applied
15.	Sumitomo Mitsui Construction Co. Ltd. Hitachi Industry & Control Solutions Ltd.	Inspection robot camera for bridge structures	Inspection Efficiency Improvement	Survey Inspection	Structures
16.	Tohoku Institute of Technology O･T･Techno Research Co. Ltd.	A simple device for supporting visual proximity of the underside of a bridge	Inspection Efficiency Improvement	Survey Inspection	Structures
17.	NEC Corporation Highway Technology Research Center	Pole hammering inspection machine	Inspection Efficiency Improvement	Survey Inspection	Structures
18.	Zivil investigation design Ltd. INTES University of Fukui	Bridge inspection support robot	Inspection Efficiency Improvement	Survey Inspection	Structures
19.	Shin-Nippon Nondestructive Inspection Co. Ltd. Nagoya University Kyushu Institute of Technology National Institute of Technology, Kitakyushu College Fukuoka Industrial Technology Center	Flight robot inspection system using close-up visual inspection, tapping inspection, etc.	Inspection Efficiency Improvement	Survey Inspection	Structures
20.	ONGA Engineering Co. Ltd.	Concrete structure deformation part detection system “BLUE DOCTOR”	Inspection Efficiency Improvement	Survey Inspection	Structures
■Initiatives on Establishment of Road AM by local Government and Universities					
21.	Hokuriku SIP Team Kanazawa University, Kanazawa institute of Technology, University of Fukui	Preparation of Hokuriku edition manuals and guidelines	Local Government Support	Road AM	Others
22.	University of the Ryukyus	Technology transfer to local government	Local Government Support	Road AM	Others

Table 7.3 List of Survey/Hearing Results (2020)

No	Institution / Company	Title of Research / Outline of Initiatives	Applicability and Effective Technology	Technology Field(s)	Field(s) Applied
■Cutting-edge Initiatives by Expressway Companies					
	Niigata Branch Office, E-NEXCO	Approach to Road Asset Management	Road AM	Road AM	Others
■Trends in Research and Development of Technologies and Systems at Universities and Research Institutes					
	National institute for Infrastructure Management	Status of the second round of road maintenance inspections (first year), activities of the	Road AM	Road AM	Others

No	Institution / Company	Title of Research / Outline of Initiatives	Applicability and Effective Technology	Technology Field(s)	Field(s) Applied
	/ MLIT	National Council for Infrastructure Maintenance, status of studies on maintenance of national roads using DX			
	JSCE	Activities of the General Committee on Infrastructure Maintenance, JSCE	Local Government Support	Road AM	Others
	Niigata City	Initiatives of the Niigata City Bridge Asset Management Study Committee	Road AM	Road AM	Others
	Yamagata Prefecture	Yamagata Prefecture Bridge Maintenance and Management System (DBMY) and other initiatives	Road AM	Road AM	Others
■Development Trends of Inspection and Maintenance Technology etc. which are Implementable Overseas by Private Companies and Universities					
	Nishimatsu Construction Co. Ltd. Saga University, Faculty of Science and Engineering	Korokoro Checker	Inspection Efficiency Improvement	Survey Inspection	Structures
	Alpha Product Co. Ltd. CHODAI Co. Ltd.	External Inspection Technology for Conceptual Structural Parts Using a Super Telephoto Lens	Inspection Efficiency Improvement	Survey Inspection	Structures
	Central Nippon Highway Engineering Tokyo Co. Ltd.	Structural Inspection and Survey Helicopter System (SCIMUS)	Inspection Efficiency Improvement	Survey Inspection	Structures
	iXs Co. Ltd.	Main girder flange gripping type inspection device (Turrets)	Inspection Efficiency Improvement	Survey Inspection	Structures
	World Link & Company Co. Ltd. Kanazawa University	Automatic Crack Detection Technology by AI Using Visible Images	Inspection Efficiency Improvement	Survey Inspection	Structures
	TOKYO ROPE MFG. Co. Ltd.	Nondestructive testing of cables using the total magnetic flux method	Non-Destructive Testing	Survey Inspection	Structures
	IHI Co. Ltd. IHI Inspection & Instrumentation Co. Ltd.	Steel Surface Inspection System	Non-Destructive Testing	Survey Inspection	Structures
	Nuclear Fuel Industries Ltd.	Integrated system of digital percussion inspection and digital visual inspection	Non-Destructive Testing	Survey Inspection	Structures
	Sumitomo Mitsui Construction Co. Ltd.	Bridge monitoring system using FBG optical fiber strain sensors (functional failure of bearings, etc.)	Measurement/ Monitoring	Survey Inspection	Structures

No	Institution / Company	Title of Research / Outline of Initiatives	Applicability and Effective Technology	Technology Field(s)	Field(s) Applied
	Kyowa Electronic Instruments CO. Ltd.	Sampling monitoring camera	Measurement/ Monitoring	Survey Inspection	Structures
	Kawakin Holdings Co. Ltd. NEC Corporation	Optical vibration analysis technology [Measurement of bearing displacement and rotation using moving images]	Measurement/ Monitoring	Survey Inspection	Structures
	Zoomscape Inc.	Non-contact displacement measurement system Measure LABO Bearing Doctor	Measurement/ Monitoring	Survey Inspection	Structures
	Kyowa Electronic Instruments Co. Ltd.	FBG type optical fiber sensor	Measurement/ Monitoring	Survey Inspection	Structures
■Initiatives on Establishment of Road AM by Local Government and Universities					
	Niigata University / Nagaoka University of Technology	Niigata City Bridge Asset Management Study Committee	Local Government Support	Road AM	Others
	Saitama University	Saitama Bridge Maintenance Study Group	Local Government Support	Road AM	Others

7.2.2 Outline of Previous Year's Interviews (2018-2019)

The following is a summary of the agencies and surveys that were interviewed during the prior year work (2018-2019).

Table 7.4 Outline of Previous Year’s Interviews (2018-2019)

Organization	Outline of the Survey
■2018	
Tokyo University	Institute of Industrial Science: Associate Professor Nagai The Niigata City Bridge Asset Management Review Committee has launched the “Contract Study Group” and “Bridge Maintenance Management Study Group.”
Gifu University	Faculty of Engineering: Professor Emeritus Rokugo, Visiting Professor Hatano, Associate Professor Kinoshita Gifu University has established a system to train maintenance experts who are engineers that can perform appropriate diagnosis and treatment for existing infrastructure facilities. Specifically, a four-week training course is held for members of society who engage in the maintenance and management of social infrastructures, and certifications have been issued since 2008.
Nagasaki University	Graduate School of Engineering: Professor Matsuda, Professor Nakamura, Associate Professor Nishikawa Nagasaki University established a system to maintain, manage, and develop human resources in collaboration with Nagasaki Prefecture, local companies, local governments, OB retirees, and the citizenry. The outline is divided into four courses, and which include: (1) Training personnel who can maintain and manage entire roads, (2) Developing advanced technology, (3) Developing personnel who can perform inspections planning and diagnosis, (4) Developing personnel who can perform inspections, and assistants.
Yokohama National Road Office	Opinion exchange meeting with Road Management Division 2 which is the maintenance department

	Exchange opinions on the current state and issues of road maintenance based on a maintenance questionnaire
Shiraito Highland Way	Exchanged opinions on operation and maintenance of toll roads by a road paving company and cases of ISO 55001 acquisition
Hakone Turnpike	Exchanged opinions on maintenance and management of toll roads by expressway affiliates
■2019	
W-NEXCO	Interview on the status of efforts related to advanced asset management The main efforts are: (1) Asset management system, (2) Large-scale reconstruction and repair project of aging structures, (3) Strengthening disaster response capabilities, (4) Engineer training center.
Honshu-Shikoku Bridge Expressway Co. Ltd.	Interview on improving service life of long span bridges and development of inspection technology These approaches are useful technologies for developing countries with many long span bridges that do not consider maintenance work such as inspection and repairs.
West Nippon Expressway Engineering Shikoku Co. Ltd.	Interview on inspection technology development and system development related to bridge inspections A particularly useful technology is the total support system for infrared survey (J system).
Public Works Research Institute	Center for Advance Engineering Structural Evaluation and Research (CAESAR): Chief Researcher Oshima Since it is a national research institute, the core principle is doing research in fields and areas that do not put pressure on the private sector. Therefore, the main activity is to perform technical evaluation. If so, it may be possible to build a scheme that takes the form of technical consultation and conveys the sophistication and knowledge of AI inspection and diagnosis. A recent topic suggest is the possibility to introduce techniques using neutrons and techniques for exploring the sedimentation of floor plates using electromagnetic radars. If we can support the research fund by collaborating with JICA, the range of activities can be expanded further.
Local government Toyama City Hall	Interview with Ueno Construction Engineering Supervisor The supervisor is implementing a training program for technology transfer and human resource development called “Ueno Juku” for Toyama City staff. Toyama City's unique activity to evaluate repair technology, the “Repair Olympic Games,” provides a trial site for repair technology and has a system in place for evaluation by university researchers.
Kanazawa University, Kanazawa Institute of Technology, Fukui University	Kanazawa University: Associate Professor Kubo Kanazawa Institute of Technology: Vice President Shikata, Professor Miyazato University of Fukui: Associate Professor Suzuki The Hokuriku SIP team is working on manuals and human resource development in collaboration with Kanazawa University, Kanazawa Institute of Technology, University of Fukui, etc., and shares issues and solutions unique to the Hokuriku region.
Ryukyus University	Professor Shimozato, Associate Professor Toyama, Assistant Professor Suda, Assistant Professor Tai The University of the Ryukyus has established a scheme to collaborate with local companies on areas of investigation such as photoimaging, as well as the combination of efforts in university and major general contractors for UAV and crack image diagnosis. A steel structure anticorrosion manual specific to the Okinawa area was developed in cooperation with the national and prefectural governments.

7.2.3 Outline of Interviews in 2020

The organizations that conducted the hearings and an outline of the surveys in 2020 are as follows.

Table 7.5 Outline of Interviews (2020)

Organization	Outline of the Survey	Hearing
Niigata Branch Office, E-NEXCO	Interviews were held on the latest trends in asset management activities on expressways. The Smart Maintenance Highway (SMH), which will be rolled out company-wide from 2020, includes: (1) reform of the maintenance management work process; and (2) development of modern technologies from inspection and investigation to repair.	Done
MLIT	Collects and organizes information on trends in infrastructure maintenance undertaken by the government. Main initiatives include the statutory establishment of inspection standards for national, prefectural, and municipal roads, the formulation of a "Basic Plan for Extending the Life of Infrastructure," financial support and human resources support such as training, improvement of the bidding and contracting system, and promotion of DX.	-
JSCE	Collects and organizes information on trends in infrastructure maintenance. Major efforts include holding infrastructure lectures organized by the Activities Subcommittee and providing research grants for the international deployment of infrastructure management technology.	-
Local government Niigata City	Interviews were held on the status and issues of the maintenance and management activities of bridges and pavements being undertaken in Niigata City. The main initiatives include: (1) review of the Niigata City Bridge Life Extension and Repair Plan, (2) Niigata City Bridge Asset Management Study Committee, (3) investigation of bridge design and construction standard estimation in cooperation with universities, etc., (4) human resource development, and (4) utilization of local construction companies.	Done
Local government Yamagata Prefecture	Interviews were held on the status and issues of maintenance and management activities for bridges, pavements, and tunnels being undertaken in Yamagata Prefecture. The main initiatives include: (1) Yamagata Prefecture Bridge Life Extension and Repair Plan, (2) Yamagata Prefecture Road Pavement Life Extension and Repair Plan, (3) Yamagata Prefecture Road Tunnel Life Extension Plan, (4) Development of a maintenance management related system (DBMY) through industry-government-academia collaboration, and (5) Human resource development.	Done
Niigata University	Faculty of Engineering, Niigata University: Professor Saeki To solve the problem of bridge maintenance activities in heavy snowfall areas, Niigata University is researching a proposal for maintenance management based on quantitative evaluation of salt damage tolerance. In addition, he has achieved low-cost specimens for salt damage surveys, which have been adopted in developing countries in island regions. They are also in charge of the secretariat of the Niigata Regional Council for the Training of Infrastructure Rehabilitation Engineers, which provides lectures and practical training for infrastructure maintenance workshops and conducts the ME Niigata certification examination.	Done
Nagaoka University of Technology	Nagaoka University of Technology: Associate Professor Miyashita His research in the field of bridge maintenance and management includes bridge monitoring, bridge design (limit state design method), and repair of steel bridges using carbon fiber sheets (CFRP bonding method). He is also a member of the "Niigata City Bridge Asset Management Study Committee".	Done
Saitama University	Exchange of opinions with Professor Emeritus Mutsuyoshi, Professor Okui, Professor Maki, and Professor Matsumoto Saitama University, in cooperation with road administrators such as Saitama Prefecture and the Omiya National Highway Office, has established the Saitama	Done

Organization	Outline of the Survey	Hearing
	Bridge Maintenance Study Group, which is working on manuals and human resource development, and is sharing unique problems and solutions in Saitama Prefecture.	

7.3 Cutting-Edge Efforts at Expressway Companies

7.3.1 Niigata Branch Office, E-NEXCO

E-NEXCO is working on the Smart Maintenance Highway (SMH), a project to dramatically improve productivity in highway maintenance by utilizing the latest technologies such as ICT and robotics, to ensure the long-term safety and security of expressways. After conducting trial verifications of the developed technologies at the SMH model offices (Sapporo, Morioka, Koriyama, Misato, Saku, and Yuzawa), the project will be rolled out company-wide in 2020, and the company is working to standardize new business processes.

7.3.1.1 Infrastructure Management Cycle and Major SMH Tools

The structure of the management cycle for highway infrastructure and the main SMH tools applied are as follows.

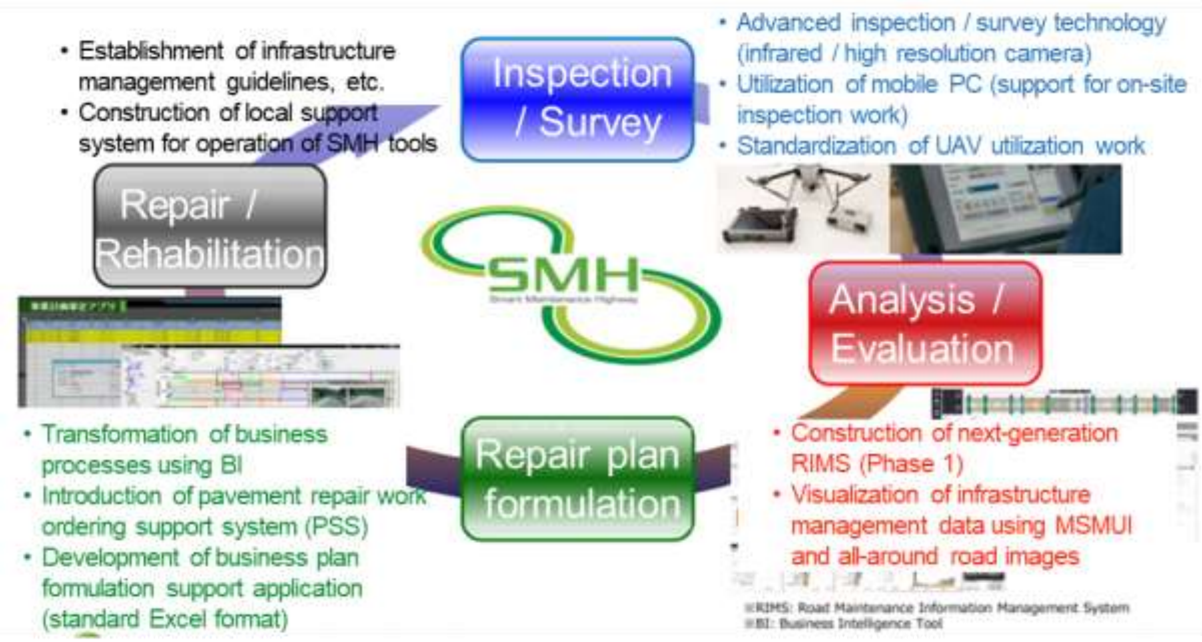


Figure 7.1 Infrastructure Management Cycle and Major SMH Tools[66]

7.3.1.2 Reform of Business Processes by Improving Infrastructure Information

As part of Road AM, we are building an integrated information infrastructure for infrastructure management (asset) information. The system has a function to select various information on bridges

[66] 2019.12.5 Study Group on Maintenance and Management of National Highways (2nd Meeting in First year of Reiwa)

(specifications, inspection records (data, photographs, damage development plans), drawings, etc.) from the route map on the information infrastructure monitor and display any information.

As a result, by displaying the necessary information on a large monitor, it is possible to make decisions at each stage of the bridge repair work process: (1) formulating an inspection plan, (2) organizing inspection records and calculating the number of deformation points, (3) determining countermeasures and analyzing deterioration factors, and (4) formulating a repair plan. This eliminates the need to prepare materials for conventional meetings, shortens the time from inspection to the implementation of repair and reinforcement work, and significantly improves productivity.

In addition, as a statistical/analytical function, the system is used as a tool for multifaceted and multilateral analysis and evaluation of a vast amount of data such as inspection results. For example, in the work process of formulating repair plans, it is possible to analyze damage trends in depth by creating graphs from various angles using arbitrary parameters, eliminating the need for conventional manpower to prepare data for tabulation and analysis.

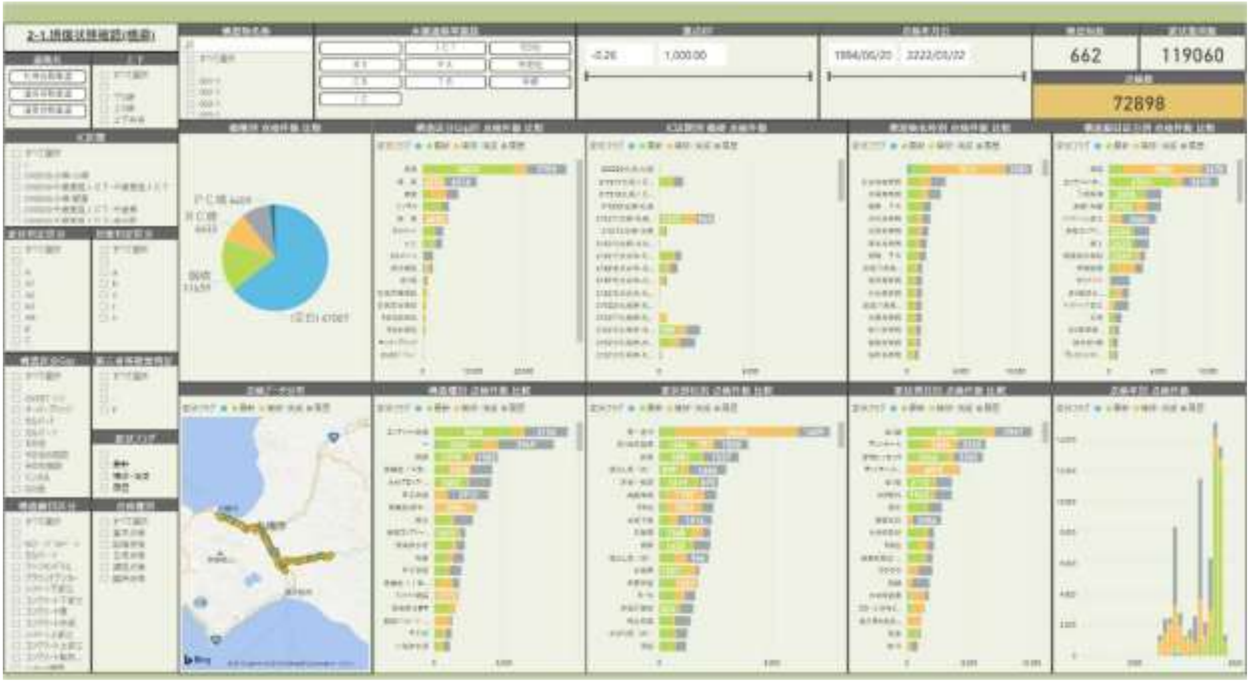


Figure 7.2 Example of Statistics and Analysis Mode Screen[67]

7.3.1.3 **Effect of Maintenance**

The effects of the improvement of business processes through SMH maintenance are as follows.

Table 7.6 Effect of SMH Maintenance on Business Process Improvement[68]

Content	Effects of Improvement
No document creation work	If you have the data in a database, there is no need to create study materials for meetings.

[67] Data from E-NEXCO
[68] Prepared by the research team based on data from E-NEXCO

Content	Effects of Improvement
Reducing rework	Since various data can be checked during the meeting and discussions can be conducted on the spot, there is no need to go back and revise documents after the meeting.
Ensuring business quality	In addition to the visualization of infrastructure data, the focus of the thought process is also standardized.

The development of the SMH has enabled us to (1) rebuild the information infrastructure to enable free visualization and analysis of data, (2) make accurate decisions based on numerical evidence (data), (3) make quick decisions using support tools, and (4) standardize not only work procedures but also decision-making processes. By concentrating on their roles as engineers, we are promoting the transformation of business processes using highway infrastructure data.

7.4 Initiatives of National, Prefectural and Municipal Roads

7.4.1 MLIT

MLIT positions 2013 as the first year of social capital maintenance, and the facility managers of various infrastructures including the national government will work together to strategically perform maintenance and reconstruction.

Specifically, outlines show current efforts in the following: (1) legislation of inspection standards for national roads, prefectural roads, and municipal roads, (2) formulation of “the initiative for improving service life of infrastructure,” (3) human support such as financial support and training through disaster prevention and safety grants, (4) improvement of bidding contract system and individual facilities. The standards and manuals of these are being reviewed.

In the future, it will be important to establish management that continuously conducts infrastructure maintenance. Including mid- to long-term budgeting based on preventive maintenance, utilization of modern technologies that will lead to labor-saving efficiency, updates to databases, continued human resource development and information sharing with infrastructure beneficiaries.

7.4.1.1 Status of the Second Round (First Year) of Inspections

In accordance with the “Periodic Inspection Guidelines for Bridges” and “Periodic Inspection Guidelines for Road Tunnels” established by the government in 2014, all bridges and tunnels are inspected by close visual inspection once every five years, and a maintenance cycle of “inspection → diagnosis → action → record” has been established. The second cycle started from 2019.

In the “Annual Report on Road Maintenance” published since 2015, the status and results of inspections of bridges, tunnels, road appendages, etc. are compiled and published to promote understanding of the status and aging of road infrastructure among the public and road users.

(1) Key Points

1) More progress in the first year of the second round of inspections compared to the first round
   In 2019, the first year of the second round of inspections, 17% of bridges, 16% of tunnels, and 18% of road appendages were inspected, which is more progress than in the first year of the first round.
2) The rate of initiation of repairs and other measures by local governments is still 30%

The percentage of bridges that were diagnosed as requiring prompt action (Category III) or urgent action (Category IV) in the first round of inspections and for which repair and other measures had been started by the end of fiscal 2019 was 69% for the Ministry of Land, Infrastructure, Transport and Tourism, 47% for expressway companies, and 34% for local governments.
However, the percentage of local governments that have started repairing or taking other measures for bridges diagnosed as Category III or IV in the 2014 inspection is lagging at 52%.

3) The percentage of changes to the state that require early or urgent action over a five-year period is 5% of the bridges that were diagnosed as sound or in a state where it is desirable to take measures from the perspective of preventive maintenance (judgment categories I and II) in the first round of inspections in 2014, the percentage of bridges that transitioned to a state where measures should be taken as soon as possible or urgently (judgment categories III and IV) in the inspections in 2019, five years later, without taking measures such as repairs, was 5% for all road managers. The total of all road administrators is 5%.
4) Increase in the number of bridges to be demolished, etc.
As of the end of 2019, the number of bridges diagnosed as judgment Category IV was 812, an increase of seventy-two from the previous year, and as a countermeasure, the number of bridges removed or decommissioned was 255 (including planned), an increase of seventeen from the end of the previous year.
5) Less than 10% of local governments have used the new inspection technology
The number of local governments using drones and other inspection support technologies for inspections in 2019 is thirty-two, with only five organizations using tunnels.

Table 7.7 shows the inspection implementation rate in 2019, and Figure 7.3 shows the status of the second round of road maintenance inspections (first year).

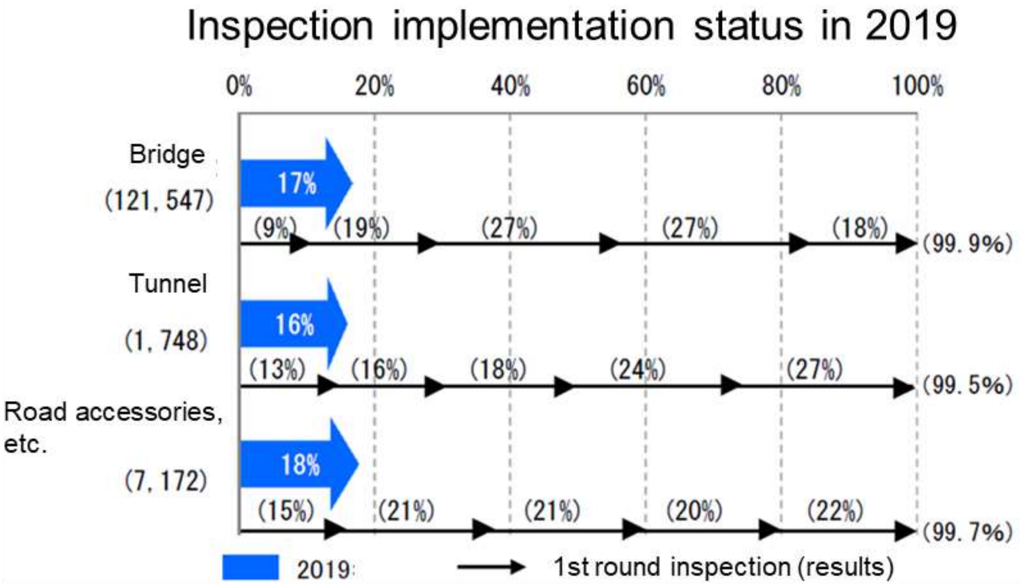
Table 7.7 Inspection Implementation Rate in 2019 (Total for all Road Managers)

	Number of Facilities Managed	Number of Facilities to be Inspected※1	Number of Inspections Conducted in 2019	Inspection Implementation Rate※2
Bridges	726,461	721,160	121,547	17% (9%)
Tunnels	11,350	10,822	1,748	16% (13%)
Road Appurtenances, etc.	41,316	40,251	7,172	18% (15%)

end point (March 2020)

※1: The total number of facilities as of the end of March 2020, excluding those that have been in service for five years or less.

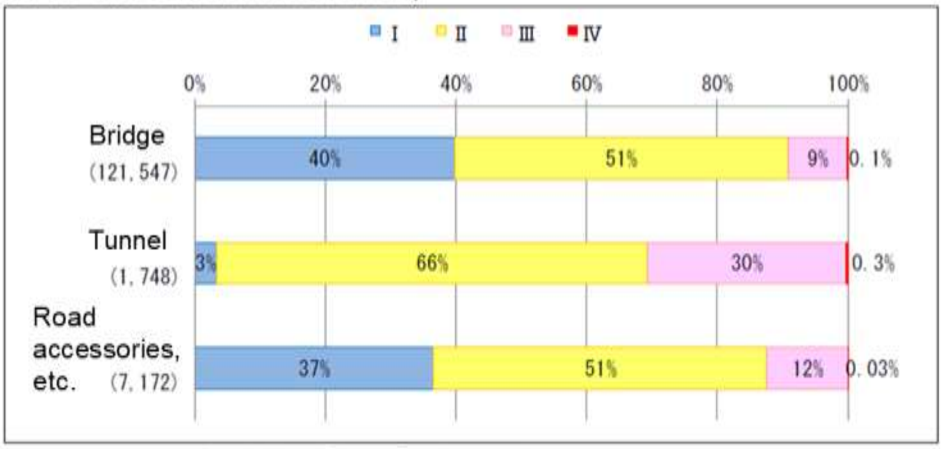
※2: Ratio of the number of inspections conducted to the number of facilities subject to inspections as the denominator. Figures in parentheses represent the inspection implementation rate in 2014.



※ ※1: Inside ( ), among the managed facilities as of the end of 2019, the number of facilities subject to inspections (excluding facilities that have been removed and facilities that have been found not to be subject to inspections in the above fields).

※ ※2: The total value may not be 100% due to rounding.

○ Percentage of judgment categories for bridges, tunnels, road accessories, etc. (total for all road administrators)



※ Inside ( ) is the total number of facilities inspected in 2019
※ The total value may not be 100% due to rounding.

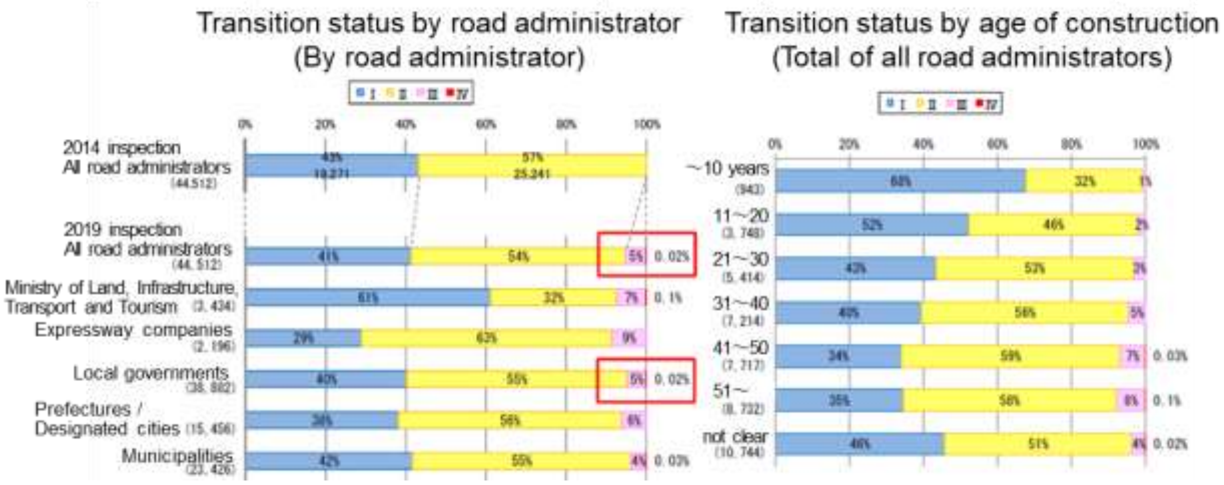
Judgment category		Status
Ⅰ	Sound	A state in which the function of the structure is not hindered
Ⅱ	Preventive maintenance stage	The function of the structure is not hindered, but it is desirable to take actions from the viewpoint of preventive maintenance.
Ⅲ	Early action stage	A state in which the function of the structure may be impaired and actions should be taken early.
Ⅳ	Emergency action stage	A state in which the function of the structure is impaired or is extremely likely to occur and urgent actions should be taken.

Administrator	(A)	(B)	(C)	(D)	year
Ministry of Land, Infrastructure, Transport and Tourism	3,427	2,359 (69%)	1, 071 (31%)	1, 068 (31%)	2014 2015 2016 2017 2018
Expressway companies	2,538	1,202 (47%)	705 (28%)	1,336 (53%)	2014 2015 2016 2017 2018
Local governments	62,873	21,376 (34%)	12,869 (20%)	41,497 (66%)	2014 2015 2016 2017 2018
Prefectures / Designated cities	20,535	9,052 (44%)	5,057 (25%)	11,483 (56%)	2014 2015 2016 2017 2018
Municipalities	42,338	12,324 (29%)	7,812 (18%)	30,014 (71%)	2014 2015 2016 2017 2018
total	68,838	24,937(36%)	14,645(21%)	43,901(64%)	

(A) : Number of facilities that require actions
(B) : Number of facilities that have started actions
(C) : Of which, completed
(D) : Number of facilities not yet started

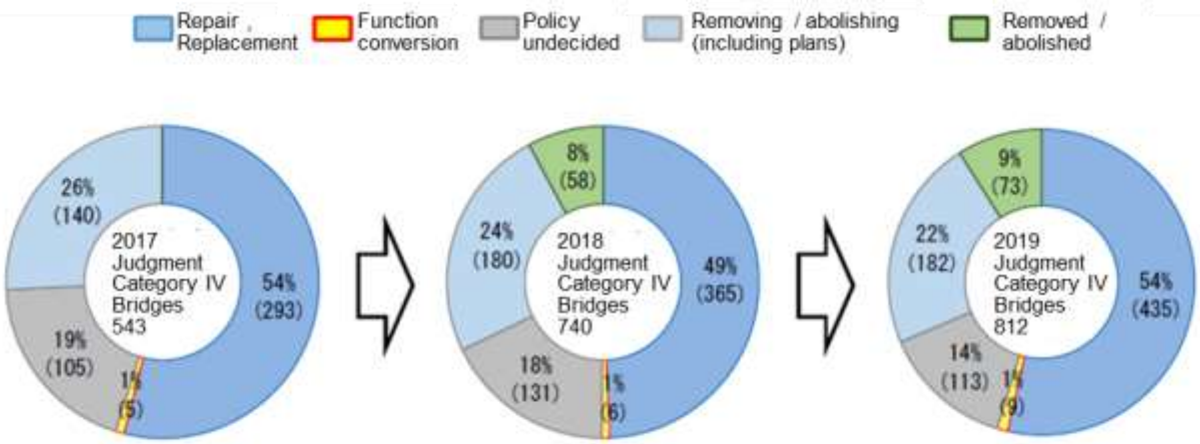
※ Percentage of facilities that have been inspected and diagnosed in 2014-2018 that have been diagnosed as Judgment Category III / IV and have started (or completed construction) repair actions (including design)
(As of the end of 2019)

: Expected pace when considering the implementation of repair actions until the next inspection as of the end of 2019
2014 inspection (5 years passed): 100%, 2015 inspection (4 years passed): 80%,
2016 inspection (3 years passed): 60%, 2017 inspection (2 years passed): 40%,
2018 inspection (1 year passed): 20%



※ Inside ( ) is the total number of bridges that were inspected in 2019 without taking any actions such as repairs, out of the bridges whose first round inspection (2014) was judged as Category I or II.

※ The total value may not be 100% due to rounding.



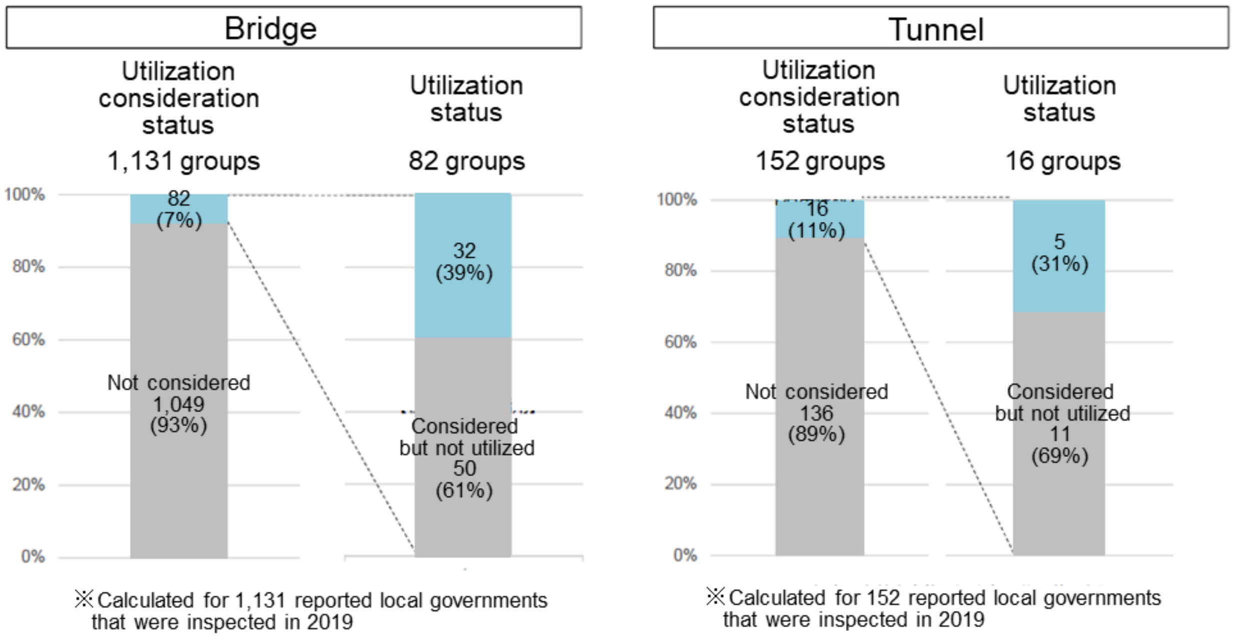


Figure 7.3 Road Maintenance Second Round Inspections (First Year)[69]

7.4.1.2 **Activities of the National Council for Infrastructure Maintenance**

In 2016, the National Council for Infrastructure Maintenance was established as a platform for industry, academia, government, and the private sector to work together to improve the efficiency and sophistication of maintenance, and discussions are being deepened through exchanges and information exchange for each item of interest and issue at various authorized forums.

The basic policy for the activities in 2020 is based on the results of previous years' efforts to (1) establish its function as a platform and (2) spread the concept of infrastructure maintenance, and to promote specific solutions to regional issues through collaborative activities using each local forum as a contact point. Furthermore, specific solutions will be promoted nationwide to enhance the effectiveness of the National Council activities.

The results of previous years and the positioning of the 2020 activities are shown in Figure 7.4.

[69] Road Maintenance Annual Report, Road Bureau, MLIT September 2020

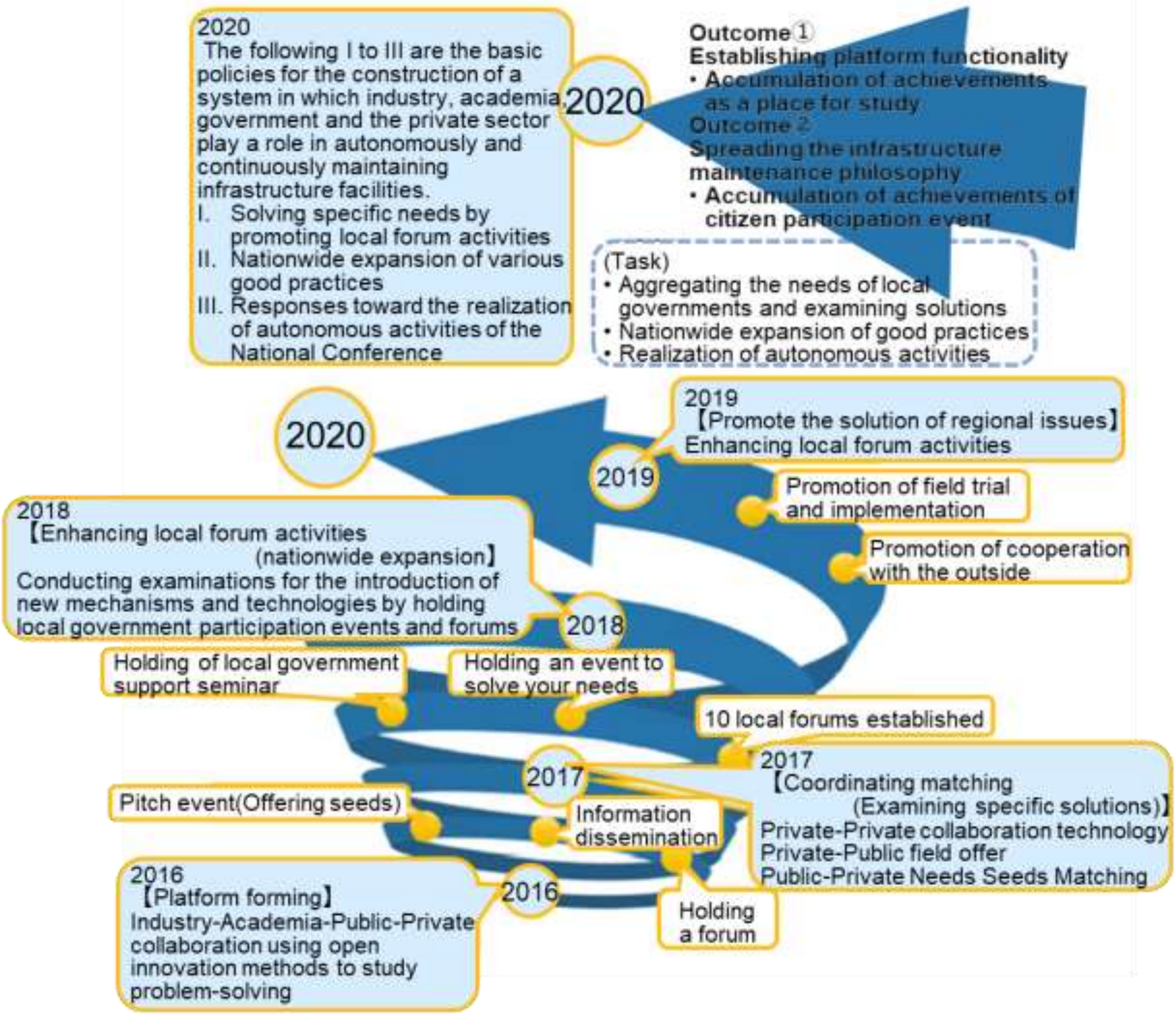


Figure 7.4 Results of Previous Years and Positioning of Activities in 2020[70]

7.4.1.3 **Domestic Trends in Infrastructure DX (Digital Transformation)**

In response to the rapid changes in socioeconomic conditions, MLIT is using data and digital technology in the infrastructure field to transform social infrastructure and public services based on the needs of the public, as well as to transform operations themselves, organizations, processes, the culture, and climate of the construction industry and MLIT, and ways of working. In addition, MLIT established the DX Promotion Headquarters at the end of July 2020 to promote public understanding of infrastructure and realize safe, secure, and affluent lifestyles.

In addition, the Road Bureau of MLIT released an interim report in June 2020 on the maintenance and management of national roads. In the field of collecting and understanding information on roads, the report calls for the introduction of ICT technology for road patrols, automatic detection of traffic obstacles through AI analysis of CCTV images, and other measures, including the use of social networking services to gather

[70] National Council for Infrastructure Maintenance 2020 Business Plan, June 2020

and analyze the opinions of residents. Improve the efficiency of road information collection and monitoring. It is stated that the project aims to (1) speed up emergency response by sharing information, (2) prevent human errors such as overlooking damaged areas, and (3) achieve systematic maintenance and management by collecting, analyzing, and accumulating data requested by residents.

In addition, based on the results of the first round of periodic road maintenance inspections, the periodic inspections of road bridges was revised in 2019, and the use of "inspection support technologies" such as drones were specified. As shown in Figure 7.5, it is important to develop inspection methods that do not require close visual inspections.

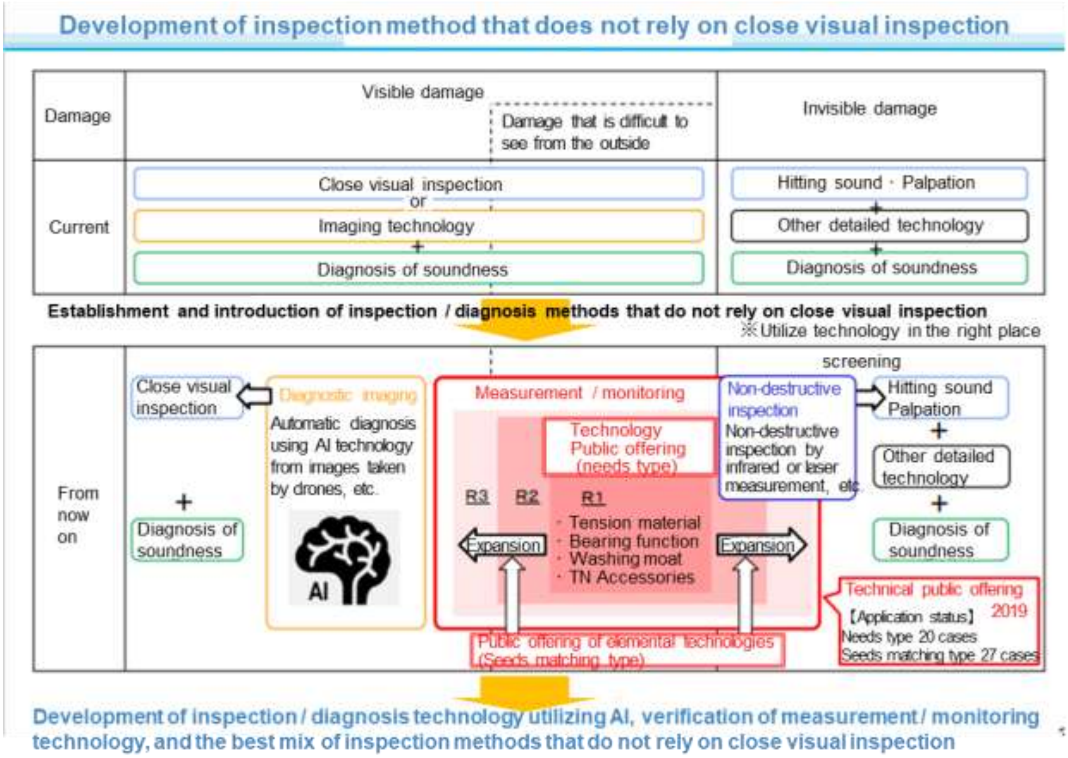


Figure 7.5 Development of an Inspection Method with no Require of Close Visual Contact[71]

7.5 Trends in R&D of Technologies and Systems at Universities and Research Institutions

7.5.1 JSCE

On April 1, 2020, the JSCE launched its five-year plan, "JSCE2020-2024: Connecting Communities, Generations, and Values to Create a Future Society,", and has launched four JSCE2020 projects to achieve its medium-term priority goals. In the field of infrastructure maintenance, in light of the aging of social infrastructure issues triggered by the Sasago Tunnel ceiling plate falling accident and the importance of maintenance in response to the recent frequent heavy rain and earthquake disasters, from 2020, the maintenance-related committees that have been working separately will be integrated to form a new committee with the aim of systematically and organically working together.

[71] The 12th Road Technology Subcommittee will release information in June 2020

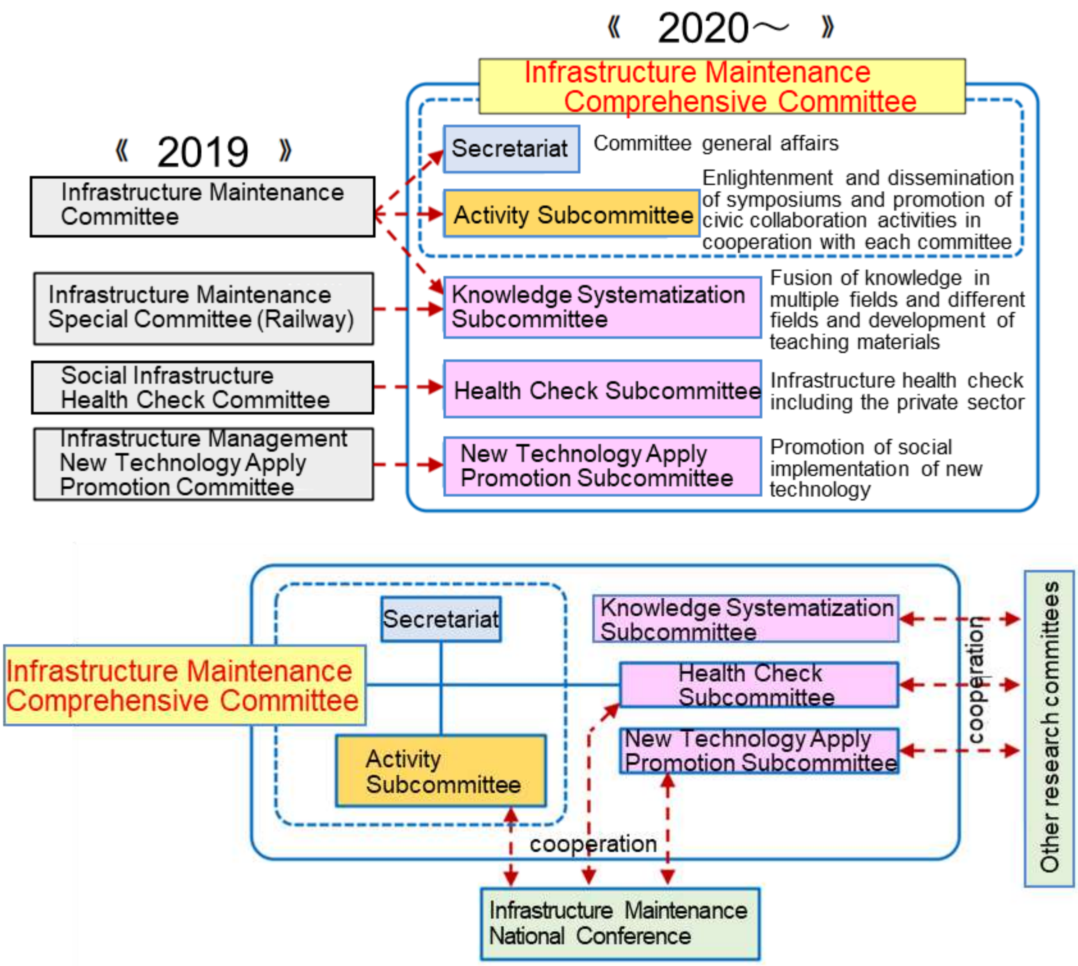


Figure 7.6 Organization of the General Committee on Infrastructure Maintenance of JSCE[72]

The functions of the General Committee are as follows: (1) the Executive Committee is responsible for the overall function (however, sub-committees are responsible for individual activities), (2) the Committee is responsible for examining basic issues and making recommendations, and (3) the Activity Subcommittee is responsible for civic cooperation, awareness-raising, and communication activities.

7.5.1.1 **Activities of Subcommittee**

The Activity Subcommittee organized a series of four online maintenance courses titled “Maintenance Courses for Local Infrastructures”, targeting local infrastructures managed by small local governments that lack sufficient financial and technical capabilities. The first session was “Introduction”, the second session was “Current Status of Infrastructure Maintenance”, the third session was “Introduction of New Technologies”, and the fourth and final session was “Citizen Collaboration on Infrastructure Maintenance”. The programs for each session are listed below.

[72] JSCE HP

Table 7.8 2020 Maintenance Course Program for Local Infrastructure[73]

<table>
<tr><td colspan="4">1st Session “Introduction”</td></tr>
<tr><td>Date</td><td>Monday, November 16, 2020</td><td>Method</td><td>Online (YouTube)</td></tr>
<tr><td colspan="4">Program
13:00 Opening Remarks JSCE President: Hitoshi Ieda
13:10 Special lecture
Senju Miki, President, Kyoto City University
“Introduction to Clinical Adult Medicine of Bridges”
14:05 Special Guest Speech
Noriko Suematsu, Mayor of Suzuka City, Mie Prefecture
“Challenges and Future Actions for Infrastructure Maintenance in Suzuka City”
Yoshiaki Kinoshita, Tamana City, Kumamoto Prefecture
“Recommendations for Handcrafted Maintenance by Local Government Officials”
15:00 Consultation corner for problems related to maintenance of local infrastructure
Coordinator: Activity Subcommittee Chair: Professor Ichiro Iwaki, Nihon University
Commentator: Noriko Suematsu, Yoshiaki Kinoshita
Mitsuyasu Iwanami, Secretary General, Infrastructure Maintenance General Committee, etc.
15:50 Closing Remarks by Mr. Yukihiro Tsukada, Executive Director, JSCE</td></tr>
<tr><td colspan="4">2nd Session “Current Status of Infrastructure Maintenance”</td></tr>
<tr><td>Date</td><td>Monday, December 14, 2020</td><td>Method</td><td>Online (YouTube)</td></tr>
<tr><td colspan="4">Program
13:00 Opening Remarks JSCE President: Hitoshi Ieda
13:10 Keynote Speech-1
Professor Hikaru Nakamura, Nagoya University Graduate School
“Current Status and Issues of Infrastructures as Seen from the Infrastructure Health Checkup”
13:35 Keynote Speech-2
Professor Mitsuyoshi Akiyama, Waseda University
“Countermeasures against deterioration? Seismic Reinforcement? ~The problem of physician certification in the presence of troubling uncertainty~”
14:05 Consultation corner for problems related to maintenance of local infrastructure
Coordinator: Activity Subcommittee Chair: Professor Ichiro Iwashiro, Nihon University
Commentator: Hikaru Nakamura, Mitsuyoshi Akiyama
Railroads Division: Takashi Shimoyama, East Japan Railway Company
River Division: Yuji Toda, Nagoya University
Water and Wastewater Division: Hiroji Sakai, Tokyo Metropolitan University
Port and Harbor Division: Mitsuyasu Iwanami, Tokyo Institute of Technology
14:50 Closing Remarks by Mr. Yukihiro Tsukada, Executive Director, JSCE</td></tr>
<tr><td colspan="4">3rd Session “Introduction of New Technologies”</td></tr>
<tr><td>Date</td><td>Tuesday, January 12, 2021</td><td>Method</td><td>Online (YouTube)</td></tr>
<tr><td colspan="4">Program
13:00 Opening Remarks JSCE President: Hitoshi Ieda
13:10 Keynote Speech-1
Toru Noda, Shimizu Corporation / Subcommittee for Promotion of New Technology Provision
“Recommendations for Local Infrastructure Maintenance - Overcoming Barriers Together by Utilizing New Technologies”
13:35 Keynote Speech-2
Tamotsu Kuroda, Professor, Tottori University / Chairman, Regional Implementation Promotion Division
“Introduction of New Technologies for Local Infrastructure Maintenance-Thinking about issues and solutions- “
14:05 Introduction of good examples in the region
Yuu Komyoji, Kimitsu City, Chiba Prefecture
“Bridge Inspection Using Drones”</td></tr>
</table>

73 General Committee on Infrastructure Maintenance, JSCE HP

<table>
<tr><td colspan="4">Makoto Kitazawa, Daisen City, Akita Prefecture
“Bridge maintenance using databases”
14:35 Consultation corner for problems related to maintenance of local infrastructure
Coordinator: Activity Subcommittee Chair: Professor Ichiro Iwaki, Nihon University
Commentator: Toru Noda, Tamotsu Kuroda, Yuu Komyoji, Makoto Kitazawa
Gifu University: Keitetsu Rokugo
Osaki Research Institute: Toshihiro Wakahara
15:15 Closing Remarks by Mr. Yukihiro Tsukada, Executive Director, JSCE</td></tr>
<tr><td colspan="4">4th Session “Civic Collaboration”</td></tr>
<tr><td>Date</td><td>Friday, January 26, 2021</td><td>Method</td><td>Online (YouTube)</td></tr>
<tr><td colspan="4">Program
13:00 Opening Remarks: Hitoshi Ieda, President, Japan Society of Civil Engineers
～Current Status of Local Infrastructures and Examples of Collaborative Maintenance with Citizens
13:10 Current status of local infrastructure (using Toyama City as an example)
Yoshihiko Ueno, Toyama City Office
13:25 Introduction of infrastructure maintenance case studies by industry, government, academia, and private volunteers
Tsutomu Imai, Shunan City Hall
13:40 Development and implementation of a self-maintenance model for bridges
ISS & Nihon University College of Engineering Wakana Asano
～Topic: Maintenance of local infrastructure as seen by the mass media
14:00 About the relationship between local communities and infrastructure
NHK Chie Goto
14:20 Reporting on infrastructure maintenance in collaboration with citizens
Masahiko Manabe, Nikkei Construction
14:45 Discussion
Coordinator: Ichiro Iwaki, Professor, Nihon University, Chair of Activity Group
Commentators: Speakers mentioned above
National Council for Infrastructure Maintenance
Koichi Iwasa, Leader, Citizen Participation Forum
15:25 Closing Remarks by Mr. Yukihiro Tsukada, Executive Director, JSCE</td></tr>
</table>

7.5.1.2 **Activities of the JSCE Research Grant for International Deployment of Infrastructure Management Technology**

The JSCE Subcommittee on Promotion of Application of New Technologies and the International Deployment Subcommittee are working on the international deployment of technologies and systems related to the maintenance and management of social infrastructure structures such as roads, bridges, and surrounding ground. As one of its activities, the Subcommittee will provide research grants for activities to apply technologies developed in Japan for measurement, evaluation, repair, and reinforcement to overseas structures starting in 2019, to create opportunities for Japanese technology to expand abroad and to support young Japanese researchers to experience practical research activities overseas. The outline of the grants for 2021 is as follows.

(1) Eligible Activities

1) Research activities to apply technologies related to the maintenance, management, and reconstruction of social infrastructure structures (roads, bridges, surrounding ground, etc.) overseas
2) Actual application of technologies developed in Japan (including the research being undertaken) to overseas structures, and implementation of measurement, evaluation, repair, etc.

3) Activities whose main purpose is to conduct literature research, interviews, or exchanges are not eligible. Surveys and exchanges incidental to the application of the technology are acceptable.
4) There is no limit to the number of countries covered. Multiple countries can be covered.
5) To smoothly apply the technology to the structures in the target country, it is desirable to collaborate with the structure managers, academic institutions, companies (including local corporations), JICA, etc. in the target country.

(2) Grant Recipients

1) Individuals or research groups represented by researchers who belong to Japanese universities or colleges of technology.
2) Academic institutions (including national research institutes), companies, NGOs, NPOs, and other organizations can participate in the research group.
3) The research group can include academic institutions such as overseas government agencies and universities.
4) It is recommended that young researchers (40 years old or younger) be included in the research group.

(3) Grant Period and Amount

Research period: From March 2021 to March 2023, after the decision of adoption
Grant amount: 4 million yen per project (maximum)

7.6 Trends in the Development of Repair and Life Extension Technologies that can be Implemented Overseas by Private Companies

7.6.1 Inspection Support Technology Performance Catalog (Draft)

The Roads Bureau of MLIT publicly solicited technologies owned by private companies that can be used for periodic inspections of road structures and formulated the “Performance Catalogue of Inspection Support Technologies (Draft)” in February 2019, which catalogs the performance values of such technologies. As of June 2020, 80 technologies owned by private companies are listed in the catalog.

In this survey, we will collect data on the modern technologies listed in the catalog (1) image measurement, (2) nondestructive inspections, and (3) measurement and monitoring), and compile an overview of the technologies.

The inspection support list is shown in Table 7.9, and the details are shown in the individual survey tables in the reference materials.

Table 7.9 Inspection Support Technology List

Technology Classification	Technology Name	Developer
Bridges, etc. Image Measurement 1	Korokoro Checker	Nishimatsu Construction Co. Ltd. Saga University, Faculty of Science and Engineering
Bridges, etc. Image Measurement 2	External inspection technology for conceptual structural parts using a super telephoto lens	Alpha Product Co. Ltd. CHODAI Co. Ltd.
Bridges, etc. Image Measurement 3	Structural inspection and survey helicopter System (SCIMUS)	Central Nippon Highway Engineering Tokyo Co. Ltd.

Technology Classification	Technology Name	Developer
Bridges, etc. Image Measurement 4	Main girder flange gripping type inspection device (Turrets)	iXs Co. Ltd.
Bridges, etc. Image Measurement 5	Automatic crack detection technology by AI using visible images	WorldLink & Company Co. Ltd. Kanazawa University
Bridges, etc. Nondestructive Testing 1	Nondestructive testing of cables using the total magnetic flux method	TOKYO ROPE MFG. Co. Ltd.
Bridges, etc. Nondestructive Testing 2	Steel surface inspection system	IHI Co. Ltd. IHI Inspection & Instrumentation Co. Ltd.
Bridges, etc. Nondestructive Testing 3	Integrated system of digital percussion inspection and digital visual inspection	Nuclear Fuel Industries Ltd.
Bridges, etc. Measurement and Monitoring 1	Bridge monitoring system using FBG optical fiber strain sensors (functional failure of bearings, etc.)	Sumitomo Mitsui Construction Co. Ltd.
Bridges, etc. Measurement and Monitoring 2	Sampling monitoring camera	Kyowa Electronic Instruments Co. Ltd.
Bridges, etc. Measurement and Monitoring 3	Optical vibration analysis technology [Measurement of bearing displacement and rotation using moving images]	Kawakin Holdings Co. Ltd. NEC Corporation
Bridges, etc. Measurement and Monitoring 4	Non-contact displacement measurement system “Measure LABO Bearing Doctor”	Zoomscape Inc.
Bridges, etc. Measurement and Monitoring 5	FBG type optical fiber sensor	Kyowa Electronic Instruments Co. Ltd.

MLIT has organized the direction of the development of inspection support technologies as shown in Figure 7.7 in the public solicitation of technologies for the “Inspection Support Technology Performance Catalog (Draft)”.

Figure 7.7 Structure of Inspection Support Technology Performance Catalog (Draft)[74]

(1) Approaches to the use of Modern Technologies in the Inspections of Bridges and Other Structures

As shown in Figure 7.8, for bridges with simple and small structures such as ditch bridges, modern technologies that contribute to work efficiency shall be used while narrowing down the inspection items. On the other hand, for bridges with a large scale and complex structure, inspection efficiency should be improved by combining various technologies according to the structure of the bridge.

[74] Information of the 74th Basic Policy Division Meeting of the Social Capital Improvement Review Committee, December 3, 2020

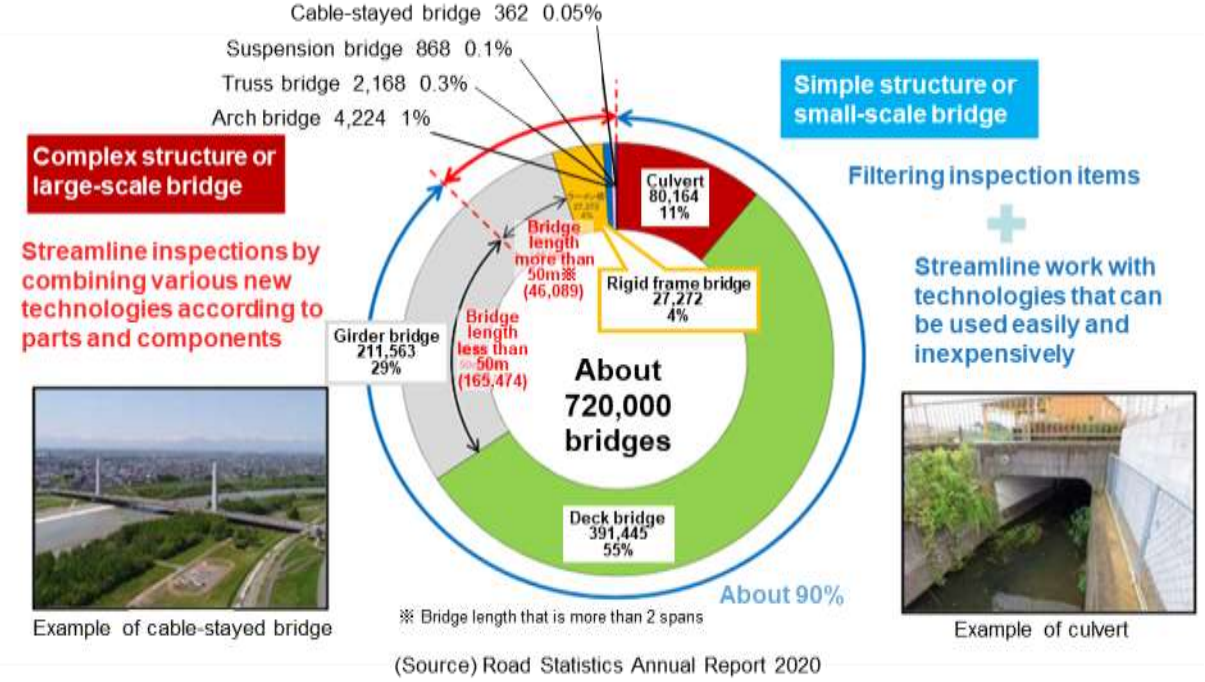


Figure 7.8 Approaches to the use of Modern Technologies in Bridge Inspections

As a direction for the use of modern technologies in periodic inspections shown in Figure 7.9, the condition evaluation of structural parts and members is intended to be carried out efficiently by combining the most appropriate technologies according to the purpose. The diagnosis of soundness is expected to be conducted by knowledgeable and skilled personnel, while also utilizing AI and other technologies.

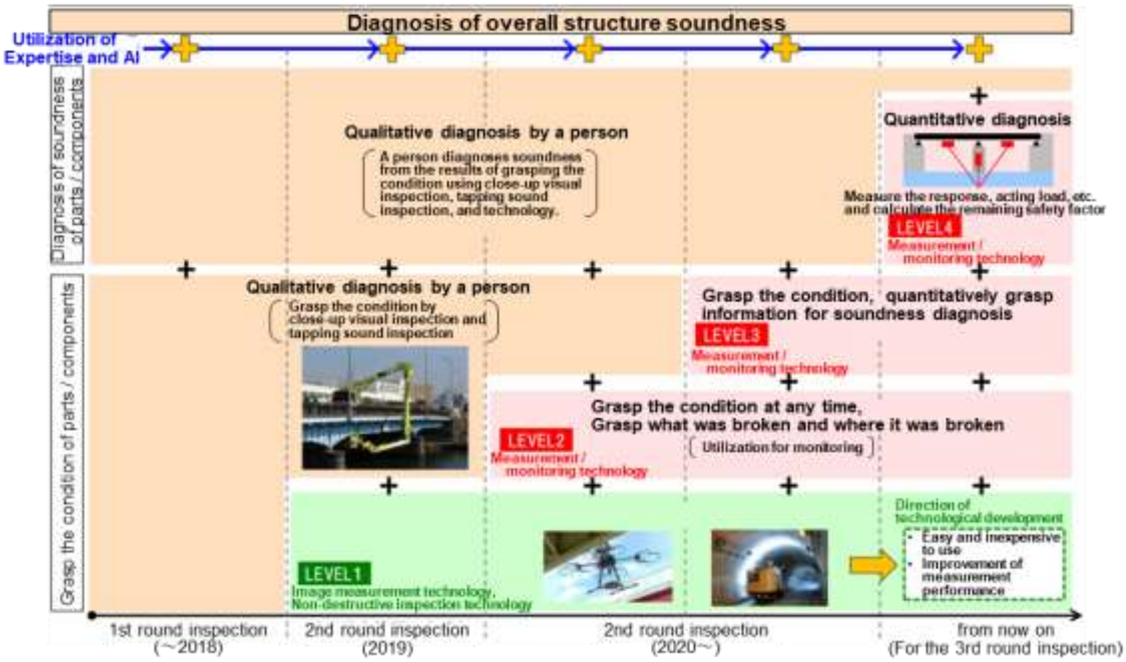


Figure 7.9 Direction of the use of Modern Technologies in Periodic Inspections (Draft)[75]

[75] MLIT, Road Bureau: Direction of Development of Inspection Support Technology

(2) Concept of Inspection and Diagnosis

In the diagnosis of soundness, the condition of each site/member and of the entire structure is ascertained and evaluated for the necessity of measures, considering the degree of damage obtained from the inspections, based on the characteristics of the structure, the cause of damage and its progress, and the bridging conditions. Therefore, in diagnosis, the information necessary for understanding the condition of each part and member should be obtained according to the purpose of the inspections.

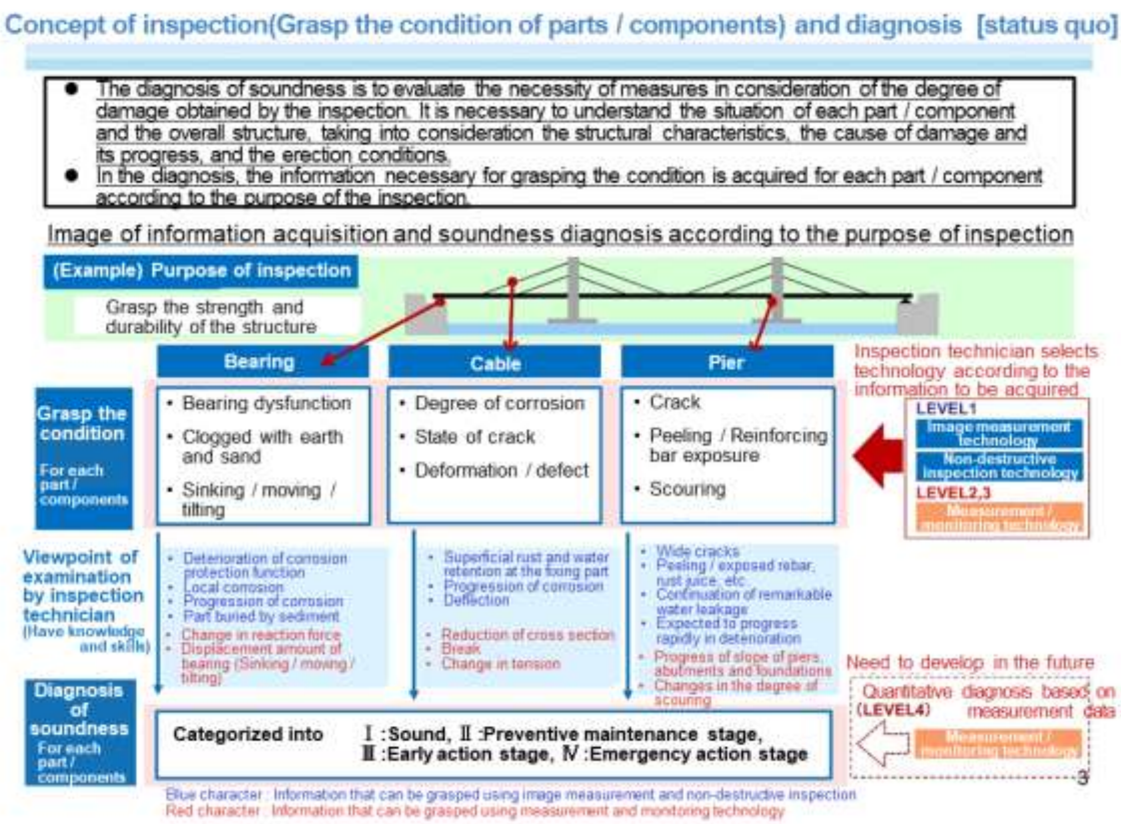


Figure 7.10 Image of Obtaining Information and Diagnosing Health[76]

(3) Classification of Modern Technologies in Inspection and Diagnosis

The classification of modern technologies in inspection and diagnosis is shown in Table 7.10.

Table 7.10 Classification of Modern Technologies in Inspection and Diagnosis[77]

New Technology Distinction	Level	Effect	Content
Image Measurement Technology	LEVEL 1	Improving work efficiency	Technology that allows inspection engineers to take images of the target structure to understand its exterior deformation, etc.
Nondestructive Testing Technology	LEVEL 1	Improving work efficiency and the quality of condition evaluation	Technology to grasp the floating of a structure without destroying the structure

[76] MLIT, Road Bureau: Direction of Development of Inspection Support Technology
[77] MLIT, Road Bureau: Direction of Development of Inspection Support Technology

New Technology Distinction	Level	Effect	Content
			from the outside. (For example, a technology that enables non-destructive identification of floating objects that were previously identified by percussion inspection by inspection engineers.
Measurement and Monitoring Technology	LEVEL 2 LEVEL 3	Condition monitoring at any time Quantitative information for understanding the condition of structures and diagnosing their health	Technology to quantitatively understand the variation of the position (displacement) and response (tension, reaction force, etc.) of the structure to be inspected by continuously measuring them over time.
Diagnostic Quantification Techniques	LEVEL 4	Quantification of diagnosis by estimating residual strength and bearing capacity of parts and components	Technology to quantitatively understand the relationship between the data acquired in LEVEL1-3 and the diagnosis of health (future)

7.6.2 New Technology Introduction Promotion Policy and Order and 2020 New Technology Introduction Promotion Plan

After the deliberation of the 2nd Round-Table Meeting on Road Technology held by the Ministry of Land, Infrastructure, Transport and Tourism on April 27, 2020, the “Policy for Promoting the Introduction of New Technologies in the Road Sector” and the “Plan for Promoting the Introduction of New Technologies in 2020” were decided as shown in Figure 7.11. The outline is as follows.

(1) Basic Policy

1) To promote the development and introduction of modern technologies, including new materials, in other industries and fields where the use of modern technologies has not been sufficiently developed, under the policy of utilizing good technologies, with the aim of providing safe, high-quality, and low-cost road services, improving the processes of people involved in road projects, and perfecting industries.
2) For this purpose, the Road Technology Advisory Council was established to visualize the initiatives (modern technology introduction promotion plan) for each fiscal year. In addition to accelerating the review process through public solicitation of technologies and exchange of opinions, the system for solving problems in the field and studying the introduction method (reflection in standards) will be strengthened.
3) Through these efforts, we have overcome the barriers to public procurement that have hindered the introduction of modern technologies, and to identify the needs inherent in the field.

Figure 7.11 Policy for Promoting the Introduction of New Technologies in the Road Sector[78]

7.6.3 Draft Guide for Local Governments on Introducing New Technologies to Maintenance Management

The vast amount of infrastructure structures managed by local governments is aging, and there is a need for efficient and effective maintenance and management of infrastructure using modern technologies, etc. However, it is sometimes difficult to utilize modern technologies due to the decrease in technical staff and lack of technical skills and information in local governments. Therefore, to promote the use of modern technologies by local governments, MLIT prepared the "Draft Guide to the Introduction of New Technologies in Infrastructure Maintenance and Management (Ver0.1)" based on field trials of modern technologies by model local governments and advice from experts and published it on March 31, 2021.

7.6.3.1 Key Points of the Draft Guide

1) For local government officials who are not familiar with modern technologies, the report describes, in easy-to-understand language, matters that should be considered when introducing modern technologies.
2) Provides examples of studies, references, and consultation services to local governments for reference on how to proceed.
3) The process of introducing modern technology is organized into five steps (Table 7.11)
4) Each step is described with figures and examples, including points of focus and points to note (Table 7.12).

[78] Materials of the 2nd Round-Table Meeting on Road Technology, April 30, 2020

Table 7.11 Process of Introducing New Technology[79]

Step（1）Preliminary review by the department in charge
✓ Clarification of issues in infrastructure maintenance and management ✓ Gather information on modern technologies, etc. ✓ Determination of whether and how to introduce the system
Step（2）Decision-making on introduction and issues for securing budget
✓ Coordination with the head of the department ✓ Coordination with the finance department
Step（3）On-site trial
Method① Joint development Method② On-site trial
Step（4）Full-scale introduction
Method③ Outsourcing Method④ Procure only equipment (Reference) Included Management Entrustment
Step（5）Briefings for field staff, evaluation, improvement and refinement
✓ Briefing session ✓ Establishing a data management system ✓ Post-implementation evaluation ✓ Improvement and refinement

Table 7.12 Examples of Modern Technology Introduction[80]

Method① Joint development：（a）Government-managed bureaucracy→（b）Private sector proposal type
1) Shizuoka Prefecture: Joint development of 3D utilization technology A case in which a specific proposal of a municipality's needs was followed by matching with a technology development company and a university, and a field trial led by the municipality's staff, leading to a continuous study for introduction.
Method② On-site trial：(a) Government-managed bureaucracy
2) Shizuoka City, Shizuoka Prefecture: Field trial of satellite SAR and laser percussion inspections A case study of the demonstration of a modern technology through on-site verification based on specific needs related to the use of satellite SAR and laser percussion. 3) Hokuto City, Yamanashi Prefecture: Field trial of road surface flatness measurement In a municipality with a population of 50,000, a case study was conducted to demonstrate the modern technology in a field trial based on two needs related to pavement maintenance and management (revision of the life extension modification plan and identification of urgent areas for repair).
Method③ Outsourcing
4) Saga Prefecture: Trial introduction and procurement of road surface flatness measurement A case in which a private company told us about a relevant modern technology, which led to the verification of the modern technology through outsourcing to several technology providers, and the full-scale introduction of the new technology in road patrol operations.
Method④ Procure only equipment
5) Kimitsu City, Chiba Prefecture: Bridge Staff Inspections by Drone Clarification of issues related to infrastructure maintenance management, field trials, revision of inspection procedures, introduction of modern technologies, training of directly managed inspection personnel, and reduction of inspection costs.
(Reference) Separation of notes and included private commissions
6) Sanjo City, Niigata Prefecture A case study of the introduction of a comprehensive private-sector contract including bridges and the introduction of a maintenance management support system.

[79] MLIT, Policy Bureau, Guide to the Introduction of New Technologies in Infrastructure Maintenance and Management (Draft), March 2021
[80] MLIT, Policy Bureau, Guide to the Introduction of New Technologies in Infrastructure Maintenance and Management (Draft), March 2021

7) Tamana City, Kumamoto Prefecture A case in which cost reduction is being promoted using separate orders for repair design, and the introduction of modern technologies is being considered through the comprehensive outsourcing of infrastructure maintenance and management to the private sector.

7.7 Initiatives on Establishment of Road AM in Local Governments and Universities

7.7.1 Niigata City

7.7.1.1 Condition of Managed Bridges

Niigata City manages about 4,000 bridges ranging from long bridges to small bridges. Of these, small bridges with a bridge length of less than 15m account for about 80%. Since most of these bridges were built during the period of rapid economic growth, they are expected to age rapidly in the future, and the number of bridges that are 50 years old or older, which was about 26% as of 2018, is expected to increase rapidly to about 70% in 20 years. It is feared that the financial burden will be extremely high if large-scale repair or replacement of these bridges becomes necessary soon.

For this reason, Niigata City is working on a plan for systematic and efficient maintenance and management that incorporates the concept of AM and is making efforts to extend the service life of bridges, level out the reconstruction period, reduce the total management cost, and ensure the safety and reliability of the road network. In 2015, the Bridge AM Study Committee was established with academic experts from local universities and other organizations as members and is promoting studies on the management system for the maintenance and management of bridges managed by Niigata City, formulation of medium- to long-term and short-term project plans, introduction of modern technologies and systems, and public relations methods.

7.7.1.2 Past Efforts in Bridge Maintenance and Management

As shown in Table 7.13, a life-extension repair plan was formulated for the three-year period from 2008 to 2010, with the aim of giving top priority to ensuring the safety and reliability of the road network, while at the same time reducing repair and replacement costs and equalizing the required budget.

Table 7.13 Past Efforts in Bridge Maintenance and Management in Niigata City[81]

Year	Contents
2012	Formulation of long-life repair plan (start of measures for aging) Start of bridge working (staff training sessions)
2013	Formulation of seismic load-bearing reinforcement plan
2014	In accordance with the revision of the Road Act, inspection of all road bridges became mandatory (close visual inspections)
2015	Bridge AM review committee established Selected as model city for SIP project, collaboration with Japan Society of Civil Engineers
2016	Long-life repair plan revised; model project started
2017	Revision of long-life repair plan, continuation of model project and verification of effectiveness
2018	Completed the first round of statutory inspections

[81] Hearing in Niigata City

Year	Contents
2019	Full-scale introduction of tablet-based small-scale bridge inspections and health evaluation meetings

With the revision of the Road Act in 2015, close visual inspections of bridges with a bridge length of 2m or more became mandatory. Through the inspections, the condition of the bridge is ascertained, and its soundness is diagnosed according to the classification in Table 7.14. This information is reflected in the life extension and repair plan, and measures are taken after considering the priority order based on the soundness and management classification.

Table 7.14 Definition of Soundness[82]

Soundness		Definition
I	Soundness	A state in which the function of the road bridge is not hindered.
II	Preventive maintenance stage	The function of the road bridge is not hindered, but it is desirable to take actions from the viewpoint of preventive maintenance.
III	Prompt action stage	A state in which the function of the road bridge may be impaired, and actions should be taken early.
IV	Emergency Action stage	A state in which the function of the road bridge is impaired or is extremely likely to occur and urgent actions should be taken.

7.7.1.3 Setting the Management Category

In Niigata City, management categories (1 to 4) have been set for all bridges according to road network functions and bridge characteristics. Of these, bridges with management categories 1-3 are inspected and repaired by the Niigata City Public Works Office. Bridges in management category four are inspected and repaired by the Niigata City Civil Engineering Office.

The management classification of the bridges is shown in Table 7.15 and the management classification adjustment details are shown in Table 7.16.

[82] Hearing in Niigata City

Table 7.15 Management Category of Bridges[83]

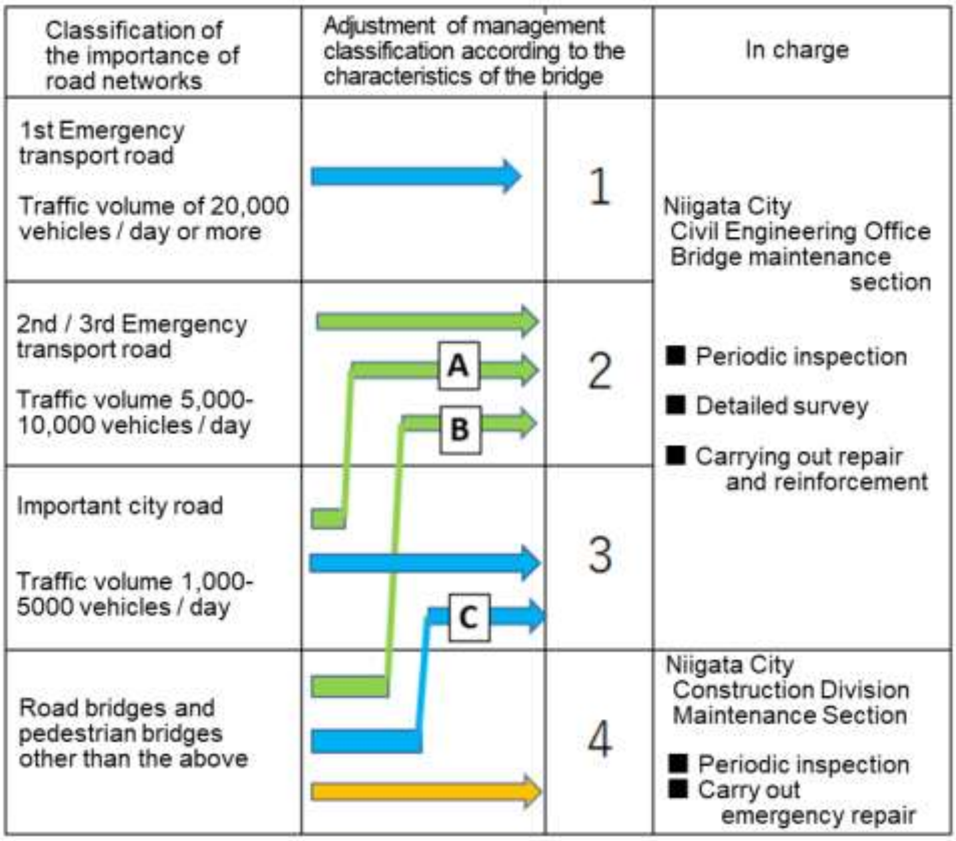


Table 7.16 Management Category Adjustment Content[84]

Details of adjustment of management classification	Characteristics of the bridge
A B	① PC bridge located in salt-damaged area
	② Special bridges such as truss bridges
	③ Overpass that is greatly affected by damage to third parties
	④ RC bridge located in salt-damaged area
C	⑤ Bridges with a length of 14.5 m or more
	⑥ Steel bridge
	⑦ Bridges with a detour distance of 3 km or more

83 Hearing in Niigata City
84 Hearing in Niigata City

7.7.1.4 Bridge Management System

Niigata City has introduced and is operating the "Niigata City Bridge Database System," a centralized management system that accumulates maintenance and management information such as bridge registers, repair histories, and inspection reports. In addition, the system is linked to the "Bridge Field Inspection System" which supports the input of inspection results by inspection companies to ensure that the inspection results are reflected in the bridge database system.

7.7.1.5 Small-Scale Bridge Inspection Using Tablet Devices

With the amendment of the Road Law in 2013, close visual inspections of all road bridges became compulsory, and Niigata City faced the issues of increasing inspection costs and shortage of inspection engineers. Therefore, the city has introduced the use of a tablet inspection system to simplify the inspections of bridges with short bridge lengths and has outsourced the inspections to local contractors who are familiar with the area. An overview of the inspections is shown in Table 7.17.

Table 7.17 Overview of Small-Scale Bridge Inspection Using Tablet Devices[85]

Item	Outline
Contract method	1. Voluntary contract to construction industry association 2. Bidding to contractors with disaster support agreement
Work contents	1. Conduct bridge inspections using tablets loaned by the city 2. Conduct inspections with a two-person team
Engineer Training	1. Hold small-scale bridge inspection workshop for inspectors 2. Half-day training on basic tablet operation and basic knowledge of bridge inspection through classroom and field practice 3. Distributed inspection manuals on how to operate tablets and points for bridge inspections

7.7.1.6 Initiatives for Bridge Working (Workplace Training Sessions)

Niigata City has been conducting human resource development training for bridge personnel in each ward and civil engineering office. The purpose of the training is to improve the technical skills of the staff in charge of bridges by (1) acquiring basic knowledge on bridge maintenance and management, (2) promoting understanding of inspection methods and effective repair methods, and (3) acquiring how to operate the database system. It is also expected to strengthen cooperation between ward offices and civil engineering offices in bridge maintenance and management operations.

7.7.1.7 Soundness Evaluation Meeting

A "Bridge Integrity Assessment Council" has been set up, consisting of third parties such as academics and related organizations, and both the parties ordering and receiving bridge inspections give presentations based on their diagnosis, and the assessors evaluate the validity of the inspection results. As an effect of this initiative, the inspections and diagnosis system has been strengthened by: (1) aligning the diagnostic criteria and reducing the variability of inspection results, and (2) sharing information and improving technical skills through the participation of not only the client and the contractor but also the staff involved

[85] Hearing in Niigata City

in bridge maintenance and management.

7.7.2 Yamagata Prefecture

7.7.2.1 Yamagata Prefecture Bridge Life Extension and Repair Plan

The road bridges managed by Yamagata Prefecture were built intensively during the period of high economic growth and are expected to age rapidly over time. If the conventional “repair after damage” approach is continued, the long-term maintenance and management costs will be enormous, making it difficult to provide safe and secure services to the public. This will make it difficult to provide safe and secure services for public use. The basic policy of bridge life extension is to shift to preventive maintenance management by actively extending the service life of road management facilities, reducing long-term costs, and equalizing management costs, including reconstruction, to ensure safety from a long-term perspective.

The distribution of the number of bridges by year of construction is shown in Figure 7.12, and the percentage of aging bridges that are 50 years or older after construction is shown in Figure 7.13.

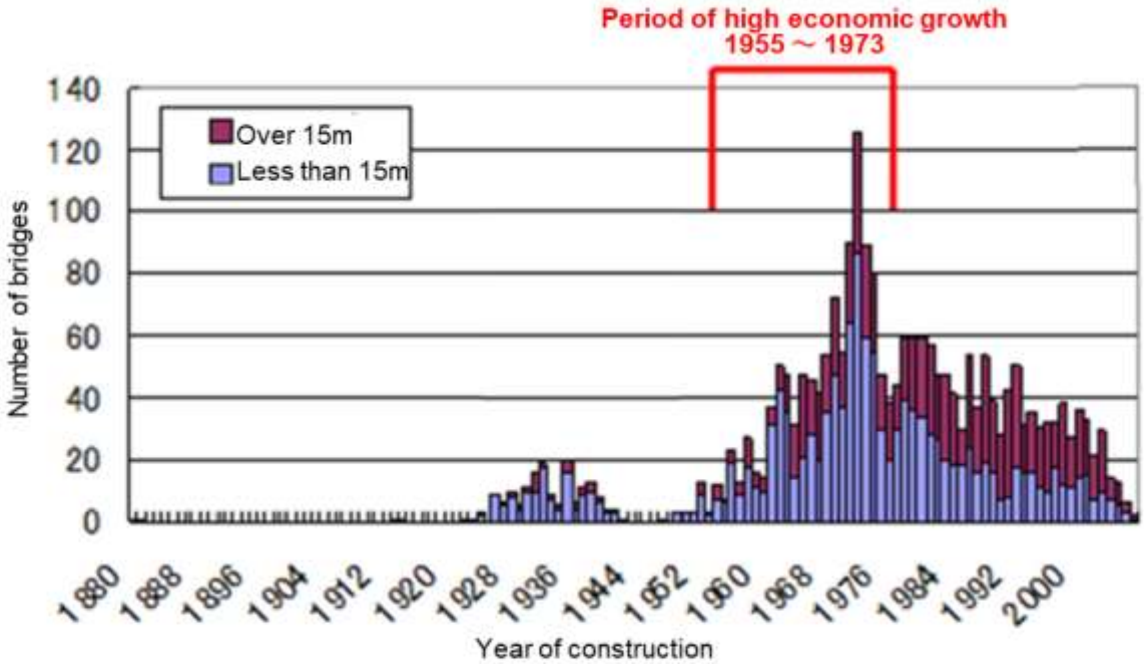


Figure 7.12 Distribution of the Number of Bridges by Year of Construction[86]

[86] Comprehensive Manual for Extending the Life of Bridges in Yamagata Prefecture, March 2020

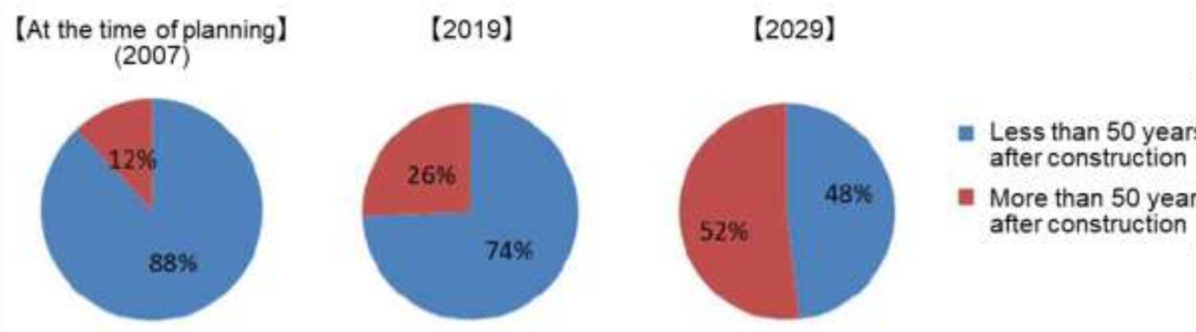


Figure 7.13 Percentage of Aging Bridges that are 50 Years or Older Since Construction[87]

7.7.2.2 Selecting the Best Management Method

As shown in Figure 7.14, to achieve the basic policy of bridge longevity, the optimal management method is selected by simulating the costs required in the future, assuming multiple management methods from a long-term perspective, and a plan is developed based on this approach.

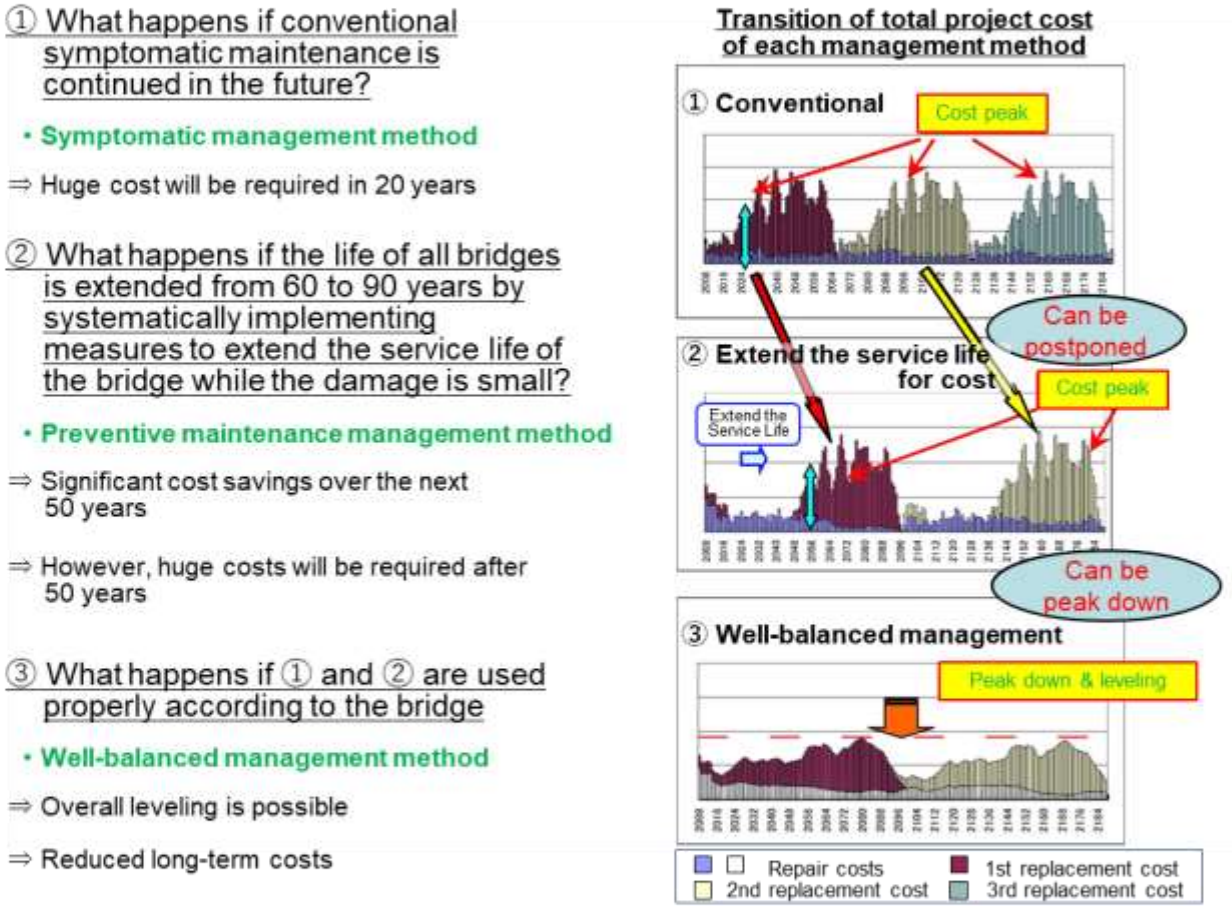


Figure 7.14 Selecting the Best Management Method[88]

[87] Comprehensive Manual for Extending the Life of Bridges in Yamagata Prefecture, March 2020
[88] Bridge Life Extension and Repair Plan Manual in Yamagata Prefecture, June 2020

7.7.2.3 Policy for Concrete Measures to Extend the Service Life of Bridges

(1) Early and Accurate Assessment of Condition

With the aim of ensuring safety and conducting systematic and efficient maintenance and management, the condition of bridges will be assessed early and accurately through regular inspections by road patrols and regular inspections of each bridge once every five years.

(2) Thorough Daily Maintenance and Management

Cleaning and road patrols are conducted to keep bridges in good condition and to protect the safety of traffic. As for the staff in charge of maintenance and management, they participate in training on bridge deterioration and inspection methods and conduct technical studies in daily management.

(3) Cooperation with Municipalities

Yamagata Prefecture provides technical support to municipalities by holding training and study sessions for municipalities as well, and sharing information on various standards, materials related to ordering, and technical materials.

(4) Emergency Response

When an abnormality is found on a bridge, the general branch office that manages the bridge takes necessary measures such as traffic control, reports the situation to the prefectural government, and shares information among the general branch offices. If necessary, emergency inspections are conducted for the entire prefecture to ensure safety.

(5) Promotion of Anti-degradation Measures to Cope with Climatic Conditions in Yamagata Prefecture

1) Water countermeasures

Among the various deterioration factors of bridges, preventing water supply (stagnant water, leakage), which causes rusting of steel and deterioration of concrete, is an amazingly effective measure for extending the service life of bridges.

Figure 7.15 Example of Girder End Corrosion Due to Water Leakage from an Expansion Device[89]

2) Salt Countermeasures

As for salt, which causes deterioration as well as water, measures to prevent salt penetration will be effective for bridges that are susceptible to salt due to coastal areas and the spraying of anti-freeze.

Figure 7.16 Examples of Salt Damage[90]

3) Wind and Cold Protection

The Shonai area is subject to strong northwest monsoon in winter, and especially in the Mogami River basin, fatigue damage of steel members due to wind has been reported because of the strong wind passing along the river. In the Mogami River basin, where fierce winds pass along the river, fatigue

[89] Comprehensive Manual for Extending the Life of Bridges in Yamagata Prefecture, March 2020
[90] Comprehensive Manual for Extending the Life of Bridges in Yamagata Prefecture, March 2020

damage to steel members caused by the wind has been reported. Therefore, we will extend the service life of bridges by implementing detailed measures according to various weather conditions, such as very windy areas like the Shonai area, and inland and mountainous areas where the temperature is low in winter.

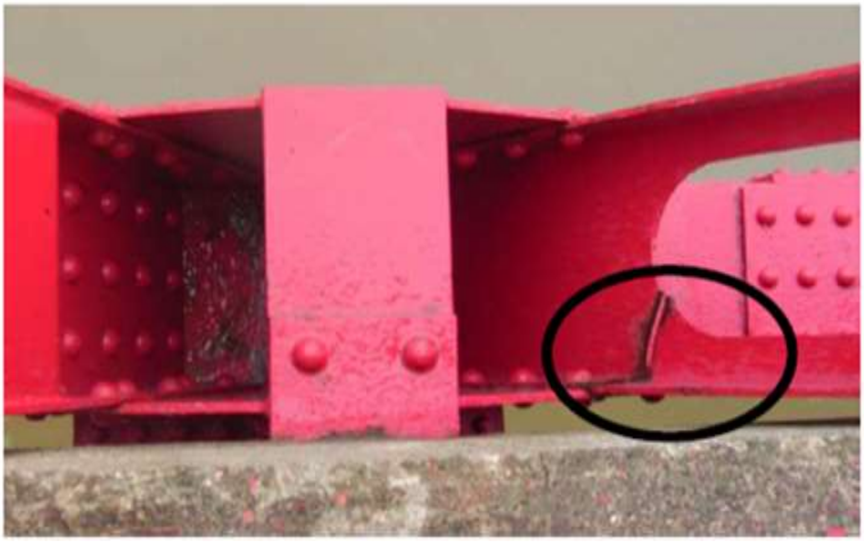


Figure 7.17 Example of Fatigue Damage to a Steel Member Caused by Wind (Fracture of the Truss Part)[91]

(6) Replacing with a Hassle-Free Bridge

The new bridges to be built will be painless and hassle-free, considering the weather conditions of Yamagata Prefecture and other factors, with reference to previous deterioration and damage, to extend their service life and reduce costs.

7.7.2.4 **Yamagata Prefecture Bridge Inspection Guidelines**

Yamagata Prefecture has prepared the “Yamagata Prefecture Bridge Inspection Guidelines” for bridge inspections, which is based on the Ministry of Land, Infrastructure, Transport and Tourism's inspection manual, but simplified to reduce inspection costs.The history of standards for bridge inspections in Yamagata Prefecture is shown in Table 7.18.

Table 7.18 History of Standards for Bridge Inspection in Yamagata Prefecture[92]

Year	Content
2004	2004 Periodic Inspection Guidelines for Bridges (Draft) (2004, Ministry of Land, Infrastructure and Transport) Due to the substantial number of items to be evaluated and recorded, it was difficult for the prefecture to continuously apply this guideline to all bridges.
2006	Bridge Inspection Guidelines (Draft) September 2006, Yamagata Prefecture) While ensuring consistency with the national guideline, the guideline was revised to simplify the work, standardize, and standardize the accuracy and quality of results, and reduce the inspection cost. →Prefecture's periodic inspections were divided into two parts: detailed inspections (all close

[91] Comprehensive Manual for Extending the Life of Bridges in Yamagata Prefecture, March 2020
[92] Yamagata Prefecture Bridge Inspection Guidelines March 2020

Year	Content
	visual inspection) and standard inspections (some distant visual inspection).
2009	Bridge Inspection Guidelines (Draft) (Revised in August 2009, Yamagata Prefecture) As the first round of periodic inspections of bridges with a length of 15 m or more has been completed and the second round is about to begin, simple inspections (proximity) and simple inspections (distant view) have been added as inspection methods to further improve efficiency, and these have been set as the prefectural standard.
2011	Bridge Inspection Guidelines (Revised in June 2011, Yamagata Prefecture) The following revisions were made to improve the applicability of the inspection results to the continuous development of the service life extension and repair plan, as well as to revise the inspection names to be more appropriate to the actual situation. Reviewed damage assessment categories to make inspection results more useful in diagnosis and deterioration prediction. Clarification of the position and importance of inspections after the second round (description of points to note, review of recording methods)
2014	Bridge Inspection Guidelines (Revised in July 2014, Yamagata Prefecture) Revised in accordance with the revision of the Road Law Enforcement Regulations and the Periodic Inspection Guidelines for Road Bridges (June 2014, Ministry of Land, Infrastructure and Transport, Road Bureau). Distant vision + proximity vision has been revised to proximity vision for all diameters. Diagnosis work that was not included before was added to the inspection guidelines as "soundness diagnosis. Diagnosis categories were changed from "OK, III, II, II+, and I" to "Ia, Ib, II, III, and IV".
2017	Bridge Inspection Guidelines (Yamagata Prefecture, revised June 29) Changes in forms and other items accompanying the start of operation of the integrated database for road and bridge maintenance in Yamagata Prefecture
2019 (H31)	Bridge Inspection Guidelines (Revised in April 1956, Yamagata Prefecture) In accordance with the revision of the Periodic Inspection Guidelines for Road Bridges (February 31, 2011, MLIT Road Bureau), the items to be noted when conducting periodic inspections and recording the condition of bridges were reviewed to understand the condition as a basis for diagnosing soundness.
2019 (R1)	Bridge Inspection Guidelines (Revised R2.3, Yamagata Prefecture) The concept of soundness diagnosis was reviewed. Regarding the evaluation of countermeasure categories, the countermeasure category III in the prompt action stage is classified into IIIa and IIIb according to the presence or absence of the viewpoint of structural safety as a road bridge. In accordance with the above, the flow of setting priorities according to the countermeasure categories was also revised. In line with the revision of the Comprehensive Manual for Bridge Life Extension, it was clearly stated that the necessity of replacement consideration should be determined at the time of soundness diagnosis.

7.7.2.5 **Integrated Database System of Bridge Maintenance, Yamagata Pref. (DBMY)**

One of the issues facing Yamagata Prefecture is the huge amount of stock to be managed and the delay in taking measures against aging in municipalities. To solve these issues, a support system was established through industry-academia-government collaboration. An overview is shown in Table 7.18.

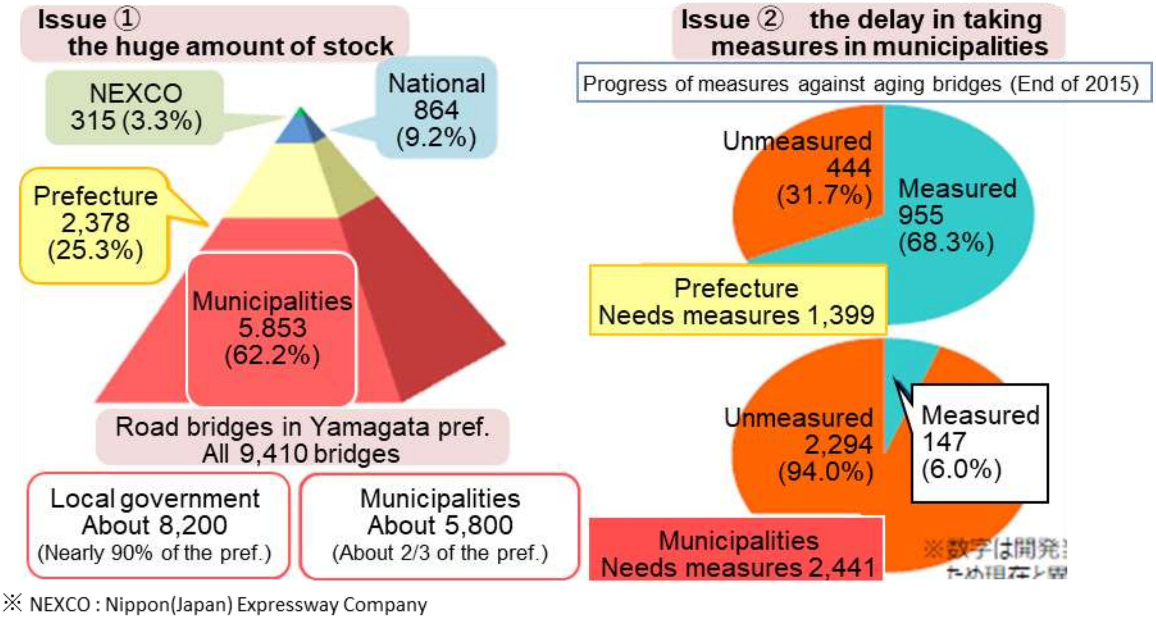


Figure 7.18 Overview of Issues Yamagata Prefecture is Facing[93]

Under this support system, a database system (DBMY) was developed in collaboration with industry, academia, and government in the project of "Infrastructure Maintenance, Reconstruction, and Management" of the Strategic Innovation and Creation Program (SIP). As a result, a high-quality and easy-to-use database system could be introduced economically in a brief period while using Yamagata Prefecture's style as before.

Figure 7.19 shows the configuration of DBMY, and Figure 7.20 shows the role of DBMY and the intended implementation effect.

Figure 7.19 Structure of DBMY[94]

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94 Yamagata Prefecture hearing materials

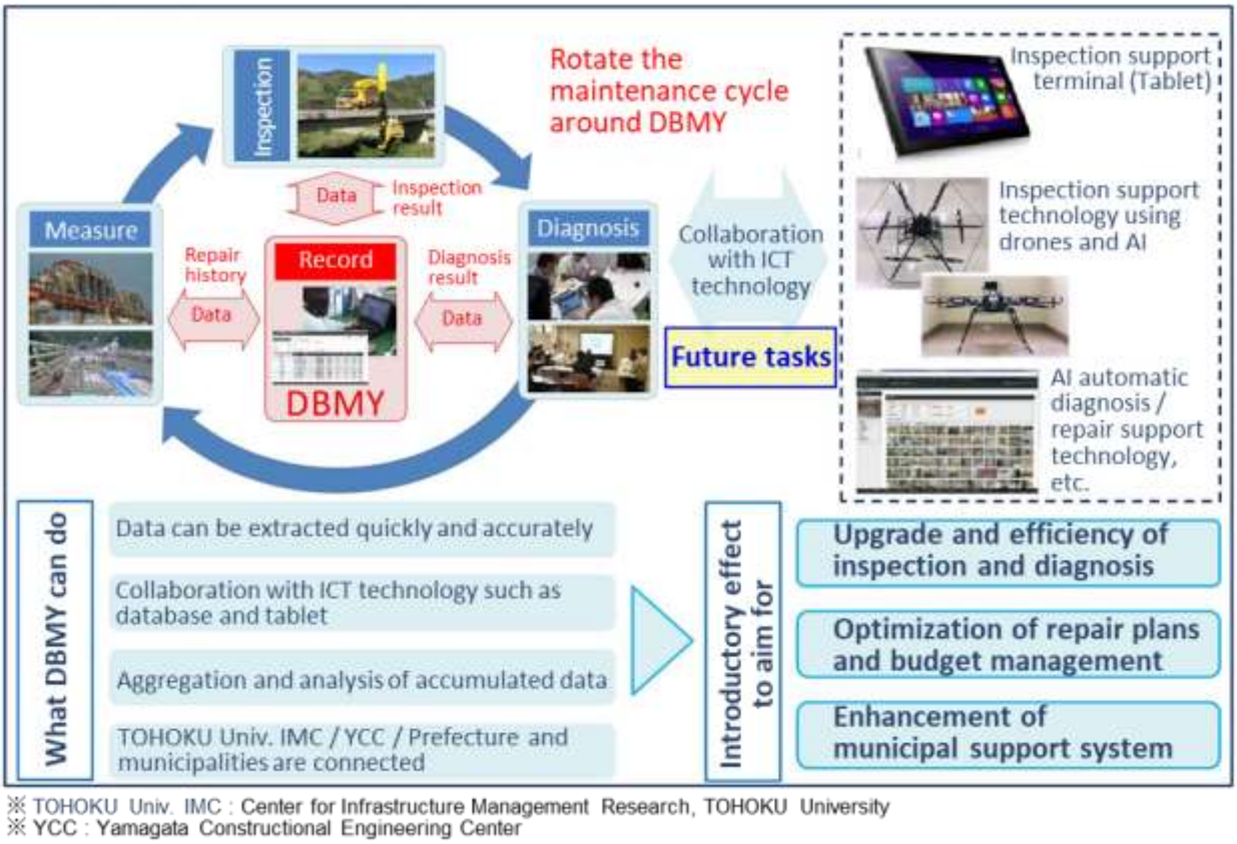

Figure 7.20 The Role of DBMY and the Targeted Implementation Effect[95]

7.7.2.6 **Pavement Maintenance in Yamagata Prefecture**

The road management extension and pavement extension in Yamagata Prefecture are shown in Figure 7.19.

Table 7.19 Management Extension and Pavement Extension[96]

Road Classification	Management Extension	Pavement Extension		Pavement Rate
		As Pavement	Con Pavement	
Auxiliary National Highway	567,405km	525,632km	19,450km	96.0%
Major Regional Roads	1,155,940km	1,070,909km	13,308km	93.8%
General prefectural roads	1,371,351km	1,212,727km	11,290km	89.2%
Total	3,094,999km	2,809,268km	44,048km	92.2%

In the Yamagata Prefecture Road Pavement Longevity Plan, maintenance and management is conducted according to the characteristics of the road, and management standards based on the MCI (Maintenance Control Index) value are set for each road category, and repair methods are selected according to the current MCI value. However, the actual repair method is finally decided at the diagnosis meeting according to the

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site conditions.

On the other hand, in addition to planned measures based on the MCI value, there are cases where priority is given to areas where there are large demands and complaints from users and residents.

The MCI value evaluates the serviceability of a pavement based on the road surface properties of "crack rate," "amount of rutting," and "flatness," and has been developed as a comprehensive index for judging pavement maintenance and repair. The management standards based on the MCI values are shown in Table 7.20.

Table 7.20 Management Criteria by MCI Value

<table>
<tr><th colspan="2" rowspan="2">Category</th><th rowspan="2">Item</th><th colspan="7">MCI</th></tr>
<tr><th>0～2.5</th><th>2.5～3.0</th><th>3.0～3.5</th><th>3.5～4.0</th><th>4.0～4.5</th><th>4.5～5.0</th><th>5.0～</th></tr>
<tr><td rowspan="9">B</td><td rowspan="3">Group ①</td><td>Diagnosis category</td><td colspan="3">Ⅲ－2</td><td>Ⅲ－1</td><td colspan="2">Ⅱ</td><td>Ⅰ</td></tr>
<tr><td>Diagnosis result</td><td colspan="3">Roadbed replacement, etc.</td><td>Repair of surface layer, etc.</td><td colspan="2">Surface function retention stage</td><td>Sound</td></tr>
<tr><td>Repair method</td><td colspan="3">Roadbed replacement or regeneration</td><td>Cutting overlay or regeneration</td><td colspan="2">Sealant injection</td><td>Daily maintenance</td></tr>
<tr><td rowspan="3">Group ②</td><td>Diagnosis category</td><td colspan="2">Ⅲ－2</td><td colspan="2">Ⅲ－1</td><td colspan="2">Ⅱ</td><td>Ⅰ</td></tr>
<tr><td>Diagnosis result</td><td colspan="2">Roadbed replacement, etc.</td><td colspan="2">Repair of surface layer, etc.</td><td colspan="2">Surface function retention stage</td><td>Sound</td></tr>
<tr><td>Repair method</td><td colspan="2">Roadbed replacement or regeneration</td><td colspan="2">Cutting overlay or regeneration</td><td colspan="2">Sealant injection</td><td>Daily maintenance</td></tr>
<tr><td rowspan="3">Group ③</td><td>Diagnosis category</td><td>Ⅲ－2</td><td>Ⅲ－1</td><td colspan="4">Ⅱ</td><td>Ⅰ</td></tr>
<tr><td>Diagnosis result</td><td>Roadbed replacement, etc.</td><td>Repair of surface layer, etc.</td><td colspan="4">Surface function retention stage</td><td>Sound</td></tr>
<tr><td>Repair method</td><td>Roadbed replacement or regeneration</td><td>Cutting overlay or regeneration</td><td colspan="4">Sealant injection</td><td>Daily maintenance</td></tr>
<tr><td colspan="2" rowspan="3">C・D</td><td>Diagnosis category</td><td>Ⅲ－2</td><td>Ⅲ－1</td><td colspan="3">Ⅱ</td><td colspan="2">Ⅰ</td></tr>
<tr><td>Diagnosis result</td><td>Roadbed replacement, etc.</td><td>Repair of surface layer, etc.</td><td colspan="3">Surface function retention stage</td><td colspan="2">Sound</td></tr>
<tr><td>Repair method</td><td>Roadbed replacement or regeneration</td><td>Cutting overlay or regeneration</td><td colspan="3">Sealant injection</td><td colspan="2">Daily maintenance</td></tr>
</table>

7.7.3 Niigata University

7.7.3.1 **Proposal for Maintenance Management Based on Quantitative Assessment of Salt-Affected Environment**

Niigata University has been conducting research on the quantitative evaluation of airborne salt environment with the aim of contributing to the establishment of a method that can appropriately consider the influence of environmental conditions in predicting salt penetration. As a result of measuring the amount of airborne salt and conducting exposure tests on mortar and concrete specimens at the same locations in Japan, it has been found that there is a correlation between the amount of airborne salt and the amount of salt penetration into concrete at each location.

The following suggestions are made for the use of the environmental evaluation results.

1) Implementation of durability design based on the macroscopic salt damage environment.
2) After the completion of the structure, evaluate the salt damage environment of each part of the structure using thin plate specimens (about 1 to 2 years).
3) Depending on the salt environment of each part of the structure, implement preventive maintenance such as surface coating only on the parts with a large amount of salt supply, or formulate a detailed maintenance management plan such as narrowing down the priority areas for inspections.

7.7.3.2 **Niigata Regional Council for the Training of Infrastructure Rehabilitation Engineers**

The social infrastructure that was intensively developed during the period of rapid economic growth is coming up for reconstruction, but the environment surrounding public investment is severe, and efficient and strategic maintenance and management of facilities is required. However, while the number of aging infrastructures is increasing, there is an overwhelming shortage of engineers who are responsible for infrastructure rehabilitation. In 2013, Nagaoka University of Technology (Nagaoka University of Technology) and other universities in Niigata Prefecture joined the project, which was launched in 2014 by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) with the aim of developing a training program for infrastructure rehabilitation engineers who can properly grasp the challenges of disasters and infrastructure maintenance and management caused by disasters. The Niigata Regional Council for the Training of Infrastructure Rehabilitation Engineers was established in 2013 with the cooperation of Niigata University, Nagaoka National College of Technology, the Hokuriku Regional Development Bureau of the Ministry of Land, Infrastructure and Transport, Niigata Prefecture, Niigata City, the Niigata Construction Industry Association, and the Hokuriku Branch of the Construction Consultant Association. The purpose of the association is to train engineers who can conduct inspections of social infrastructure facilities and equipment, and it holds ME training courses twice a year. The fall course is a program on general structural inspections, while the spring course is on inspections of disaster prevention facilities and equipment. Table 7.21 shows the curriculum of the ME Niigata (structural) training course (2015).

Table 7.21 Curriculum for ME Niigata (Structural) Training Course (2015)[97]

No	Title of Lecture (Hours)	Lecturer	Content of Lecture
1	Guidance (2h)	Nagaoka Institute of Technology Prof. Satoru Otsuka	1) Objectives, contents, and implementation methods of the ME Niigata training course
2	Social infrastructure structures in the Hokuriku region (general introduction) (1h)	Nagaoka Institute of Technology Prof. Hisamichi Maruyama	1) The Environment of the Hokuriku Region from the Viewpoint of Weather, Topography and Geology 2) Current Status of Infrastructures in Niigata Prefecture 3) Maintenance management methods and

[97] Niigata Regional Council for the Training of Infrastructure Rehabilitation Engineers, 2015 Implementation Report

No	Title of Lecture (Hours)	Lecturer	Content of Lecture
			repair/reinforcement measures for structures from the viewpoint of deterioration factors 4) Future issues in maintenance management
3	Overview of inspection of road accessories (1h)	Hokuriku Branch of Kenkon NCE Corporation Toshio Kusakabe	1) Purpose of Inspection and Legal System 2) Basics and Points to Note for Inspections of Lighting and Road Signs 3) Points to be inspected for lighting and road signs, guidelines for filling out forms, and diagnosis 4) Inspection parts and materials of culverts, and the nature of their deformation 5) Inspection Points, Form Completion Procedure and Diagnosis of Culvert Works 6) Safety management during inspections
4	Field practice (culverts, road signs, lighting lights) (3h)	Hokuriku Branch of Kenkon NCE Corporation Toshio Kusakabe	1) Inspection practice at the culvert near the Yugawa IC, National Route 7 Shinzuni Bypass 2) Inspection practice of lighting and large sign at Dao Xingno IC, National Highway No.7 Shinzou Bypass
5	Special lecture on the future of road administration (1h)	Director General, Niigata National Highway Office, Hokuriku Regional Development Bureau, MLIT Jun Kondo	1) “Commentary on “The Last Warning: Turn to Maintenance Now! 2) The history of Bandai Bridge and the people involved 3) Restoration of roads for daily life (wise use of roads)
6	Current Status of Road Structures in Hokuriku Region (0.5h)	Technical Information Manager, Hokuriku Technical Office, Hokuriku Regional Development Bureau, MLIT Shinji Ohya	1) Changes in the number of local government engineers 2) Status of structures managed by the Hokuriku Regional Development Bureau 3) Current Status of Structures Managed by Niigata Prefecture 4) Status of Bridge Inspection by Manager
7	Introduction to Maintenance and Inspection of Tunnels (1.5h)	Hokuriku Branch of Kenkon Construction Engineering Center Co. Tsutomu Matsumura	1) Objectives of Tunnel Maintenance and Management 2) Characteristics of Tunnels in Niigata Prefecture 3) Inspection Guidelines (Scope, Items, Types of Deformation) 4) Introduction of measures, countermeasure methods and repair examples 5) Inspection points (types, procedures, characteristics of construction methods) 6) Characteristics, geology, and inspection history of the Agawa Tunnel
8	Field Training (Tunnel) National Highway No. 49 Old Agegawa Tunnel (3h)	Hokuriku Branch of Kenkon Construction Engineering Center Co. Tsutomu Matsumura	1) Inspection Practice at Yangchuan Tunnel 2) Filling out the inspection form 3) Confirmation of cold joint striking sound 4) Marking cracks

No	Title of Lecture (Hours)	Lecturer	Content of Lecture
9	What is a Concrete Bridge (1h)	Japan Prestressed Concrete Contractors Association Kawada Construction Co. Hidekatsu Yanagihara	1) What is a concrete structure (RC/PC)? 2) Applicable spans for each bridge type 3) History of Concrete Bridges 4) Changes in PC Technology 5) Role of the PC Construction Association
10	Maintenance and Management of Concrete Structures (2h)	Tokyo University Institute of Advanced Industrial Science and Technology Special Professor Taishi Tanaka	1) Types and history of concrete structures 2) Deterioration Mechanisms (Phenomena) and Deformation 3) Maintenance and management methods for deteriorated bridges 4) Tohoku Regional Development Bureau's Efforts for High Durability Concrete
11	What is a Steel Bridge (1h)	Japan Bridge Construction Association Hitachi Zosen Corporation Yushi Mishima	1) History of Steel Bridges 2) Classification and Type of Steel Bridge 3) Basic Structure 4) Design, Fabrication, and Installation Flow
12	Maintenance and Management of Steel Structures (2h)	Nagaoka University of Technology Associate Professor Tsuyoshi Miyashita	1) Types of damage to steel bridges and repair methods 2) Mechanisms and examples of damage (corrosion, fatigue, deformation, loosening, falling off) 3) Methods for evaluating the soundness of damaged members (corrosion and fatigue) 4) Repair and reinforcement methods and examples
13	Introduction to bridge inspection (1h)	Technical Information Manager, Hokuriku Technical Office, Hokuriku Regional Development Bureau, MLIT Shinji Ohya	1) Flow and contents of daily inspections 2) What is bridge inspection (legal basis for inspection guidelines, etc.)? 3) Inspection points for steel bridges 4) Inspection points and focus points for concrete bridges 5) Damage trends and points to note 6) Record format
14	How to fill out an inspection report (steel bridge), explanation of nondestructive testing techniques (1 h)	Hokuriku Branch of Kenkon Development Engineering Consultant Naoki Terada	1) Inspection Record Form 2) Notes on filling out the form 3) How to sketch and photograph the damage 4) Explanation of non-destructive testing methods by Mr. Okura, Diagnostic Technology Co.
15	On-site training Racecourse IC bridge (5h)	Hokuriku Branch of Kenkon Development Engineering Consultant Naoki Terada	1) Practical training of nondestructive testing (ultrasonic testing, magnetic powder testing) 2) Inspection using bridge inspection report (cracks in substructure, ASR, deterioration of coating on main girder, damage to floor slab)
16	On-site training Eastern trunk drainage channel bridge	Technical Information Manager, Hokuriku Technical Office, Hokuriku Regional Development Bureau, MLIT Shinji Ohya	1) Practical training of non-destructive inspection (rebar exploration, strength check by Schmidt hammer) 2) Inspections using bridge inspection report (cracks in substructure, ASR, deterioration of coating on main girder, cracks in floor slab)
17	Compilation of inspection results and group discussion	Hokuriku Branch of Kenkon Development Engineering	1) Compilation of inspection results in a form 2) Presentation of the results by the

No	Title of Lecture (Hours)	Lecturer	Content of Lecture
	(2h)	Consultant Naoki Terada Hokuriku Regional Technical Office, Chief Technical Information Management Officer Shinji Oya	representative 3) Critique by lecturer
18	Preparation of inspection report by iPad (1h)	Nagaoka National College of Technology Associate Professor Yasushi Ibayashi	1) Overview and operation of the inspection system using iPad
19	On-site training Sakuragi IC Bridge (5h)	Hokuriku Branch of Kenkon KAIHATSU GIKEN Co. Osamu Kondo	1) Inspection practice using bridge inspection report using elevated work vehicle (cracks in substructure, ASR, spalling condition of main girder ends, corrosion of shoes, etc.)
20	On-site training Shirane 36 ditch bridge (5h)	Nagaoka National College of Technology Associate Professor Yasushi Ibayashi Director for Technical Information Management, Hokuriku Regional Technical Office Shinji Oya	1) Practical training on bridge inspection system using iPad developed by Dr. Ibayashi 2) Inspection practice (cracks and leaks in the substructure, cracks in the main girder, road surface cavities)
21	Compilation of inspection results (2h)	Hokuriku Branch of Kenkon KAIHATSU GIKEN Co. Osamu Kondo Nagaoka National College of Technology Associate Professor Yasushi Ibayashi Hokuriku Technical Office, Chief Technical Information Manager Shinji Oya	1) Compilation of inspection results in a form 2) Presentation of the results by the representative 3) Critique by lecturer
22	Points to keep in mind for inspection and diagnosis (1h)	Hokuriku Branch of Kenkon Dainippon Consultant Co. Makoto Konya	1) Flow of Inspections and Diagnosis 2) Points of focus for diagnosis 3) Points of concern and examples of diagnosis (steel bridges, concrete bridges, substructures, and appurtenances) 4) Precautions for diagnosis
23	Maintenance and Management of Bridges by AM (2h)	I.S.S. Corporation Akira Maruyama	1) What is AM? 2) Transition of AM 3) Life extension and repair plan for bridges the future direction of AM
24	Repair and reinforcement methods for bridges (2h)	Hokuriku Branch of Kenkon Tokyo Consultants Co. Toshihiko Minato	1) Repairing and Reinforcing Steel Bridges (Types of Damage, Repair Policy, Repair Method and Examples) 2) Repair and reinforcement of concrete bridges (types of damage, repair policy, repair method and examples) 3) Repair and reinforcement of substructures (types of damage, maintenance policies,

No	Title of Lecture (Hours)	Lecturer	Content of Lecture
			reinforcement methods and examples) 4) Points to keep in mind during repair and reinforcement construction and maintenance management
25	Field practice (bridge repair and reinforcement site) (3h)	Hokuriku Branch of Kenkon Tokyo Consultants Co. Toshihiko Minato	1) Field training at the Toyota Crossing Bridge managed by Niigata Prefecture 2) Checking the status of cracks 3) Checking the status of deterioration of the surface coating method and observing the removal work 4) Confirmation of the crack injection method 5) Confirmation of sedimentation of floor slabs and understanding of the construction status of the surface treatment
26	Final exam (7h)	-	1) Descriptive test one question 2) Optional test twenty questions 3) Interview test three questions

7.7.4 Nagaoka University of Technology

7.7.4.1 Research and Development of CFRP Repair of Steel Structures

In steel bridges, corrosion at the girder ends is the most generic form of corrosion, and road managers are struggling to repair it. For this reason, Nagaoka University of Technology is researching a simple repair method using carbon fiber reinforced plastic (CFRP) sheets (Figure 7.21). Based on the results of the research, the CFRP bonding method has been reflected in various repair manuals and design guidelines (Figure 7.22 and Figure 7.23), and there have been about 30 domestic construction projects by 2017.

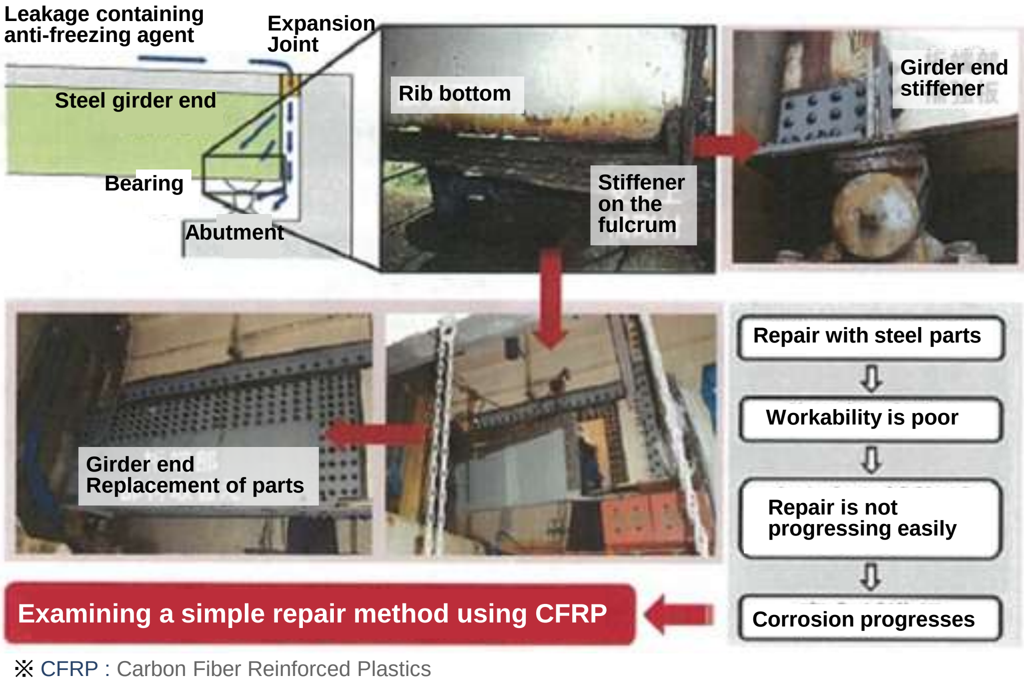

Figure 7.21 Challenges for Steel Bridge Girder End Corrosion[98]

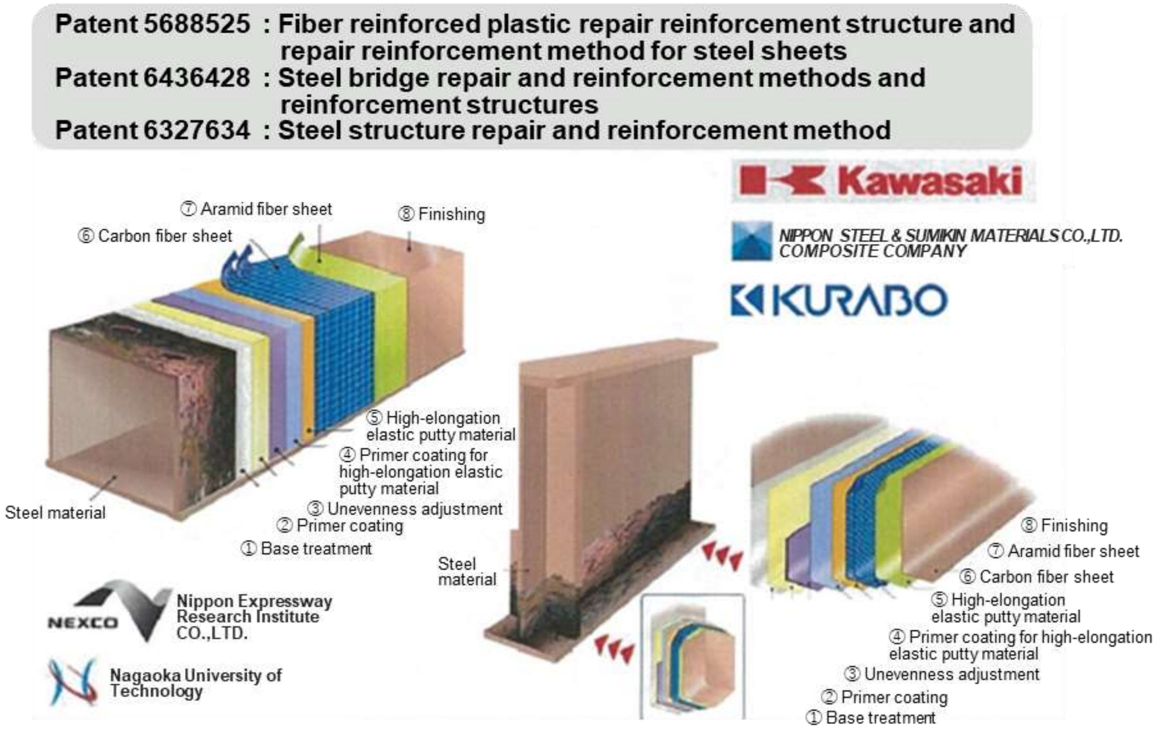

Figure 7.22 Patent Information on CFRP Repair of Steel Structures[99]

98 Nagaoka University of Technology Hearing Materials
99 Nagaoka University of Technology Hearing Materials

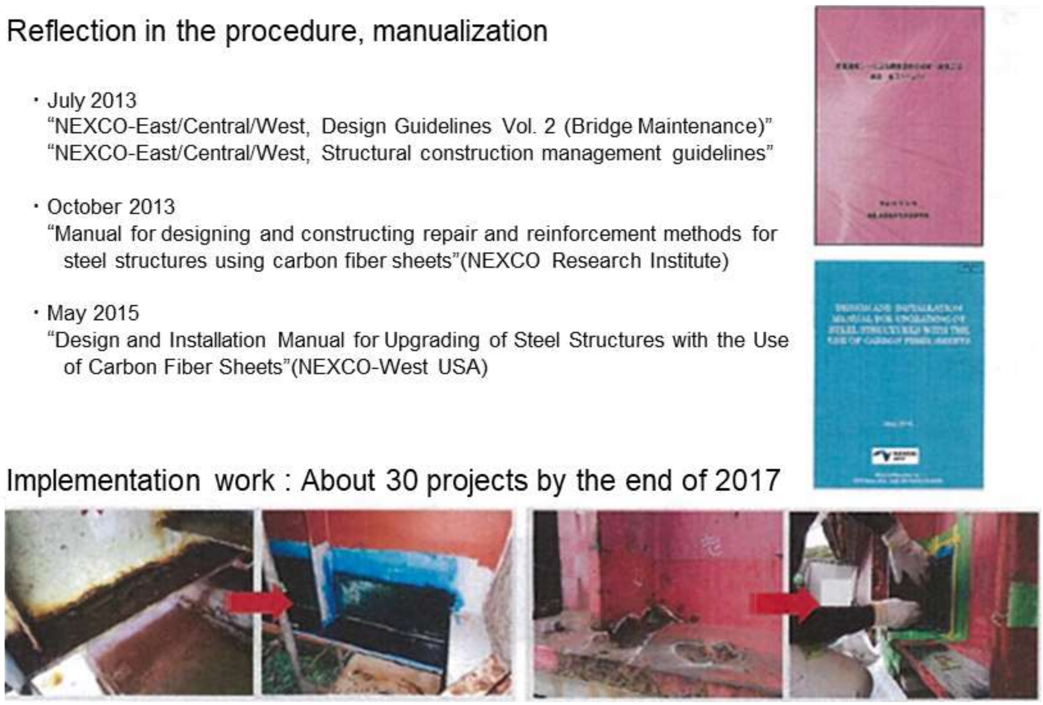

Figure 7.23 Reflection of the CFRP Repair Method in the Guidelines and Construction Examples[100]

7.7.5 Saitama University

7.7.5.1 Saitama Bridge Maintenance Study Group

In accordance with the revised Road Act enacted in September 2013, the first maintenance cycle for road structures such as bridges, in which road administrators conduct inspections, diagnosis, and recording of measures over a five-year period, ran its course at the end of 2018, and the second cycle will begin in 2019. Many local governments are struggling to cope with the shortage of staff, technical capacity, and budget. In Saitama Prefecture, which has the third largest number of municipalities in Japan, the regional support team of the Saitama Prefecture Road Maintenance Council and the Saitama Bridge Maintenance Study Group were launched at the same time in 2018 and are working to improve the efficiency of bridge inspections, diagnosis, and measures through collaboration between industry, academia, and government.

The main objectives of the Saitama Bridge Maintenance Study Group are to collect a wide range of information on the maintenance and management ("Inspection", "Diagnosis", "Repair and Reinforcement") of road bridges, which are road infrastructure facilities in Saitama Prefecture, to study and research maintenance measures and techniques, and to train bridge engineers in the prefecture to contribute to the efficiency of bridge maintenance in the prefecture.

Figure 7.24 shows the organizational chart of the Saitama Bridge Maintenance Study Group. The Saitama Bridge Maintenance Study Group was established by Saitama Prefecture, the Saitama Construction Consultant Technical Training Association, and International Institute for Resilient Society Saitama

[100] Nagaoka University of Technology Hearing Materials

University, and was later joined by Saitama City and the Omiya National Highway Office of the Kanto Regional Development Bureau. To contribute to the efficiency of bridge maintenance by studying and researching bridge maintenance policies and technologies and training bridge engineers, three working groups are operating: (1) Engineer Training, (2) Approaches to Repair and Reconstruction, and (3) Inspection Methods and Results.

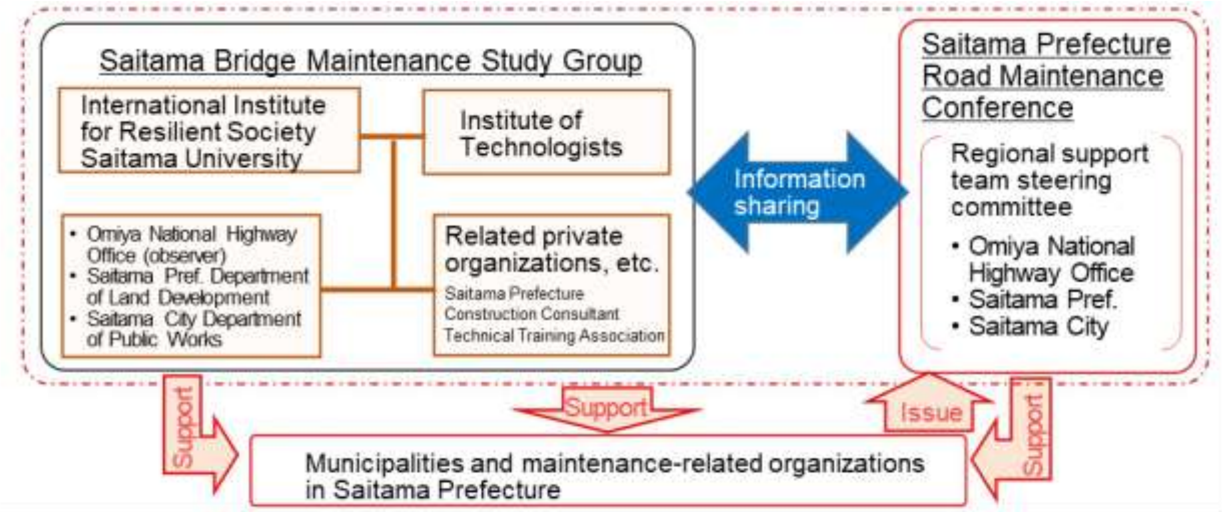

Figure 7.24 Organization Chart of Saitama Bridge Maintenance Study Group[101]

7.7.5.2 **Activities (2018-2020)**

(1) General Meeting

It deliberates on the activity policy of this study group and proposals from the Planning Institute and each working group. It meets about four times a year.

(2) Planning Committee (Secretariat: Concurrently Working with Working I)

The new implementation plan of this study group and the method of returning the results of the activities are planned and submitted to the above general meeting. The committee consists of one member from Research Organization of Saitama University, two members from Monodzukuri University, one member from Saitama Prefecture, one member from Omiya National Highway Office of MLIT, and five members from Saitama Construction Consultant Technical Training Association.

(3) Working I [Planning and Training]

The Road Act was revised in June 2013, and the inspection standards for road bridges were made statutory. In March 2014, the Ministerial Ordinance of the Ministry of Inspection stipulated that the inspections should be conducted once every five years based on close visual inspections.

While these nationwide developments have made the responsibilities of those involved in road bridges increasingly important, the current situation surrounding road bridges is becoming increasingly severe due to the need to improve the technical skills of administrative staff and to secure contracted inspections

[101] Nagaoka University of Technology Hearing Materials

contractors. In addition, the number of civil engineering staff in municipalities has been decreasing nationwide since its peak in 1996, and even today, some staff who have not majored in civil engineering are assigned to the maintenance and management of road bridges.

Against this backdrop, we decided to conduct a training course to acquire basic technical knowledge and convey the appeal of road bridges, targeting administrative staff, employees who conduct inspections, and students who will be the future leaders of the industry.

The workshop was held in a series of three sessions to train bridge maintenance engineers in a step-by-step manner, targeting local government employees in the prefecture who engage in bridge inspections, repair, and other maintenance work, as well as private-sector engineers and students interested in bridge maintenance.

■The first session will be held on Thursday, November 29, 2018, from 13:00. to 17:00.
General knowledge and maintenance of PC bridges and steel bridges (first session)
Number of participants: 53 (24 from government, sixteen from private sector, thirteen from members)

■The second session will be held on Tuesday, June 11, 2019, from 13:15 to 16:50.
General knowledge and maintenance of PC bridges and steel bridges (second session)
Number of participants: 85 (45 from government, twenty-two from private sector, eighteen from members)
Number of participants in two consecutive sessions: 17 (6 government, two private sectors, nine members)

■The third session will be held on Tuesday, November 21, 2019, from 13:15 to 16:35.
General knowledge and maintenance of PC bridges and steel bridges (third session)
Number of participants: 49 (14 from government, sixteen from private sector, forty-nine from members)
Number of participants: 7 (2 government, three private sectors, two members)

The training sessions will be held once a year as a series of three sessions to encourage continued participation and hopefully improve technical skills.

(4) Working II [Focus on Bridge Replacement]

Currently, the number of aging bridges that are 50 years old is on the increase, and systematic and preventive maintenance measures are required to ensure the safety of bridges as before under the severe financial situation. Each municipality has a large number of bridges under its management, and the degree of soundness of these bridges varies. Therefore, it is necessary to take measures according to the degree of deterioration of each bridge, but especially for bridges whose integrity has deteriorated significantly, it is estimated that huge repair costs will be required at one time and in one place.

It is estimated that bridges whose soundness has deteriorated significantly will require huge repair costs concentrated at one time. Therefore, Working II compiled a draft document, “Points to Consider in

Repairing and Replacing Existing Bridges," as a reference material for local government officials to consider specific repair methods when planning or revising the service life extension plan for bridges under their management. The document also mentions replacement as one of the methods to deal with severely damaged bridges and mentions conversion from bridge structures that require high maintenance costs to other structures when it is difficult to abolish or integrate bridges.

The "Draft Points of Focus for repair and replacement of Existing Bridges" is included in the "Saitama Bridge Maintenance Study Group Activity Report 2018-2020" and is organized as follows.

1) Study flow for bridges under management
2) List of points of focus for repair and replacement
3) Explanation of the list of points of focus for repair and replacement
4) List of reference materials

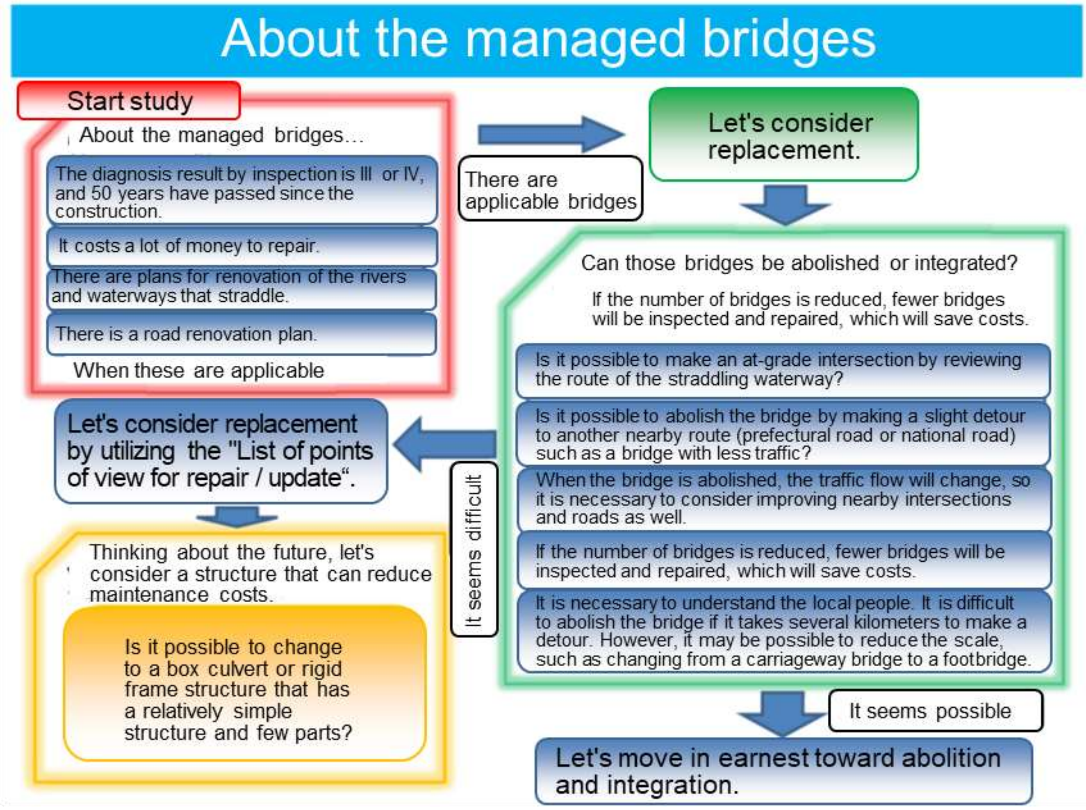

Figure 7.25 Study Flow for Bridges under Management[102]

[102] Saitama Bridge Maintenance Study Group Activity Report 2018-2020, March 2021 Saitama Bridge Maintenance Study Group

List of points to focus on repair / update (draft)						
When you look at the inspection results and the actual bridge, you may think, "It's old and there are many damaged parts, so it's better to replace it?" Or "What should I be careful about when replacing it?" If you think so, please refer to this list.						
The more applicable items there are, the better it is to replace the bridge.			Points to focus			Method
Check	Item	Point	Structure	Function	Economy	
□ 1	Is it possible to abolish the target bridge?	It does not have to be a bridge if you are not using the space under the bridge. In the case of a bypass plan, there is also the option of not making a bridge by integrating irrigation canals.	○	○	○	Administrative judgment
□ 2	Is it possible to integrate the target bridges?	Is it possible to consider traffic conversion to another bridge even if it is a slight detour?	○	○	○	
□ 3	Is it part of a road rehabilitation plan?	When attaching a sidewalk to a bridge without a sidewalk, a sidewalk bridge is often installed, but replacement can also be considered.	—	○	○	Comparison
□ 4	Comparison of life cycle costs	Compare the replacement cost with the future repair cost and budget situation and adopt the cheaper one.	—	—	○	
□ 5	Mismatch with current standards	Is the design content such as road width and slope "existing ineligible" that does not satisfy the standard values such as road structure ordinance and river planning?	—	○	—	Degree evaluation
□ 6	Is there any part that causes damage to third parties?	The overpass or the space under the girder is used as a parking lot. Expensive for inspection and repairs.	—	○	—	
□ 7	Is it necessary to increase the design load to meet current standards or allow heavy vehicles to pass?	Is it possible to improve load bearing performance by repair?	○	○	—	
□ 8	Improved earthquake resistance performance	Earthquake reinforcement reduces river area and increases flood risk	○	○	—	
□ 9	Has it been more than 50 years since the service started?	As a guide, if more than 50 years have passed since the start of service, it is thought that the increase in repairs and the progress of damage will accelerate.	○	—	—	
□ 10	What is the degree of damage?	If the judgment based on the inspection result is III or higher, consider replacement.	○	—	—	
□ 11	Even if earthquake reinforcement is planned, the specified strength cannot be achieved.	If the structure is not suitable for earthquake reinforcement, it may not be possible to secure the specified earthquake resistance.	○	—	—	
□ 12	Corrosion of parts due to salt damage and alkali-silica reaction	In Saitama Prefecture, the amount of flying salt is low, but corrosion due to salt damage occurs due to ant freezing agents.	○	—	—	

□ 13	Corrosion of steel parts is in progress	There are many parts that cannot be dealt with by cross-section restoration, etc.	○	—	—	
□ 14	Insufficient tension in PC parts	If there are cracks along the PC steel or cracks on the side of the end of the main girder, compare with the inspection judgment.	○	—	—	
□ 15	Displacement of piers and abutments, cracks	If there is fatal damage to the substructure, it may not be possible to deal with it by repair alone.	○	—	—	
□ 16	Concrete peeling of main girder, exposed rebar	In the main girder, which is the main member, if there is peeling or exposed rebar at the stress concentration point, it may be difficult to recover the function only by repairing.	○	—	—	

Figure 7.26 Draft List of Points to Focus on for Repair and Replacement[103]

(5) Working III [Improving the Efficiency of Bridge Inspections]

In accordance with the revision of the Enforcement Regulations of the Road Law, it was stipulated that road bridges should be inspected by close visual inspections once every five years according to a uniform standard set by the government. Under this system, the inspections of road bridges managed by Saitama Prefecture (about 2,800 bridges) is planned to proceed at a rate of about six hundred bridges/year, making one round in five years. These bridges are not only of various lengths, but also diverse in bridge types such as girder bridges, arch bridges, and suspension bridges, as well as bridges crossing railroads, roads, rivers, and valleys.

In Working III, we studied "Standardization of the Annexes to the Simplified Record", "Matching of New Inspection Technologies and Robot Inspection", and "Study on the Inspection Method of Overpasses" with the aim of promoting efficient and labor-saving bridge inspections.

■Standardization of the record form attached to the simplified version of the record form

The record forms that follow the "Periodic Inspection Guidelines for Road Bridges" (Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism) are listed in the "Reference Materials for Preparing Record Forms (Periodic Inspection Version for Road Bridges)".

■Matching of new inspection technologies and robot inspections

With the revision of the "Guidelines for Periodic Inspections of Bridges" (March 2019), inspections that used to be conducted in principle by close visual inspection are now allowed to be conducted by other methods if it is judged that the diagnosis is equivalent to that by close visual inspection. In this report, we compare the inspection photos taken by a drone with those taken by close observation as other methods.

■Examination of inspection methods for railway overpasses

It takes an extended period of consultation with the railroad company from the inspection

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plan to the implementation of the bridge. In addition, the rules for applying the notification of work in proximity are complicated, so we organized this report including a comparison of inspection methods for the bridge.

Chap.8 Status of Road AM Initiatives Outside Japan

8.1 Target of the Chapter

In the field of road maintenance and management in developing countries, the WB and ADB also support Road AM. In order to collaborate with other organizations and implement effective support, it is important to understand the concept of Road AM not only in Japan but also throughout the world. It is believed that stakeholders in developing countries also have knowledge of Road AM in developed countries through information on the Web.

In this work, the United States was used as a case study of Road AM in developed countries.
In the U.S., roads were being built about 30 years earlier than in Japan and are aging. The government is forced to deal with limited financial resources and is serious about promoting Road AM. Although the start of Road AM initiatives was slightly later than in the UK and Australia, the federal government is actively promoting Road AM measures through its own initiatives, incorporating trends and best practices from other countries. The U.S. also has a high level of information disclosure, and plenty of useful information is available on the Web.

Road AM is deeply tied to the policies of the country concerned. For this reason, we also focused on the legal system for Road AM in the United States. The background of each country and what they are trying to pursue will also affect the direction of Road AM. Road AM is considered to be a tool used by each country to achieve its national objectives rather than a universal scheme.The survey was conducted through a web-based literature review. The Federal Highway Administration (hereinafter referred to as the FHWA) and state departments of transportation have published many AM documents on the web, and we have extracted and summarized some of these documents that are useful for Road AM in developing countries.

8.2 Overview

The U.S. federal government enacts the Surface Transportation Authorization Act every five to six years, which clearly states that it will keep highways in a state of good repair, and is actively engaged in AM. Rather than repairing the deteriorated parts in order, extention of the service life of structures are examined by adopting measures appropriate to the state of damage and considering life cycle costs with preventive maintenance in mind. The condition of the structures is inspected and evaluated every one to two years for pavement, and every two years for bridges; the data is then analyzed. Minimum pavement and bridge management standards are set at the federal level, and management standards are added to those at the state level.

With regard to pavement, the required level of performance has traditionally been ensured by repeated periodic cutting overlays, but in recent years preventive maintenance such as chip seal work has been implemented at an early stage to reduce the frequency of overlay work.Also, for bridges, efforts are being made to reduce lifecycle costs, for example, by implementing preventive maintenance such as cleaning of slabs and girder ends, slab sealing and crack injections, instead of the conventional method of repeated slab repair and reconstruction, which allows for postponing the implementation of large-scale reconstruction work.

8.3 About Road AM in the U.S.

8.3.1 Definition of Road AM in the United States

The FHWA defines AM as follows.
"A strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost."

8.3.2 Challenges of Road AM[104]

The "worst-first" approach, which focuses on renewing bridges starting with those that have deteriorated, will result in high long-term costs. Therefore, it is important to strike a balance between preventive maintenance and reinforcement/reconstruction, and also to implement maintenance management through a strategy that takes preventive maintenance into account.

The basic idea of AM is very simple: "If appropriate measures are taken at the right time, the overall lifecycle cost will be reduced, but if damage or deterioration is left untreated, it will cost much more to repair". However, the following issues have made this simple concept increasingly complicated.

1) The number of assets managed by road agencies is expansive and diverse, with different ages and different levels of damage, and therefore different ways of dealing with them.
2) If repairs are to be carried out at the right time, it is necessary to constantly update the asset data base and damage status in order to accurately grasp the road asset condition.
3) It takes several years from planning to implementation of repair work. It is necessary to consider this issue well in advance so that it is not too late.
4) Since financial resources are not always sufficient, there is no choice but to focus on the most severely damaged areas. As a result, damage to unaddressed areas will proceed.
5) Lack of proper funding due to lack of understanding of AM by state legislatures and relevant committees.

8.3.3 Features of Road AM

The characteristics of Road AM in the U.S. are shown below.

1) Although the U.S. is a latecomer in Road AM, it is taking into account the best practices of other countries in its development.
2) The specific funds for road infrastructure (mainly funded by the federal fuel tax) are already in deficit, and the shortfall is being made up from general funds to specific funds. With a limited budget, the government is actively promoting Road AM in an effort to efficiently maintain and manage the aging

[104] MnDOT [2017], Asset management gap assessment

road infrastructure.

3) Numerical targets for Road AM have been set at the federal and state levels and are being managed to achieve with achievement in mind.
4) Focusing on life cycle costs and adopting a management approach that emphasizes preventive maintenance.
5) International organizations such as the WB and ADB are also likely to refer to the US Road AM movement. Information disclosure is also progressing, and it is likely that engineers in developing countries are also looking at the relevant websites.

8.3.4 Organization for Road AM

(1) AASHTO- American Association of State Highway and Transportation Officials

AASHTO is a non-profit, non-partisan organization representing the U.S. highway and transit sectors and all modes of transportation, including aviation, highways, public transit and rail. The main objective is to promote the development, operation, and maintenance of an integrated transportation system. AASHTO also serves as a liaison between the State Department of Transportation (hereinafter referred to as State-DOT) and the Federal Department of Transportation (hereinafter referred to as US-DOT). It is also the body that sets the technical standards for all phases of highways, and technical standards are set in many technical areas, including design, construction, and materials.

(2) FHWA- Federal Highway Administration

The FHWA is an agency within the US-DOT that assists state and local governments in the design, construction, and maintenance of highways. Through financial and technical assistance to state and local governments, the FHWA is responsible for making America's roads and highways the safest and most technologically sound in the world.

8.3.5 Legal System for Road AM

8.3.5.1 About the Surface Transportation Act[105]

In the U.S., the federal government has developed a Surface Transportation Act for land transportation, including roads, public transportation, and railroads, for a period of approximately five to six years. This will determine what the federal government will spend on projects, as well as budget caps and funding sources. The actual projects are implemented by the states, but since a significant portion of the financial resources depends on federal aid, the authorization law has a significant impact on the implementation of the projects.

MAP21 Century Act, an authorizing law approved by then President Obama in 2012 secured about 12 trillion yen ($105 billion) for the budget of 2013 to 2014. The promotion of Road AM was also a major focus, and MAP21 was a landmark initiative that transformed the federal government's road policy

[105] Express Highway Research Foundation of Japan [2018], New Edition of Western Highway Policy, https://www.express-highway.or.jp/info/document/201806.pdf

regarding Road AM.

Subsequently, the Fixing America's Surface Transportation Act (hereinafter referred to as FAST) was approved in 2015 to take over the measures of MAP21, authorizing a total of 34 trillion yen ($305 billion) in spending over five years through 2019. With the passage of FAST, state departments of transportation were assured of receiving federal funding in the medium term for the implementation of infrastructure projects. Although though FAST was set to last until 2019, it is still in the process of being extended until the next new authorization law is passed.

8.3.5.2 Road AM in the Surface Transportation Act

(1) Performance-based Policy Promotion

MAP21 and FAST called for numerical clarification of targets, increased accountability and transparency, and better decision-making for project promotion. Achievement targets have also been set for highways so that the results of implementing the necessary projects can be quantified. The overall goals for federal surface transportation are presented first, with the goals related to Road AM listed second.

1) Significantly reduce traffic fatalities and injuries on all roads.
2) Keep highways in a state of good repair.
3) Significantly reduce traffic congestion on highways.
4) Improve the efficiency of land transportation.
5) Improve the freight transportation network and contribute to the economic development of the region.
6) Environmental protection.
7) Decrease in project implementation delays.

Specific numerical targets are specified in the Code of Federal Regulation, which states that poor pavement conditions on highways should be reduced to 5% or less, and bridges to 10% or less.

(2) Promotion of Preventive Maintenance

MAP21 and FAST emphasize the important role of preventive maintenance in keeping roads in good condition. Traditionally, federal funding has focused on rehabilitation and reconstruction projects, but in recent years, subsidies have also been provided in the area of preventive maintenance, and the entire country is working on preventive maintenance.

The FHWA has established performance indicators in pavement and bridges, and states are to report on their progress. States that fail to meet performance targets for pavement and bridges will submit a report to the FHWA describing their improvement plans. The Ministry of Transportation also requires each state government to formulate a Transportation AM plan. The plan will promote road improvement and preservation, focusing on pavement and bridges for the time being, and it will be reviewed every four years. The following is a list of items that are required to be included in the AM plan.

1) Asset summary and condition of road pavement and bridges
2) Objectives and indicators of AM.
3) Performance gaps.
4) Life cycle cost management and risk management.
5) Financial plans.

6) Investment plans.

The following information is provided in the federal regulations for the preparation of the above AM plan.

1) State-DOTs will develop AM plans to achieve national highway performance measures at the lowest cost over the entire life cycle of state controlled assets.
2) State-DOTs will implement life cycle planning at the network level, build deterioration models, and develop strategies to minimize life cycle costs.
3) State-DOTs will establish risk management and consider the risks of damage and increased costs due to extreme weather, climate change, earthquakes, etc.
4) State-DOTs will develop a financial plan for a minimum of 10 years. Costs in the financial plan will be calculated based on the AM plan. The amount of funds to be raised shall be feasible and shall be set after considering past performance.
5) State-DOT will analyze the current pavement and bridge conditions using PMS and BMS from the available data, predict future damage conditions, and then prepare an appropriate AM plan.

8.4 Life Cycle Planning in the United States(Life Cycle Planning)

8.4.1 The Three Decision-Making Levels of AM

There are three decision-making levels in AM plans for pavement and bridges.
They are Strategy (Level 1), Network (Level 2), and Project (Level 3).

(1) Level 1: Strategy

A long-term strategy for AM will be developed and explained to management as well as to external organizations. Clarify goals regarding asset condition, formulate strategies such as how much emphasis to place on preventive maintenance to achieve the goals, determine how to allocate funds among each asset and how much to raise in the future.

(2) Level 2: Network

Develop a network-level maintenance plan for pavement and bridge management. Using the current state of network conditions as a starting point, develop a plan to achieve the goalusing a management system such as PMS or BMS. Formulate multiple strategies such as “conventional approach”, “combination of preventive maintenance and reconstruction” and “preventive maintenance oriented planning”, as well as planning under various budget constraints. At this time, Level 1 strategies will be also reviewed as necessary. It determines which sections should be maintained, repaired, improved, and renewed, when and to what extent, and in what manner.

(3) Level 3: Project

After the implementation of maintenance and repair is decided at the network level, design and construction order preparation are carried out at the project level for implementation.
The design of repair methods and materials will be discussed, and detailed field surveys will be conducted as necessary. In addition, LCCA (Life Cycle Cost Analysis) will be used to select an appropriate repair

method, taking into account the user benefits.

8.4.2 The LCP Process

Life Cycle Planning (hereinafter referred to as LCP) is at the heart of AM, and it develops ways to minimize life cycle costs while achieving asset condition goals. LCP is mainly focused on network-level analysis. Therefore, it will be included in the scope of strategy (Level 1) and network (Level 2) shown above. Level 3 project phase planning is necessary to determine the specific repair details after the scope and timing of the project have been determined by the LCP.

(1) Selecting Target Assets and Setting up the Framework

First decide which routes and assets will be analyzed. The FHWA directs each State-DOT to cover at least pavement and bridges. Also, the state government decides whether only national highways or other roads are to be included. In addition, consider analyzing concrete bridges and steel bridges separately (for pavement: asphalt and concrete).

(2) Formulate LCP Strategy

Next, the LCP strategy for AM of bridges in the network shall be examined. The LCP strategy is a policy setting that determines the extent to which preventive maintenance is incorporated compared to conventional strategies. For example, the conventional strategy is to perform minimal maintenance and make major repairs at the “Poor Stage” when structural defects occur. Preventive maintenance (moderate) is a balance between preventive maintenance and major repairs, while preventive maintenance (aggressive) is set to focus solely preventive maintenance.

In order to calculate the degree of future soundness that can be secured by each LCP strategy, it is necessary to set the rules for selecting repair methods, prediction of damage deterioration, repair unit price, improvement effect by repair, and repair interval. As for the interval of repair, it is easier to set the interval of repair if there is historical data of past repairs. If there is no historical data, experts can be asked or standard repair interval can be set tentatively.

For the three strategies set above, the future deteriotaion level is projected, for example, based on the current budget level. While the Current Strategy and Moderate Preservation improve the situation in the short term, the medium- to long-term condition of the assets will still decline. On the other hand, in the case of Aggressive Preservation, the recovery of the condition would be slow in the short term, but in the medium to long term, the condition will improve.

(3) Creating LCP Scenario

Next, create a scenario for LCP based on the three strategies described above while considering any future budget constraints. Enable the organization to make decisions about which scenarios to plan for. If budget constraints are expected to be severe, organizational goals will need to be dropped, and the goals themselves may need to be revised.

8.5 About Pavement AM in the United States

8.5.1 Setting Management Levels

8.5.1.1 Federal Management Indicators/Levels of Control

With the passage of the FAST Act, state governments are required to report road conditions to the FHWA annually. The management indices of the road are obtained from the three indices of IRI, cracks and rutting per 160 m section (0.1 mile). The lowest condition of the three measured indices is considered to be the pavement condition of the section.

8.5.1.2 State-Level Management Indicators/Levels of Maintenace

At the state level, a variety of management indicators are used. The base layer, road-bed condition, and structural bearing capacity are also useful data, but they are also costly to collect. They are measured as needed, except for the surface layer.

The Pavement Condition Index (hereinafter referred to as PCI), is an index developed by the U.S. Army Corps of Engineers that converts damage conditions such as cracks and pot holes into a numerical value from 0 to 100 for each section. 0 is the worst state and 100 is the best state.

(1) Colorado

The State of Colorado has introduced a Durability Life (hereinafter referred to as DL) index of how long the pavement in the section can remain in an acceptable driving condition. DL is calculated based on the smoothness and safety of the road surface, with smoothness being calculated usingg IRI and safety being calculated by assessing cracks and ruts.

The pavement management level is controlled by the index according to the above DL, and the selection of countermeasure works is also determined by considering the DL. Since the state management standards are more stringent, it is assumed that if the state management standards are met, the federal standards will also be met.

(2) Oregon State

In Oregon, the Condition Score is set for (1) rutting, (2) cracking, (3) longitudinal and transverse cracking, (4) patching, and (5) labeling (loss of pavement surface compound) of the pavement on a scale of 0 to 100, taking into account the degree of damage and the extent of damage in a 160-meter section. The overall management index is set. In this case, flatness indices such as IRI are not considered in the Condition Score because the appearance time of deterioration is later than that of pavement structure indices such as cracks. The selection of repair methods and the timing of implementation can be adequately addressed by determining factors other than IRI.

The state of Oregon has set a goal of 85% of its road assets having a Condition Score of 46 or higher (fair, good, very good) as a management indicator. In addition, Oregon's own management goal is to increase the percentage of assests that score higher than 46 (fair, good, very good) to 85%.

8.5.2 Data Collection

The measurement of road surface properties used to be carried out directly by road administrators, but in recent years, the use of measuring vehicles has been increasingly outsourced to the private sector. The data obtained is to be checked for compliance with the quality control standards set forth by the federal government (23 CFR Part 490.319(C)).

In the case of outsourcing to the private sector, the company's experience and measurement methods are also taken into account as evaluation points. It can be seen that in addition to price, the selection process is primarily based on experience and research methods.

8.5.2.1 Examples of Selection of Countermeasure Workers

(1) Utah State

In Utah State, where the pavement index PCI is between 70 and 100 and the pavement is relatively good, sealing work is to be installed as preventive maintenance. Low sealing (chip seal work, etc.) is used for low traffic sections with a daily traffic volume of 7,000 vehicles or less, medium sealing (micro-surface work, etc.) is used for sections with a daily traffic volume of 7,000 to 15,000 vehicles, and high sealing (thin overlay, etc.) is used for sections with a daily traffic volume of 15,000 vehicles or more. In addition, the cutting overlay and thin overlay are set to be applied to areas with relatively poor pavement conditions with a PCI between 50 and 70.

(2) Ohio State

The conventional approach in Ohio State has been to perform cutting overlay works on a regular basis, but it became apparent that the pavement condition would deteriorate in the long term when future budgetary conditions were taken into consideration. For this reason, chip sealing and other works are to be carried out at an early stage on low traffic volume routes. Forty-eight percent of the national roads can be chip-sealed, and calculations show that a reduction of 75 mUSD/year is possible if chip-sealing is applied to 50% of the routes.

(3) Washington State

In Washington State, the life cycle cost of repeated overlays was found to be 2.5 times that of employing chip sealers. Therefore, in principle, chip sealing is adopted for routes with a daily traffic volume of 10,000 vehicles or less. Areas that were previously replaced with asphalt pavement are now being converted to chip-sealed construction, which the State-DOT calls “chip seal conversion”. Between 2010 and 2017, 2,500 miles of roads underwent chip seal conversions, with chip seal extensions increasing from 25% to 36.7% in 2017. Another 700 miles of conversions are planned by 2025.

8.5.3 Pavement Preservation Methods[106] [107]

(1) Crack Sealing Work（Crack Seal）

Crack sealing involves injecting an asphalt-based sealant into the cracks, using a material that has the viscosity to follow the fluctuations in crack width. This method prevents rainwater from seeping through cracks and eroding the base layer and roadbed. The function retention period after installation is 2-4 years, and the construction cost is 250 yen per lane meter (conversion rate is 1 USD = 110 yen).

(2) Chip Sealing Work

Chip sealing is also called Bituminous Surface Treatment (BST) and is used to increase slip resistance, correct bumps and bleeding, and seal pavement surfaces. Immediately after emulsion application, chips are applied and then rolled with a tire roller. In order to protect the aggregate from being scattered by passing vehicles, the fog seal work described below is often carried out after the chip sealing is finished. In Minnesota, it is standard practice to implement these works at locations with a daily traffic volume of 10,000 vehicles or less, and it is expected to be effective for 5-7 years. Construction costs are about 890 yen/lane meter and 250 yen/m2.

(3) Micro Surface

Micro-surfacing is a thin layer of asphalt emulsion, filler, and fine aggregate, which does not improve the pavement function but can deal with surface damage such as small cracks, small bumps, and rainwater infiltration. In addition, when doing micro-surfacing it is necessary to clean the area beforehand and remove the demarcation lines. It is used in conjunction with the chip sealing work described above, and in Minnesota, it is expected to be implemented in areas with a daily traffic volume of 10,000 vehicles or more. It is expected to be effective for 5-7 years, and the construction cost is 1,300-1,700 yen per lane meter, or 360-460 yen per square meter.

(4) Thin Overlay

This overlay of about 1.3cm to 4cm thickness added to the existing pavement, and can be applied when the pavement damage is minor and there is no structural strength problem and no need for drastic repair. Since the pavement thickness is thin, it can be constructed at low cost. The construction cost is about 760-1,200 yen/m2 for 4cm thickness (including cutting of 3mm). This method can be expected to last for 8-10 years.

(5) Fog Seal Work

Fog sealing is a simple method of spraying emulsified asphalt, which is installed over asphalt pavement shoulders, parking lots, and chip sealing works. It is not related to pavement strength, but can be used for labeling, rainwater infiltration, and small cracks. Construction costs are 60-290 yen/lane meter and 20-100 yen/m2This method can be expected to last for 2-4 years.

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106 Road Conservation Technology Center [2010], Asphalt Pavement Maintenance Technology
107 Minnesota DOT [2019], MnDOT Pavement Preservation Manual

8.6 AM of Bridges in the US

8.6.1 Management Indicators/Management Levels

The federal government has set standards to keep the state of “Poor” highways below 10%.

(1) Colorado State

Colorado's management indicators are the same as those of the federal government, but the management level also sets a target value for Good, and the target value for Poor is stricter than the federal government standard.

(2) Minnesota State

Minnesota's management indicators are subdivided from the federal indicators and each indicator has its own management level.

(3) Wisconsin State

In addition to the evaluation values in the NBIS, the State of Wisconsin also considers the values from the bridge element inspections described below, and adds evaluation criteria for joints, steel bridge coatings, and bearings.

Wisconsin State focuses on slabs, joints, steel bridge coatings, and bearings with the folliwing criteria.

(Slab) Experience has shown that slabs are designed to last 75 years and can last 40 to 50 years without maintenance. With proper maintenance, the life span can be extended by 30-40 years. It has been found that if slab seals are applied every four years when the slab is sound, the service life is extended by 10 to 12 years.

(Joint) Leakage from the joint causes severe damage to the girder, bearing and substructure.

Empirically, proper maintenance of joints has been shown to extend the aging of the upper and lower structures by 8 to 12 years.

(Steel Bridge Painting) In general, steel bridge coatings have a life span of 25 to 40 years. Appropriate repainting and coating can extend the life of steel bridges to 100 years.

(Bearing) Experience has shown that lack of bearing smoothness, tilting, and corrosion can adversely affect the slab and superstructure. Maintaining the bearings in proper condition will extend the life of the bridge.

8.6.2 Data Collection

Data is collected every two years during periodic inspections for each slab, superstructure, substructure, and C-box according to the federal government's National Bridge Inspection Standard (NBIS). The purpose of periodic inspections is to obtain information to be entered in the bridge data base in order to determine the necessity of maintenance and repair, and to understand the properties and functions of the components of the bridge over time. The inspection results are rated on a 10-point scale.

Due in part to the 2007 Mississippi bridge collapse of a steel truss bridge, apart from the NBIS evaluation mentioned above, AASHTO developed a bridge element inspection manual in 2013, and in 2014, the

FHWA established a framework for element-specific inspections and reporting of inspection results. The bridge element evaluation divides the bridge into several components and evaluates each component.

8.6.3 Planning Countermeasures

(1) Minnesota State

In the State of Minnesota, daily maintenance work is considered to be sufficient for about 20 to 30 years after the construction of a new bridge. Major Preservation may be required afterwards.
If the project cost exceeds 30% of the new construction cost, repairs should be carried out, and if it exceeds 70%, replacement should be carried out.

(2) Ohio State

Ohio State is planning to emphasize preventive maintenance for bridges as well, changing from the conventional method of repeatedly renewing slabs every 50 years or so to a plan to postpone major repairs by repeatedly taking preventive maintenance measures such as cleaning and sealing floor slabs.

8.7 Results of Discussion with the WB

A web conference was held on Wednesday, December 9, 2020 from 16:00 to 17:20 with the following attendees.

●Attendee
The WB (Transport Global Unit, Infrastructure Practice Group)
Mr. Binyam Reja, Ms. Jen Jung Eun Oh
The University of Tokyo Associate Professor
Mr. Nagai
Gifu University Associate Professor
Mr. Kinoshita
Civil Engineering Society Researcher
Mr. Nobuta
JICA Mr. Kanenawa, Mr. Yoshioka,Mr.Wachi
JEXWAY Mr. Okamoto, Mr. Kasamatsu, and others

After presenting their activities, the participants exchanged opinions. The following is a summary of the WB activities and the opinions exchanged. In addition, presentation materials on the activities will be attached as reference materials.

【The WB】

- ✓ The purpose of our organization is to obtain advanced technologies and knowledge related to mobility and connectivity and provide them to developing countries in the best possible way.
- ✓ The WB has conducted a number of capacity building activities in the past and has provided training to government employees. However, it has become clear that this is not always a sustainable approach, as trained staff often change jobs. For this reason, I believe it is important to conduct capacity building

not of individuals but of the organizations themselves, such as road agencies. It is also important to enlist the help of universities and other institutions. In this regard, JICA's Zambia project is a very good example. It is also necessary to support training centers and other organizations that can educate a large number of engineers. Programs on how to support them could be discussed jointly with JICA.

- ✓ Numerous studies and analyses have been conducted in the WB, and a huge amount of data has been accumulated, but it is not always systematically organized, and the data is not immediately accessible for those who wish to access it. It is necessary to compile the information and create a portal site. Perhaps collaboration with JICA is possible in this field as well.
- ✓ We plan to accumulate and organize knowledge on e-mobility and decarbonization of the transportation sector as our core research. We are also considering forming partnerships with universities and research institutes that are conducting those studies. There is a plan to work with the regional departments as well.
- ✓ In terms of knowledge dissemination, we plan to publish various reports and organize workshops and webinars. In particular, we would like to have more reports and publications. The goal is to push the WB to a position where it can lead the dissemenation of advanced technology in the transportation sector and raise it to a position where we can discuss new directions. This will allow the public at large, not just a few experts, to have access to information about the sector.
- ✓ Support for regional and country programs is also part of the mission. We want to provide technical assistance to individual projects and improve the quality of their programs.
- ✓ Partnerships with external organizations are important. We have signed MOUs with IRF, PIARC, and various universities. We need to be responsible for the WB's partnerships with external organizations, and we think we can assist JICA in forming partnerships with other organizations.
- ✓ An inter-donor fund has been established and many donors are considering providing funds to the WB and other institutions to advance their research. Themes include decarbonizing the transportation sector, improving air quality, inclusive mobility, disaster recovery and urban resilience, safe transportation systems, and transformative technologies in mobility and logistics. If the Japanese government or JICA is interested, we would be happy to provide further details.
- ✓ We think the project in Zambia and the acceptance of long-term trainees is a very good initiative.
- ✓ We would like to know in which fields and regions capacity building could be implemented collaboratively. We have a lot of projects in progress. It could also help fund the establishment of something like a knowledge center in many countries. Also, if there are any regions or countries that JICA is targeting, please let us know. In the presentation, Africa and Southeast Asia were mentioned, but is there a target region?
- ✓ We would like to thank you for setting up this opportunity today. Thanks for the great presentations. We would like to continue to exchange opinions with JICA.

【JICA】

- ✓ The WB has been conducting seminars for external stakeholders from the perspective of disseminating knowledge, and the Japanese side is also making similar efforts. For example, a webinar on Road AM is being conducted in September by the Japan Society of Civil Engineers with a focus on Myanmar. Five Japanese university professors spoke at the webinar, and we have received great support from the university community in Japan. We believe we can collaborate with the WB.

- ✓ Currently, the technical cooperation projects are being implemented mainly in Southeast Asia, East Asia and Africa. However, our target is developing countries all over the world, including countries such as Mongolia and Tajikistan in Central Asia.
- ✓ Today's meeting was a very valuable opportunity to exchange information with the WB. We also would like to continue to exchange information. For example, how about having another meeting in six months? We will also be able to inform you about the status of the project in Zambia.

【Associate Professor Nagai, The University of Tokyo】

- ✓ A webinar was held by the Japan Society of Civil Engineers (JSCE) for engineers in Myanmar, but engineers from 12 countries other than Myanmar also watched the webinar. We gave a presentation on Road AM from both technical and management perspectives. We would like to expand this kind of initiative to other countries in the future.

【Associate Professor Kinoshita, Gifu University】

- ✓ Since JICA is conducting a technical cooperation project on bridge maintenance in Zambia, we are working in Zambia with a focus on bridges. However, the maintenance experts at Gifu University are targeting all infrastructure structures. We are also looking at AM for roads in general, not just bridges.
- ✓ Many young researchers in Japan are interested in Africa. This is because the Asian countries have already been studied by veteran researchers and there is no room for new ones to come up. Therefore, young and mid-career researchers want to go to Africa.

8.8 Results of Discussions with ADB

A web conference was held on September 8, 2020 (Tuesday) from 14:00 to 15:50 with the following attendees.

●Attendee

ADB (Sustainable Development and Climate Change Department)

Mr. Michael Anyala, Mr. Ritu Mishra, Mr. David Fay

ADB Consultant Mr. Cornie

JICA Mr. Kanenawa, Mr. Wachi

JEXWAY Mr.Okamoto, Mr. Kasamatsu and others

After presenting their activities, the participants exchanged opinions. A summary of the ADB's activities and the exchange of views is provided below. In addition, presentation materials related to the activities ill be attached to the reference materials section.

【ADB】

- ✓ The results of a questionnaire survey of 26 ADB member countries on the problems of Road AM revealed that the lack of financial resources for maintenance and management was the biggest problem, followed by inappropriate maintenance and overloaded vehicles.
- ✓ ADB has carried out a number of Capacity Building studies on Road AM. We have also adopted

many Performance Based Contracts. However, project-based financing for Road AM is scarce. Project-based financing allows governments to improve their road assets at the network level, and they will also lead to road safety and climate change response, which the ADB considers important.

- ✓ We are planning to provide technical assistance (TA) on a number of Road AMs in DMCs (development member countries). One of them is “Strengthening of Quality Investment”. The project has applied to the Japan for Poverty Reduction (JFPR) for $2 million.
- ✓ Within this TA, training and drills for Senior Executives are being planned. JICA seems to be focusing on training students, but we are targeting the upper anks of the organization and have already reached out to government agencies.
- ✓ In addition, the ADB's Operations Department is seeking to improve the level of technology and safety related to Road AM. In support of this, we are considering extracting and proposing innovative technologies and know-how that will enable Road AM to be properly operated hrough this TA.
- ✓ The application of digital technologies is also being considered. This is related to the new technology in Japan that was announced by JICA. We would like to learn more about Japanese technologies and adopt those that can be applied. We also want to make our infrastructure more resilient.
- ✓ JFPR has also requested that we use Japanese technology to spread the word. This is one of the objectives of today's meeting. They want to understand what JICA does and how we canimport Japanese technology from JICA.
- ✓ There are two groups of ADB member countries that are promoting Road AM. One is CAREC (Central Asia Regional Economic Cooperation Program) and the other is SASEC (South Asia Sub regional Economic Cooperation).
- ✓ As shown in the PowerPoint presentation, we are going to conduct a maturity evaluation of Road AM to identify gaps that should be emphasized in each country and areas that should be prioritized for action. While the ADB aims to form projects that will help member countries, it is also focusing on analyzing and monitoring the current situation.
- ✓ CAREC has published best practices on Road AM in 2018, and efforts are underway to incorporate good practices on Road AM from other countries and regions. In addition to this, a report on the maturity evaluation of Road AM in each country is currently being prepared.
- ✓ The main output of the maturity evaluation is the degree of activity and maturity of each item. Priorities are set according to this. We are also developing a model to enable self-evaluation and third-party evaluation of maturity. These will allow us to understand the implementation status of our Road AMs and identify issues for future support. We would like to refer to the maturity evaluation model conducted by JICA, so can you share the details?

【JICA】

- ✓ It was understood that Pakistan is in the process of implementing a TA for ADB's Road AM. We may be able to support ADB's activities through technical webinars and scholarship programs. It would also be possible to hold a joint seminar on Japanese inspection ｓ and monitoring technologies, and academic experts could be sent to Pakistan to hold joint seminars.
- ✓ In the future, we suggest holding an opinion exchange once or twice a year.

【JEXWAY】

- ✓ The results of the survey on the challenges of road maintenance and management in DMCs are very interesting. As you can see from our research report, we have identified similar problems from our research. There is room for JICA and ADB to collaborate on what measures should be implemented to address these issues.

Chap.9 Follow-up on Monitoring of Training from Past Fiscal Years

9.1 Target of the Chapter

Monitoring and other activities are implemented for the Bridge Maintenance group training conducted in past fiscal years. Medium-term monitoring involves the monitoring of factors such as the implementation status of action plans created in past training for bridge maintenance, and the status of the diffusion and spread of knowledge, technology, and the like gained from the training; the aim is to aid locally toward the further diffusion and spread of the knowledge and technology. The target countries are the Solomon Islands (short-term monitoring conducted in fiscal 2016) and Tunisia (short-term monitoring conducted in fiscal 2017). The short-term monitoring activities conducted in past fiscal years are reviewed in advance, and seminars and interviews are conducted at the organizations with which the trainees that participated in Technical Training in Japan are affiliated. Notably, this seminar is conducted with cooperation from trainees who participated in Technical Training in Japan.

9.2 Overview

Solomon Islands	Target of monitoring: Trainees who participated in bridge maintenance training in 2016 Results: Interviews of trainees on April 7, 2021 Online seminar: May 21, 2021
Tunisia	Target of monitoring: Trainees who participated in bridge maintenance training in 2016 and 2018 Results: Interviews of 2018 trainee on March 1, interviews of their superiors on March 9, interviews of 2016 trainee on April 15, 2021 Online seminar: March 30, 2021

9.3 Monitoring and Follow-up Activities

9.3.1 Monitoring Group Training

Group training is designed and planned by the Japan side and offered to developing countries. In the group training titled “Bridge Maintenance,” trainees spread the knowledge and the like they gained from the training everywhere throughout their home countries with the aim of improving their countries’ capacity for bridge maintenance. After the training, onsite monitoring is conducted in countries selected for the progress they have made on the action plans drafted by the trainees during Technical Training in Japan. Onsite monitoring conducted within one year of the completion of Technical Training in Japan is considered short-term monitoring; because the monitoring on this occasion is three years later, it is considered medium-term monitoring. Note that long-term monitoring is scheduled to be conducted 10 years after the short-term onsite monitoring.

9.3.2 Follow-up Activities of Medium-Term Monitoring

This medium-term monitoring involves the monitoring of trainees from the Solomon Islands and Tunisia—the targets of short-term on-site monitoring in fiscal 2016 and 2017, respectively, as part of the group training titled "Bridge Maintenance (2015-2017)"—for the implementation status of action plans and the status of the diffusion and spread of the knowledge, technology, and the like gained from the training with the aim of providing assistance locally toward the further diffusion and spread of the knowledge and technology. Notably, in addition to the target trainees, trainees who took part in JICA group training in the same field and belong to an organization was also interviewed as to circumstances after their return to their home countries.

The spread of COVID-19 throughout the world made it impossible to travel to these countries to conduct this medium-term monitoring; therefore, the monitoring was conducted remotely via online interviews and webinars.

9.4 Results of Monitoring in the Solomon Islands

9.4.1 Details of Past Short-Term Monitoring

9.4.1.1 Overview of Short-Term Monitoring Activities

The following is an overview of short-term monitoring activities.

- Confirm the progress on action plans, gain a full understanding of activities
- Discuss information entered bridge inventory
- Improve capacity to create proposals
- Observe Bailey bridges

9.4.1.2 Trainee Action Plans

The target trainee created three action plans during the group training. The trainee presented Action Plans A and B after returning to the Solomon Islands and received approval from their organizations; however, because Action Plan C is not yet approved, the short-term monitoring only targeted Action Plans A and B. The following is an overview of the action plans.

Table 9.1 2016 Bridge Maintenance Trainee Action Plans

Plan A

Title	Create Bridge Database/Maintenance Manual Assessment of technical structure		
Purposes	1. Improve bridge inspection system (Improve accuracy of data collected by consultant in Piloted Province) 2. Develop the technical manuals for bridge inspection & bridge maintenance 3. Develop and prepare bridge inspection & maintenance budget plan		
Expected outcomes	1. Contractor and staffs are trained 2. Survey data collected 3. Data inpui databade 4. Engineers who are responsible to formurate and create the manual have the ability, capacity building and experience 5. Produce annual budget plan for bridge inspection & maintenance works	Evaluation indices	- Number of staff and contractor trained - Quality filled forms & filled spread sheets - Quality database with correct data - Technical manuals for bridge inspection & bridge maintenance are approved and implemented - The budget plan is approved and implemented according to the annual work plan
Activities	1. Conduct workshop to review Data collection Manual for inventory and condition survey 2. Implementation of Survey in Piloted Province 3. Data input and check 4. Conduct workshop to create the manuals 5. Conduct workshop to quantify required inspection & maintenance works and estimated costs on prioritized bridges that need maintenance works	Inputs	- Cost of Trainer if outsourced, cost of required tarining manual and equipment, cost of training venue hire - Cost of outsourced contract, cost of equipment & manuals - Cost of required training manual & equipment: cost of tarining venue hire
		Required resources	- Trainer, training venue, training mrequired materials - Consultants, Engineers

Plan B

Title	Procure Maintenance Equipment Budget allocation		
Purposes	1. Required inspection equipment to be procured and purchased 2. To promote Low salary rate (experienced staff9 to high salary rate 3. Control laboratories and research institutes availability should be in place in pilot areas		
Expected outcomes	1. Asset management unit is well equipped with inspection equipment and materials 2. Maximum output quality resuls of work from engineers and works officers/supervisors with related to bridge maintenance and management	Evaluation indices	- 1 Engineer at AMU - 3 Engineers at Transport Infrastructure Department - Human Resource Officer, Public Service Minister & PS, Transport Infrastructure Bridge engineer & Director - Asset engineers, Transport Infrastructure Engineers
Activities	1. Identify list of required equipment 2. Get Specification & formulate tender document to procure a supplier 3. Advertise 4. Evaluate 5. Award to Eligible Supplier 6. Training 7. Conduct workshop	Inputs	Cost of Trainer if outsourced Cost of required training material and equipment Cost of training venue hire
		Required resources	Trainer Training venue Training required materials Powerpoint

Source: Trainee action plans

9.4.1.3 Progress of Action Plans

The following is the progress of the action plans as of the short-term monitoring.

Table 9.2 Progress of Action Plans as of Short-Term Monitoring

Action Plan (Completion of Training)	Progress as of Short-Term Monitoring
1) Action Plan A Create Bridge Database/Maintenance Manual	Contract changes were made to an existing project, an order was placed to a consultant, and operations are complete. Bridge inventory and a database are established.
2) Action Plan B Prepare Maintenance Equipment	Agreements have been reached within ministries, but no progress has been made; technical guidance for preparing internal proposals for securing budgets was desired.

9.4.1.4 Assistance for Actualizing Plans

The following on-site activities were implemented during short-term monitoring to aid with actualizing plans.

- ✓ Demonstration of a road roughness evaluation system
- ✓ Workshops

Workshops were conducted under two themes: types of symptoms of deterioration in bridge structures and members (a desire discovered in interviews), and examples of simple equipment used in scheduled inspections and technical assistance for proposals.

The Solomon Islands has been advised to conduct quantitative analysis based on scheduled inspections.

9.4.2 Results of Medium-Term Monitoring on this Occasion

9.4.2.1 Overview of Medium-Term Monitoring

Medium-term monitoring was conducted remotely via interviews of trainees and online seminars based on questionnaires distributed in advance. The following is an overview.

1) Interviews of Trainees

Progress on action plans was checked and a full understanding of activities was gained remotely. The status of organizational efforts was also checked, specifically training content diffusion activities such as the holding of briefings after trainees returned to the Solomon Islands, and the obliging of trainees to transfer their technology to successors.

2) Seminars Aiming to Improve the Technical Capacity of Trainees' Organizations

The seminars comprised programs focusing on essential issues in the Solomon Islands in collaboration with separately related operations and considering trainees' desires.

9.4.2.2 Interviews of Trainees

On April 7, 2021, a total of three target trainees—targets of monitoring and participants in JICA group training in past fiscal years—were interviewed based on the questionnaires sent out in advance.

(1) Target Trainees

Table 9.3 Target Trainees

Name	Affiliation	Position	Details of Interview	JICA Training
Ms. Ellen Kiro	Ministry of Infrastructure Development (MID)	Chief Engineer Asset Management Unit (AMU)	Status of action plan	Bridge maintenance training (fiscal 2015)
Mr. Wawane Lawrence	Ministry of Infrastructure Development (MID) Bridge Division, Department of Public Works, and Highway	Engineer II	Status after return from Japan, etc.	General bridge training (fiscal 2013)
Mr. Moffat HOA	Ministry of Infrastructure Development (MID)	Senior Road Asset Engineer	Status after return from Japan, etc.	Road asset management (fiscal 2019)

(2) Results of Interviews

1) Progress of action plans

No progress had been made on either Action Plan A or Action Plan B since the short-term monitoring.

Other trainees also indicated that they had presented their action plans and shared them internally after returning home from group training.

2) Status of Maintenance in the Solomon Islands

a) Status of Manual Creation

Written specifications and standards exist for roads and bridges, but bridge maintenance and repair manuals have not been created. A road maintenance manual was created in 2013 by a consultant paid for by a foreign fund.

b) Status of Bridge Inspections

The responsible unit in the MID conduct's daily inspections and scheduled inspections in years where the budget allows. However, MID does not own inspection equipment; they conduct visual inspections only.

c) Implementation System for Repair Work

Repair work is outsourced, but there is no quality control manual; it cannot be said that a quality control system has been created. Contractors in the Solomon Islands only perform small-scale bridge repairs; large-scale bridge repairs are supervised by foreign consultants.

d) Database System

Road bridge inventory data is logged into the Solomon Islands Transportation Asset Management System (SITAMS) by AMU. Note that a nationwide inventory inspection survey is presently being conducted. Additionally, regarding road inspections, a road monitoring system application known as ROADROID has been introduced with support from the WB, and AMU staff members have taken part in training.

3) Details of Exchanges of Opinions on Bridge Maintenance

The trainees are aware of the need to create a BMS and reported that a road bridge inventory inspection survey is presently being conducted by a contractor in the Solomon Islands. Given the importance of gathering data primarily while creating a BMS, the survey team recommended the gathering of essential information in advance of BMS development because it would make it possible to fully understand priorities and the details of damage immediately after it is introduced and can be used as the basis for formulating budget plans. The survey team also conveyed the importance of gathering detailed inspection data, drawings, and photographs and sketches of damage in addition to inventory data.

The trainees have a firm understanding of the importance of preventive maintenance. In Japan, preventive maintenance is understood as making small repairs as needed, even when damage is minor; the trainees were advised that preventive maintenance is an extremely important part of daily maintenance and were given examples of sufficiently effective preventive maintenance specific to the Solomon Islands (e.g., weeding around bridge piers, scheduled bridge cleaning to prevent chloride damage).

Regarding the present status of the organization, they have enough people but not enough equipment; they have asked for a list of recommended equipment with which to make a budget request. The survey team recommended the introduction of basic equipment to start with and provided a list of essential inspection equipment to procure later (e.g., binoculars, stepladders, hammers, sheet thickness gauges). The survey team also provided specifications for nondestructive testing equipment.

The trainees indicated their desire for JICA technical cooperation or training for improving the capacity to formulate budgets and create manuals for bridge maintenance in the Solomon Islands.

9.4.3 Details of Seminar Activities

On May 21, an online seminar was held for officials of MID, the trainees' organization. Nagasaki University Assistant Professor Nishikawa, who conducted short-term monitoring and group training for bridge maintenance in past fiscal years and is quite familiar with circumstances in the Solomon Islands, was invited to be the instructor, and provided an outline of bridge maintenance. Efforts of JICA's road asset management platform were also introduced, and Kumonos Corporation presented crack measurement technology as modern technology from Japan.

People who were unable to participate from their homes or offices due to the lack of reliable internet connections in the Solomon Islands, or who could not use external facilities due to the pandemic gathered in an MID conference room to participate in the seminar. Nonetheless, a total of nineteen people participated, and the MID director-general expressed the view that the seminar was very worthwhile and that they wished to continue to receive requests for cooperation in the future.The following are details about the program and participants.

(1) Program

JICA WEB SEMINAR ON ROAD ASSET MANAGEMENT (Bridge Maintenance) 2021

1. Venue: WEB Online (Microsoft Teams)
2. Date: Friday, May 21st, 2021
3. Time: 13:00～16:00@ Solomon Islands (11:00~14:00@Japan)
4. Participants: Ministry of Infrastructure Development (MID), Contractor, Consultant, JICA HQ, JICA Solomon Islands Office, Nagasaki University, etc.
5. Programs:

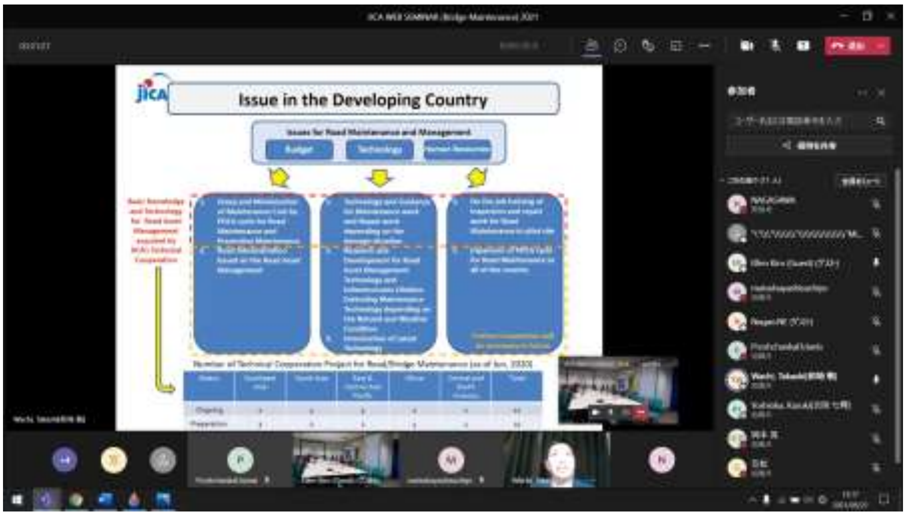
THE SEMINAR PROGRAM on Road Asset Management

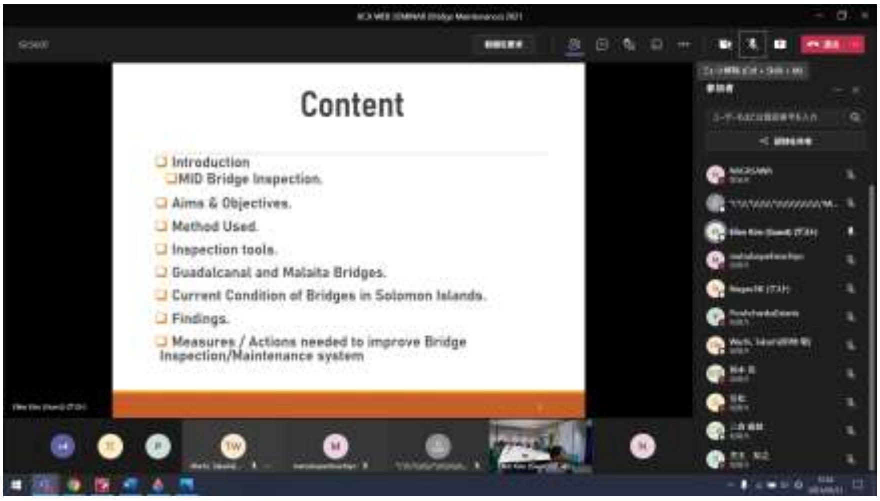
DATE/TIME	ACTIVITIES	IN-CHARGE
Date: **May 21st , 2021** (Friday)		
12:45 – 13:00	Registration	Supporting Staff
13:00 - 13:10	Opening Remarks	Mr. Koyanagi JICA HQ
13:10 - 13:20	Speech by MID	MID
13:20 - 14:20	Bridge Maintenance	Dr. Nishikawa, Nagasaki University
Break (14:20-14:30)		
14:30 - 15:00	Condition Assessment of bridges in SI	Mr. Moffat Hoawe, AMU, MID
15:00 - 15:20	Road Asset Management Platform	Mr. Wachi JICA HQ
15:20 - 15:50	Introduction of new technology for Bridge Maintenance (Innovative Crack Inspection System KUMONOS)	Mr. Dennis KUMONOS Corporation
15:50 - 16:00	Closing Remarks	MID

(2) List of Participants

Work Unit	Number of Participants
Engineering-MID	9
Construction Material Testing-MID	2
Works Supervision-MID	1
Asset Management Unit-MID	4
Consulting Firm (Azimuth Surveys, Trades Transformation Company)	2
Construction Company (Build Solomon)	1

(3) Images of the Online Seminar





9.4.4 Impressions, Recommendations, etc. in the Solomon Islands

Participants in group training in past fiscal years are affiliated with many prominent organizations and have been cooperative with monitoring activities. They are quite conscious of bridge maintenance and have conducted bridge inspections on the island of Guadalcanal based on knowledge they learned in Japan in addition to conducting training for newly graduated engineers. Furthermore, in the bridge inspections, they use the templates shared with them in the group training, and their reports are extremely well organized and easy to read.

Even though Bailey bridges are the main type of bridge in the Solomon Islands, they are not properly maintained, and appear to be in a state of advanced deterioration. Given budgetary limitations and other problems, it would be difficult to replace all the bridges. Accordingly, it is important to continue aiding as to methods of management for proper maintenance with their limited budget, human resources, and equipment.

9.5 Results of Monitoring in Tunisia

9.5.1 Details of Past Short-Term Monitoring

9.5.1.1 Overview of Short-Term Monitoring Activities

The following is an overview of short-term monitoring activities.

1) Confirm progress on action plans, gain a full understanding of activities
2) Promote maintenance through collaboration between industry, the government, and academia
3) Observe bridges and provide advice on maintenance
4) Discuss the course of maintenance
5) Observe the construction sites of new pedestrian bridges

9.5.1.2 Trainee Action Plans

The following is an overview of the action plans formulated by the target trainees during the group training.

Table 9.4 Bridge Maintenance Trainee Action Plans

PlanA:

Title	Data base and records Improvement		
Purposes	Reliable and useful data base and records		
Expected outcomes	Records are easily exploitable: prioritization list, statistics, and reliable data for inspection	Evaluation indices	Number of bridge inspected per year. Perform inspection by DGPC officers.
Activities	1.Acquire a digital data base 2.Acquire As-built drawings	Inputs	▪ Paper format ▪ Cost cannot be identified (this action can be added to the project of road data base) Private consultancy (as for the road data base) under the survey of department of road exploitation and maintenance
		Required resources	Possible funding : • PMIR (AfDB) Extra money from AFESD dedicated for the construction of 33 bridges

Plan B

Title	**Periodic inspection Improvement**		
Purposes	Initiate the periodic inspection		
Expected outcomes	• Check the condition of bridge. Avoid incident Budget optimization: Prioritization list for detailed inspection and repair.	Evaluation indices	Perform inspection by DGPC officers.
Activities	1.Consider bridges inspection in the annually program of the DGPC. 2..Provide basic equipment for inspection: hammer, camera…	Inputs	DGPC and RD Engineers Listing of targeted officers
		Required resources	Possible founding: • PMIR (AfDB) • Extra money from AFESD dedicated for the construction of 33 bridges Our own means Department of formation's budget.

Plan C

Title	—		
Purposes	Acquire bridge inspectors		
Expected outcomes	1.Improve practice and the experience of DGPC and RD engineers. 2.Reducing cost comparing to private consultancy	Evaluation indices	Perform inspection by DGPC officers.
Activities	1.Initiate the periodic inspection 2.Schedule targeted trainings and seminars.	Inputs	DGPC and RD Engineers Listing of targeted officers
		Required resources	Possible founding : • PMIR (AfDB) • Extra money from AFESD dedicated for the construction of 33 bridges Our own means Department of formation's budget.

9.5.1.3 Progress of Action Plans

The following is the progress of the action plans as of the short-term monitoring.

Table 9.5 Progress of Action Plan as of Short-Term Monitoring

Action Plan (Completion of Training)	Progress as of Short-Term Monitoring
1) Plan A Database and Records improvement	Focused on four tasks—strengthening employee capacity for bridge maintenance, creating maintenance manuals (inspections, diagnoses, repairs), developing a BMS, and procuring essential equipment for maintenance work—and received approval within the ministry. Submitted an official request to JICA.
2) Plan B Periodic Inspection Improvement	
3) Plan C Acquire bridge inspectors	
4) Purchase bridge maintenance vehicles (bridge inspection vehicles)	Added to the official request as a new implementation item
5) Procure maintenance manuals	Same as above

9.5.1.4 Assistance for Actualizing Plans

The following on-site activities were implemented during short-term monitoring to aid with actualizing plans.

1) Tour of the Center for Testing and Construction Techniques (CETEC (Centre d'Essais et des Techniques de Construction)
2) Observation of bridges (Viaduc de la pénétrante sud, Rades-La Goulette Bridge)
3) Seminar
4) Observation of the construction sites of new bridges

Of the bridges observed, plans were formulated on various aspects (e.g., daily inspections, scheduled inspections) of the Rades-La Goulette Bridge, which is the product of assistance and technical cooperation from Japan, and scheduled inspections were conducted according to the indicated schedule. Also, it was confirmed that a monitoring system comprising images and measurements of wind speed and vibrations was introduced in addition to daily inspections.

At the seminar—which was attended by roughly 40 people including ministry officials, university personnel, and others—a lecture was given on the bridge maintenance system of Nagasaki Prefecture (promotion of maintenance through collaboration between industry, the government, and academia) at the request of the trainees, with the aim of highlighting the importance of bridge maintenance and encouraging universities and other research institutions and people in the construction industry to participate in maintenance.

9.5.2 Results of Medium-Term Monitoring on this Occasion

9.5.2.1 Overview of Medium-Term Monitoring

Medium-term monitoring was conducted remotely via interviews of trainees and their superiors, and online seminars based on questionnaires distributed in advance. The following is an overview.

1) Checking the Status of Action Plan Development

   Trainees and their superiors were interviewed remotely to check the progress of action plans and the status of activity development since the short-term monitoring. Specifically, trainees' superiors were asked about the status of organizational efforts.

2) Interviews about Present Conditions

A questionnaire was created and used to interview respondents on each topic. Respondents were concurrently asked about issues they were facing at the time.

3) Seminars Aiming to Improve the Technical Capacity of Trainees' Organizations

The seminars comprised programs focusing on essential issues in Tunisia.

At the seminars, JICA's road asset management efforts were introduced; specifically, the importance and ongoing implementation of road asset management were introduced. AI technology and the like introduced at road asset management seminars was also introduced.

9.5.2.2 Interviews of Trainees

As the result of preliminary confirmations, trainees who participated in bridge maintenance training in fiscal 2016—the target of medium-term monitoring—are in Japan for a master's course at Kyoto University and internship program at Hanshin Expressway Company Limited under the ABE Initiative, an initiative to develop young Africans into industrial human resources. The trainees have already organized their action plans into official requests; therefore, the monitoring on this occasion was conducted as a follow-up activity for trainees from group training in past fiscal years. The monitoring involved checking with trainees as to their present status based on questionnaires distributed in advance and checking with trainees' superiors as to the status of organizational efforts and bridge maintenance in Tunisia.

(1) Target Trainees and Their Superiors

Table 9.6 Target Trainees and Their Superiors

Name	Affiliation	Position	Details of interview	JICA Training
Mr. Mohamed Zied MILI	General Department of Bridge and Roads (DGPC), Ministry of Equipment, Housing and Territorial Department	On an internship with Hanshin Expressway Company Limited	Status after return from Japan, etc.	Bridge maintenance training (fiscal 2016)
Mr. Wiem TAHER	General Department of Bridge and Roads (DGPC), Ministry of Equipment, Housing and Territorial Department	-	Status after return from Japan, etc.	Bridge maintenance training (fiscal 2018)
Mr. Slah Zouari	General Directorate of Bridges and Roads (DGPC)	General Director	Present state of bridge maintenance in Tunisia	-

(2) Results of Interviews

1) Progress of Action Plans

The official requests organized during the short-term monitoring had already been submitted to JICA, and discussions were moving toward the development of the technical cooperation projects.

No progress has been made on any of the three action plans created by trainees who participated in bridge maintenance training in fiscal 2018—Action Plan 1 for creating a steel bridge inspection manual, Action Plan 2 for creating a database, and Action Plan 3 for training for visual inspections—but efforts are taking place to establish a new department for bridge maintenance in the ministry, and preparation is under way for implementing the technical cooperation projects.

2) Present State of Maintenance in Tunisia

a) Status of Manual Creation

A manual from France known as IQOA (Image de la Qualité des Ouvrages d'Art) is being used, and although it does set out methods of evaluating the condition of bridges, it is not an organizational maintenance manual.

b) Status of bridge Inspections

Ministry officials conduct visual inspections; when anomalies are discovered, outside consultants conduct detailed inspections. However, it cannot be said that the work has been implemented properly since 2010 because new human resources are not being developed.

c) Status of Bridge Maintenance and Inspection Equipment

The EPEC Testing Technology Center has the equipment needed to inspect basic girder bridges, medium-scale bridges, and slab bridges, but it is limited to inspection equipment for concrete bridges.

d) Present State of Bridges in Tunisia

At present, inspections and surveys are being conducted on five hundred bridges in Tunisia; they have been completed for 470 bridges. The ministry formed an advisory panel to examine matters, resulting in the decision to replace forty of those bridges.

e) State of Bridge Repairs

Regarding repairs, bids have been held to select contractors for fifty projects within Tunisia. Two or three prominent domestic contractors are skilled at emergency repair work; talented contractors do exist in Tunisia, but they engage in new construction as well, and place a low priority on repair work.

f) Organizational Status

The ministry is presently considering and preparing for strategic reforms. A bureau for bridges (independent of roads) has been established within the ministry’s general bureau of roads and bridges and will serve as the department that performs maintenance for bridges. At the regional level as well, plans exist to establish a bridge department, assign a head of the department, and increase the number of employees in each of the twenty-four governorates.

Additionally, while establishing the bureau specializing in bridges, preparation is under way for improving the existing bridge database, which consists of data gathered and organized in spreadsheets. At the regional bureau level, teams have been formed, leaders have been assigned, and databases are being established under the leaders. Supervisory committees have been established to monitor progress.

9.5.3 Details of Seminar Activities

On March 30, an online seminar was held for officials of DGPC, the trainees' organization. Additionally, at the request of the trainees, the seminar was attended by bureau officials as well as people involved in maintenance in the ministry and regional bureaus, the outside consultants who created the bridge inspection reports, contractors, and university personnel.

Gifu University Assistant Professor Kinoshita, who collaborated with the JICA technical cooperation projects in Zambia and helped establish an engineer training program at the University of Zambia, was invited to be the instructor, and introduced examples of collaboration between industry and academia in Zambia. Efforts of JICA's road asset management platform were also introduced, and AI technology for assisting with bridge inspections and evaluations was presented as modern technology from Japan.

Fifty people from the Tunisia side participated, and a very lively Q&A session took place after the lecture. The participants expressed great curiosity about detailed inspection methods and the AI technology demonstrated during the lecture. They were also extremely interested in having their organizations engage in partnership projects and long-term trainee programs with the university. The participants commented that the entirety of the seminar content was helpful and furthered their understanding of maintenance.

The following are details about the program and participants.

(1) Program

JICA WEB SEMINAR ON ROAD ASSET MANAGEMENT 2021

1. Venue: WEB Online (Microsoft Teams)
2. Date: March 30th , 2021 (Tuesday)
3. Participants: General Department of Bridge and Roads(DGPC), University, Contractor, Consultant, JICA HQ, JICA Tunisia Office, Gifu University, etc.
4. Programs:

THE SEMINAR PROGRAM on Road Asset Management

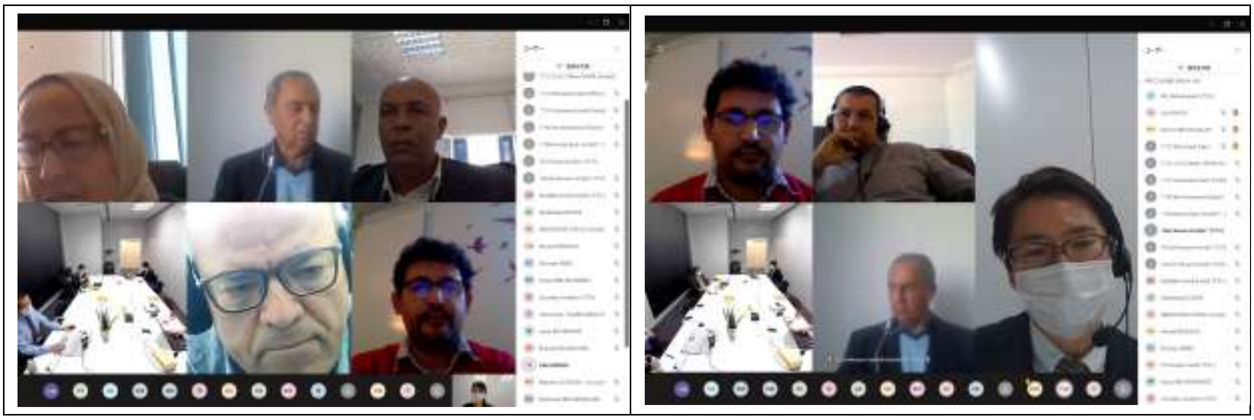
DATE/TIME	ACTIVITIES	IN-CHARGE
Date: **March 30th , 2021** (Tuesday)		
08:45 - 09:00	Registration	Supporting Staff
09:00 - 09:10	Opening Remarks	*JICA HQ
09:10 - 09:20	Speech by DGPC	Mr. Slah ZOUARI Director General, DGPC
09:20 - 09:50	Overview of Bridge Maintenance in Tunisia	Ms. Wiem TAHER DGPC
09:50 - 10:25	Road Asset Management Platform	*JICA HQ
Break (10:25-10:40)		
10:40 - 11:10	Examples of academia-government collaboration projects between Zambia university and Gifu university	Dr. Koji Kinoshita Gifu University
11:10 - 11:40	Introduction of AI technology for Bridge Maintenance	Mr. MAKI Yuji, Dr.Eng. Nippon Engineering Consultants Co., Ltd.
11:40 - 12:10	Discussion	
12:10 - 12:20	Closing Remarks	Mr. Slah ZOUARI Director General, DGPC

The presentation time is included translation to French language

(2) List of Participants

Work Unit	Number of Participants
General Department of Bridge and Roads (DGPC)	18
General Department of Program and Trainings (DGPFC)	1
Regional Department	11
Center for Testing and Construction Techniques	1
Bureau conseil en ingénierie de construction(BCIC)	1
Bureau Tunisien des Etudes(BTE)	1
Contractor	1
UNIVERSITY OF SFAX	12
Unknown	2

(3) Images of the Online Seminar



9.5.4 Impressions, Recommendations, etc. in Tunisia

Official requests for the technical cooperation projects have already been organized and submitted to JICA, and preparation is under way for establishing bridge maintenance systems. Tunisia is grappling with the need to maintain structures constructed 30 years ago. Specifically, the country has acknowledged a lack of experience in maintaining and repairing steel bridges and is aware of its lack of knowledge; thus, they desire cooperation from JICA in engineer development.

The country is also ambitiously moving ahead with creating BMS and bridge inventory but must investigate the condition of reinforcement steel in structures for which no completed drawings exist. Concurrently, they must attempt to restore drawings, and continue amassing and storing data.

A manual has been created for the Rades-La Goulette Bridge, which was constructed with cooperation from Japan, and inspections and monitoring are progressing smoothly; however, the country must establish a bridge maintenance system for other bridges because they have yet to maintain them or gain a full understanding of the damage to them.

9.6 Details of Recommendations for the Future

(1) For Countries Subject to Monitoring

Regarding the Solomon Islands, from a short-term perspective, assistance in the form of technology, equipment, and materials is needed because the organization and human resources have yet to be fully established. From a longer-term perspective, it is important to continue aiding as to methods of management for proper maintenance with their limited budget, human resources, and equipment.

Regarding Tunisia, monitoring must continue within the technical cooperation project because the project is set to begin soon.

(2) Revise Action Plans Created During Training

The organizational systems, budget conditions, support from other donors, and other factors trainees face in these countries often change once roughly three years have passed since short-term monitoring. Thus, it is sometimes necessary to revise action plans to make them feasible.

(3) Ongoing Assistance

The follow-up activities on this occasion—namely seminars and specific recommendations stemming from interviews with experts—were highly regarded as being worthwhile for furthering understanding about maintenance. The two countries wish for the implementation of follow-up activities to continue. Organizations also voiced their ardent desire for assistance in acquiring technology and knowledge; it is also important to aid by implementing the technical cooperation projects that correspond to conditions in target countries.

(4) Monitoring Activities

The target trainees in the two countries in which follow-up activities were implemented on this occasion were extremely initiative taking in cooperating with the survey team for the medium-term monitoring that followed the short-term monitoring conducted previously and are also making ambitious efforts in activities in their countries. Short-term and medium-term monitoring has a substantial impact on whether trainees stay motivated and whether training produces results, and thus should be conducted in more countries and followed by ongoing monitoring activities. Long-term monitoring is important as sustainable support in the target country, especially if it cannot be turning into a technical cooperation project in that country.

Chap.10 New Subject Specific Training "Quality Infrastructure Development Promoting DX"

10.1 Target of the Chapter

Japan has been promoting i-Construction using ICT and BIM/CIM and has advanced construction production and management systems. In international cooperation with developing countries that are undergoing rapid urbanization, Japan is expected to actively introduce and disseminate its technical standards and construction production and management systems for infrastructure development in the transportation and traffic fields, and to promote the realization of innovation, productivity improvement, and improvement of safety and comfort in work under severe environmental conditions. In addition, it is expected to improve the safety and comfort of work under severe environmental conditions. Considering these circumstances, this report examines the planning proposal and program contents of the new issue-specific training program, which is expected to start newly in 2022.

10.2 Overview

In planning the training content for "High-quality infrastructure development promoting DX," the following were organized as efforts for high-quality infrastructure development promoting DX in Japan. ["Trends in core technology"," DX in the infrastructure field"," Outline of i-construction," "Trends in ICT technology utilization in the field of road maintenance," "Overseas expansion of high-quality infrastructure"]

The contents of the training are based on the "lecture covering the structure of DX measures in the field of infrastructure in Japan" and the "tour program", and the following are assumed.

[Working on i-Construction (1) ICT technology, (2) standards, (3) ordering method, (4) overseas expansion by packaging data systems]

From the above, the concept paper (draft), schedule (draft), and curriculum (draft) were created.

10.3 Overview of Knowledge Co-Creation Program

JICA's Knowledge Co-Creation Programs are proposed by Japan to developing countries and are implemented in cooperation with many domestic organizations concerned to contribute to solving the problems faced by developing countries through the knowledge and experience shared by Japan. About 400 Knowledge Co-Creation Programs are planned and implemented each year, covering a wide range of fields, and there are few other projects of this scale with practical content for which trainees are accepted.

The implementation period of the Knowledge Co-Creation Program is evaluated and reviewed every fiscal year, and the continuation, reconstruction, or discontinuation of projects is reviewed after a three-year period and can be renewed if the need is recognized. New projects and reconstruction projects are reviewed in the two years prior to implementation, and projects that are deemed appropriate for implementation are reviewed in the year prior to implementation to determine whether they should be implemented.

10.4 Efforts to Develop High-Quality Infrastructure Promoting DX in Japan

10.4.1 Background

In the field of infrastructure in Japan, there is a growing need for disaster countermeasures and measures to deal with the aging of infrastructure, while there is also concern about a serious shortage of labor in the future. MLIT has been promoting i-Construction, which aims to improve productivity at construction sites using ICT technology, since 2016. In addition, the outbreak of the new coronavirus infection has led to the urgent task of accelerating the construction of an economic structure that is resilient to the risk of infectious diseases, including a shift to non-contact and remote work methods at public construction sites. Considering these circumstances, MLIT will respond to the drastic changes in socioeconomic conditions and use data and digital technology in the infrastructure field to transform social infrastructure and public services based on the needs of the public, as well as to transform the business itself, the organization, processes, and the culture and working style of the construction industry and MLIT. In 2020, MLIT established the DX Promotion Headquarters in the infrastructure field to promote cross-ministry efforts to transform public understanding of infrastructure and to realize safe, secure, and prosperous lifestyles.

In addition, the new coronavirus is expected to trigger the digitalization of society, which will lead to major changes in both work and work styles, such as online meetings and regional residency.

※The concept of DX (Digital Transformation): Transforming people's lives for the better through the penetration of advanced digital technologies.

10.4.2 Trends in Core Technology

Table 10.1 shows the trends in core technologies for DX.

Table 10.1 Technology Trends[108]

Core Technology	Trends
5G: High-speed data transmission	With the launch of the fifth-generation mobile communication system (5G) service in 2020, an ultra-high speed (20 times), ultra-low latency (1/10), and many simultaneous connections (10 times) environment is expected to be realized. In addition, the spread of IoT devices and the expansion of data transmission and reception are expected to increase.
AI: Data recognition and judgment	With the expansion of the image recognition market due to the deepening of deep learning, the image analysis field is expanding to various industries due to the enhancement of peripheral devices such as cameras, etc. In addition, language analysis is expected to expand and is expected to be applied to document management, etc. in the future.
Cloud: Data storage process	The size of the domestic market for cloud services has been expanding year by year, and the movement of companies to migrate their existing systems to the public cloud is accelerating. On the other hand, AWS (Amazon), Azure (Microsoft), and GCP (Google) are becoming oligopolistic.

[108] Prepared by the survey team based on data from the first meeting of MLIT's Headquarters for the Promotion of DX in the Infrastructure Field, July 29, 2020

10.4.3 DX in the Infrastructure Field

As shown in Table 10.2, Japan aims to promote public understanding of infrastructure and realize a safe, secure, and prosperous world through changes in social capital, public services, organizations, processes, culture and climate, and ways of working through the respective DX of “behavior,” “knowledge and experience,” and “goods.

Table 10.2 Composition of DX in the Infrastructure Sector[109]

DX of “action”	Promote ways of working that are not bound by the face-to-face approach To avoid the so-called “three densities” and to ensure the functioning of construction sites even under the circumstances of the spread of the new coronavirus, a new way of working at construction sites that is not bound by the face-to-face system, such as supervision and inspections using video data, will be promoted.
DX of “knowledge and experience”	Using AI in the Infrastructure Field to Pass on Skilled Skills The results of decisions made by skilled engineers in construction setups and infrastructure inspection are used as teacher data and provided to the private sector to promote the development of AI in the private sector and transform the field of construction work and infrastructure maintenance.
DX of “objects”	Transformation of the construction production process through the introduction of BIM/CIM The internal structure and assembly shape that had been inferred from multiple drawings can be understood at a glance. In addition, it is possible to automate the calculation of quantities and construction costs, which will revolutionize the way both the client and the customer work.

In the promotion of DX measures in the infrastructure field, it is said that various standards will be reviewed and the measures shown in Table 10.3 will be implemented, with the digitization of infrastructure, the acquisition of real data, and the use of stock data all playing a role in the utilization of digital data.

Table 10.3 Details of DX Measures in the Infrastructure Field[110]

Measures	Content
Transformation of services in administrative procedures and daily life	1) Speeding up administrative procedures, etc. 2) Improve services in daily life 3) Services to enhance safety in daily life
Improving safety and efficiency at workplaces by supporting people using robots, AI, etc.	1) Realization of a safe and comfortable working environment 2) Improving work efficiency using AI and other technologies 3) Efficient acquisition of skills through digitization of proficient skills
Transform work processes and work styles by utilizing digital data	1) Transformation of investigation work 2) Transformation of supervision and inspection operations 3) Improving the efficiency of inspections and management operations
Realization of a data utilization environment that supports DX	1) Solving social issues using digital data 2) Development of 3D data utilization environment

109 Prepared by the survey team based on data from the first meeting of the MLIT's Headquarters for the Promotion of DX in the Infrastructure Field, July 29, 2020
110 Prepared by the survey team based on data from the third meeting of the MLIT's Headquarters for the Promotion of DX in the Infrastructure Field, January 29, 2021

10.4.4 Overview of i-Construction

Japan is currently facing a society with a declining population, and to increase the potential for growth and expand new demand, there is a social need to increase productivity to exceed the decrease in the number of workers. In addition, it is important to promote reforms in the way of working to secure mid- to long-term leaders in the industry and develop human resources, and from this perspective, productivity improvement is also required. Under these circumstances, MLIT has been promoting "i-Construction" since 2016, which promotes the use of ICT (Information and Communication Technology) in construction sites and the equalization of construction periods. This "i-Construction" has been tackled in the four categories shown in Table 10.4.

Table 10.4 Four Categories of "i-Construction"[111]

Category	Content
Full Utilization of ICT	This is an initiative to fully utilize ICT in all construction production processes, including surveying, design, construction, and inspections.
Introduction of Total Optimization	To optimize the entire production process, including design, ordering, procurement, processing, assembly, and maintenance management, efforts are being made to utilize concrete and precast products with enhanced fluidity, and to formulate guidelines for factory fabrication of prefabricated steel bars, etc.
Leveling of Construction Period	Efforts by MLIT, prefectures, and municipalities to reduce the unevenness in the timing of public works operations during the year, to efficiently allocate human resources and materials, to secure vacation time, and to stabilize income.
Utilization of 3D Data	The introduction of three-dimensional design (BIM/CIM) in all construction production processes, from surveying and measurement to design, construction, inspections, maintenance, and reconstruction, will enable the use of modern technologies such as ICT construction equipment, as well as the introduction of concurrent engineering and front-loading concepts that consider constructability and quality control at the survey and design stages. This is an initiative to introduce the concept of front loading.

※Concurrent engineering/CE: In product and system development, personnel from all departments, from design engineers to manufacturing engineers, gather to discuss various issues and work together in a coordinated manner.

※Front-loading: In the field of system development and product manufacturing, the process of intensively examining in advance any changes in specifications that may occur in later processes during the initial stages of the process to improve quality and shorten the construction period.

10.4.5 Trends in the use of ICT Technology in Road Maintenance Management

In June 2020, the Road Bureau of MLIT released an interim report on the maintenance and management of national roads. In the field of collecting and understanding information on roads, the report states that ICT technology will be introduced to road patrols, automatic detection of traffic obstacles through AI analysis of CCTV images, and other measures will be taken to collect and analyze the opinions of residents using SNS. It is stated that the project aims to improve the efficiency and sophistication of information collection and understanding of road conditions, and to (1) speed up emergency response by sharing

[111] Prepared by the research team based on materials from the MLIT i-Construction Promotion Consortium

information, (2) prevent human errors such as overlooking damaged areas, and (3) achieve systematic maintenance and management by collecting, analyzing, and accumulating data requested by residents.

In addition, based on the results of the first round of periodic road maintenance inspections, the periodic inspections of road bridges will be revised in 2019, and the use of "inspection support technologies" such as drones will be specified. It is important to develop inspection methods that do not require close visual inspections as shown in Figure 10.1.

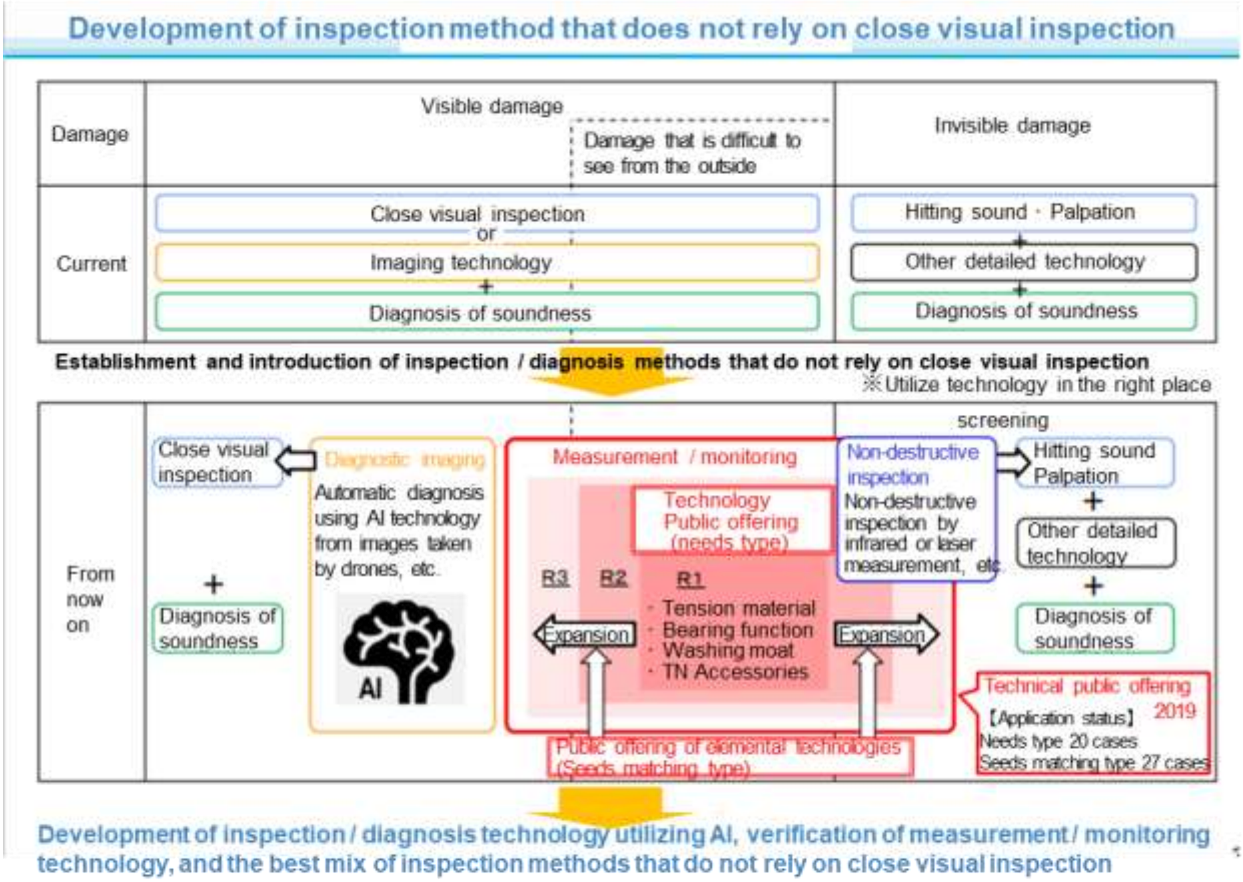


Figure 10.1 Development of an Inspection Method that does not Require Close Visual Contact[112]

As described above, in the maintenance and management of national highways (managed by the national government), the introduction of new technologies such as ICT and AI is helping to solve the following problems: (1) dealing with aging road facilities, (2) increasing the volume of work due to the increase in the length of management and the response to frequent and severe disasters, and (3) the aging of the construction workforce, the shortage of workers, and the reform of work styles. We are working to maintain and improve the level of road services within a limited workforce and budget and to ensure the implementation of EBPM (Evidence-based Policy Making[113]).

[112] Handout for the 12th Subcommittee on Highway Engineering, June 2020
[113] EBPM (Evidence-based Policy Making): Policy planning should not rely on ad hoc episodes, but should be based on evidence after clarifying policy objectives (Cabinet Office website)

On the other hand, about the maintenance and management of expressways, the following information was included in a report jointly issued by the three NEXCO companies in the 47th meeting of the National Highways Committee of the Road Subcommittee of the Social Infrastructure Development Council in January 2021: "Maintenance and Reconstruction of Expressways.

✓ With an eye on the future of expressways, new capital investment is needed to "promote DX in road management systems" - the realization of x Road - by combining and utilizing CCTV image analysis data and sensing data with AI and BI technologies to improve the efficiency and sophistication of road management.

The efficiency and sophistication of road management, inspections and repair is shown in Figure 10.2.

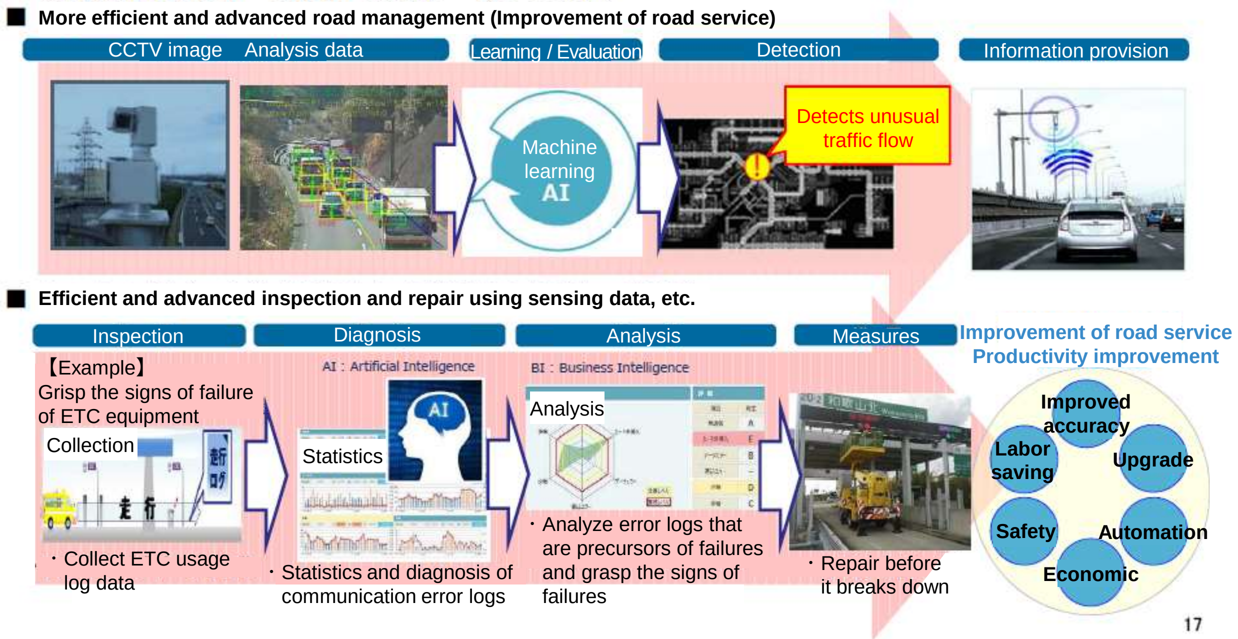


Figure 10.2 Improving the Efficiency and Sophistication of Road Management, Inspection, and Repair[114]

10.4.6 Overseas Development of High-Quality Infrastructure

In recent years, the world's economic level has been rising, and demand for medium- and long-term infrastructure support, such as roads, ports, airports, and railroads, has been increasing dramatically in developing countries, especially in Asia and Africa. The gap between such high demand and the financial supply of donors has become a global issue. In response, not only public funds but also private funds and technological capabilities are being utilized, and emerging countries that have gained economic power are providing infrastructure support to developing countries. However, with the increase in the number of donor countries, there are increased cases where the infrastructure developed is not benefiting the region. Therefore, a consensus has emerged around the world that infrastructure support should be of higher quality and truly benefit developing countries.

114 January 2021: 47th meeting of the National Highways Subcommittee of the Road Sectional Committee of the Social Infrastructure Development Council

This high-quality infrastructure has been an initiative of the Japanese government and has been communicated to the world. The Japanese government announced the "Quality Infrastructure Partnership" in 2015, and the same year the goal of the UN Sustainable Development Goals (SDGs) included the same. Later, at the G7 Ise-Shima Summit in 2016, Japan took the lead in adopting the G7 Ise-Shima Principles for Promoting Quality Infrastructure Investment. At the G7 Iseshima Summit in 2016, Japan took the lead in adopting the "G7 Iseshima Principles for the Promotion of Quality Infrastructure Investment," which calls for countries to adhere to five principles when developing infrastructure: building infrastructure that can be used safely and reliably over the long term, even if it costs a little more; not destroying local communities and the environment; and creating jobs in the local community. This was the birth of the trend. The details are shown in Table 10.5.

Table 10.5 "The G7 Ise-Shima Principles for the Promotion of High-Quality Infrastructure Investment"

1)	Economic efficiency and safety in terms of life cycle costs
2)	Local employment, technology transfer
3)	Social and environmental considerations
4)	Consistency with social and development strategies, including financial soundness of the recipient country
5)	Effective mobilization of funds, including from the private sector

Subsequently, at the G20 Osaka Summit in June 2019, the G20 Principles on Quality Infrastructure Investment were approved for infrastructure development in developing countries. These principles consist of six items: (1) sustainable growth, (2) economic efficiency, (3) environmental considerations, (4) resilience to natural and other disasters, (5) social considerations, and (6) governance. The details are shown in Table 10.6.

Table 10.6 G20 Principles on Quality Infrastructure Investment[115]

Principle 1: Maximize the impact on sustainable growth and development Promote a virtuous economic cycle by investing in infrastructure that creates jobs and transfers technology, thereby building capacity, increasing productivity, and promoting private sector investment. Promote sustainable development and strengthen connectivity by investing in infrastructure in line with the SDGs, etc., while maintaining consistency with national strategies.
Principle 2: Economic efficiency in terms of life cycle costs Value for money (VFM) should be achieved. It is important to consider the total cost of the infrastructure, including not only its construction but also its operation and maintenance (O&M). The risk of project delays and cost overruns should also be considered. Innovative technologies are also useful.
Principle 3: Consideration should be given to the environment. The impact on ecosystems, biodiversity, climate, etc. should be considered. The use of green finance products through improved disclosure of environment-related information is also important.
Principle 4: Resilience to natural disasters and other risks Management of natural and man-made disaster risks needs to be considered from the design stage. Disaster risk insurance encourages a resilient infrastructure.
Principle 5: Social Considerations There is a need to encourage economic participation and social inclusion of all people. Openness of use, safety, gender, and consideration for vulnerable groups are important.
Principle 6: Infrastructure Governance Openness and transparency in procurement, efforts to prevent corruption, and access to information and data are important.

115 June 28-29, 2019, G20 Osaka Summit

Not only financial sustainability on a project-by-project basis, but also debt sustainability at the macro (country) level is important.

10.5 Planning the Training Content for the Knowledge Co-Creation Program"Quality Infrastructure Development Promoting DX"

10.5.1 Basic Concept

- ✓ The lecture and inspection program will cover the structure of DX measures in the infrastructure field in Japan.
- ✓ i- The content of the curriculum will be studied assuming overseas deployment by packaging (1) ICT technology, (2) standards, (3) ordering methods, and (4) data systems that are being worked on in i-Construction.

① ICT technology

Table 10.7 Typical Examples of the use of Modern Technologies in Construction Production Processes

Process	Examples of the use of Modern Technologies	Implementing Agency
Surveying	Acquisition of 3D survey point cloud data ・ Laser scanner ・ UAV ・ Narrow multibeam	Geological survey companies, surveying companies
Design	Design by 3D CAD	Consultant
Construction	Leveling by ICT construction equipment	Construction Company
Inspection	Field inspections by GNSS rover etc.	Construction Company/Client
Maintenance and Update	Monitoring of earthworks by aerial laser surveying Confirmation of the integrity of underwater structures using an acoustic video camera	Construction Company/Consultant

② Standard

Standards to be maintained for the use of 3D data

- Survey standards
- Design standards
- Construction management standards
- Inspection standards

③ Ordering Method

Method for ordering i-Construction

- Order and contract method
- Accrual basis

④ Data System

By creating a database of big data such as 3D data created in the construction production and management process and each production stage, including surveying, measurement, design, construction, inspections, maintenance, management, and reconstruction, the data will be effectively utilized for further productivity improvement, maintenance, management, and reconstruction.

Major examples of data utilization are as follows.

- ✓ Visualization and efficiency improvement of construction sites using construction history data
- ✓ Identify facilities that have the same or similar risk of accidents and abnormalities
- ✓ A function to accumulate cracks and other changes over time has been added, and the inspection history (cracks, leaks, etc.) can be referenced to further improve the efficiency of maintenance management

1) In accordance with the principles of quality infrastructure development, consideration should be given to economic efficiency and stability in terms of life cycle costs, and consistency with social and development strategies, including technology transfer and financial soundness, including innovative technologies based on the current situation in developing countries.
2) To deepen the understanding of the effects of introducing 3-D design (BIM/CIM) in all construction production and management processes, from survey and measurement to design, construction, inspections, maintenance, and reconstruction.
3) The curriculum should include the acquisition of basic knowledge about core technologies such as AI diagnosis and 5G, and the deepening of knowledge about applied inspection and diagnosis technologies.
4) Training participants are expected to be staff members of organizations that plan and order infrastructure development projects and staff members of construction companies who have experience in construction production and management systems for infrastructure development in the transportation and traffic fields, targeting developing countries around the world.
5) The training is equivalent to regular training in Japan and is regarded as a human resource development and dissemination type training (a project that aims to disseminate knowledge and skills that are meaningful when acquired by a large number of people).

Table 10.8 Content of the Training Plan for Quality Infrastructure Development Promoting DX

Training Name	Quality infrastructure development promoting DX
Training Period	2 weeks
Target Group	Employees belonging to organizations that plan and order infrastructure development projects Staff belonging to construction companies Department managers (young managers) class
	Years of experience: About 5 years of experience related to construction production systems.
Objectives	Knowledge and skills related to quality infrastructure development promoting DX will be acquired, and measures and improvements will be formulated to meet the actual conditions of the country.
Main Contents of Training	【Training in Japan】 1) DX measures for the infrastructure sector in Japan (lecture) 2) Promotion of i-Construction (productivity revolution in construction sites) (lecture) 3) Use of digital data in social capital management (lecture) 4) Basic knowledge of informatization construction (lecture and observation) 5) Laser and photogrammetric surveying technology using GNSS and other drones (lecture and practice) 6) Next generation construction production system by automation of construction machinery (lecture, observation) 7) Design, construction, and maintenance management examples using BIM/CIM 3D models (lecture, practice) 8) Introduction of ICT-based technologies in design, construction, and maintenance management (lecture, demonstration) 9) Efforts to develop information infrastructure for maintenance management database collaboration (lecture) 10) Have participants extract two or three technologies and knowledge acquired in the training and prepare a report proposing measures and improvements applicable to their own countries. 【Post-event activities】 1) Share the contents of this training and proposal reports with your organization

10.5.2 Draft Concept Paper of Knowledge Co-Creation Program

<table>
<tr><td colspan="4">Quality Infrastructure development utilizing Digital Transformation (DX)</td></tr>
<tr><td colspan="4">Main Subject: Transportation and Traffic</td></tr>
<tr><td colspan="4">Secondary Subject: Transportation and Traffic</td></tr>
<tr><td colspan="4">Language: English</td></tr>
<tr><td colspan="4">Case Outline</td></tr>
<tr><td colspan="4">The development of infrastructure for economic growth toward self-sustaining development in developing countries requires not only quantitative development, but also high-quality infrastructure (economic and social infrastructure) that is "inclusive," "sustainable," and "resilient" to improve the lives of people, including the socially vulnerable. Furthermore, in response to the drastic changes in the socioeconomic environment, there is a growing need in the infrastructure sector to utilize data and digital technologies to improve productivity and safety, and to transform social infrastructure and public services. The objective of this seminar is to acquire knowledge and skills in the use of DX for quality infrastructure development, including methods for utilizing advanced technologies in the infrastructure field.</td></tr>
<tr><td colspan="2">Target / Achievement</td><td colspan="2">Target Organization / Personnel</td></tr>
<tr><td colspan="2">【Target】
Knowledge and skills related to quality infrastructure development using DX will be acquired, and countermeasures and improvement measures that match the actual situation of the country will be formulated.
【Achievement】
1. Clarify the current status and challenges of planning, construction, operation, and maintenance of Japan's infrastructure.
2. Understand the status of Japan's efforts, research and development in the field of DX in the field of infrastructure, and examine the technologies and knowledge that can be applied in your country.
3. To be able to prepare a report that proposes measures and improvements that can be applied in your country, and to explain and share the report with your organization.</td><td colspan="2">Staff belonging to organizations that plan and order infrastructure development projects, staff belonging to construction companies, department managers (young managers) class, 5 years of experience related to construction production systems</td></tr>
<tr><td colspan="2">Contents</td><td rowspan="2">Japan Course period</td><td rowspan="2">2022/9～2022/9</td></tr>
<tr><td colspan="2" rowspan="5">【Program】
1. DX measures for the infrastructure sector in Japan (lecture)
2. Promotion of i-Construction (productivity revolution in construction sites) (lecture)
3. Utilization of digital data in social infrastructure management (lecture)
4. Basic knowledge of information-based construction (lecture, observation)
5. Laser and photogrammetric surveying technology by drones using GNSS, etc. (lecture, practice)
6. Next generation construction production system through automation of construction machinery (lecture, observation)
7. Examples of design, construction, and maintenance management using BIM/CIM 3D models (lecture, practice)
8. Introduction of technologies using ICT, etc. in design, construction, and maintenance management (lecture, demonstration)
9. Efforts to develop information infrastructure for maintenance management database linkage (lecture)
10. The participants were asked to extract two or three technologies and knowledge from those acquired in the training, and to prepare a report proposing measures and improvements that can be applied to their own countries.
【Follow-up activities】
Share contents of this training and proposal reports with your organization</td></tr>
<tr><td>Responsible Department</td><td>Infrastructure Management Department</td></tr>
<tr><td>Competent Domestic Agency</td><td>JICA Yokohama</td></tr>
<tr><td>Relevant Authorities</td><td>MLIT</td></tr>
<tr><td>Fiscal year</td><td>2022～2024</td></tr>
<tr><td>Major cooperating organizations</td><td colspan="3">MILT</td></tr>
<tr><td>Special remarks, etc.</td><td colspan="3"></td></tr>
</table>

10.5.3 Knowledge Co-Creation Program Schedule

Quality infrastructure development Promoting DX (draft) is shown in Table 10.9.

Table 10.9 Quality Infrastructure Development Promoting DX (Draft)

Date		Style	Content of Training (Draft)	Lecturer Request (Draft)
Sept	Day		Visit to Japan	
	Mon		Opening Ceremony Briefing and Program Orientation	
		Lecture	【Introduction】 Digital Transformation Measures in the Infrastructure Sector in Japan	MLIT, Technical Research Division, Minister's Secretariat
		Lecture	【Standard and ordering method】 Promotion of i-Construction (productivity revolution in construction sites)	MLIT, Technical Research Division, Minister's Secretariat
		Lecture	【Research】 Effects of introducing i-Construction	Professor Tateyama, Ritsumeikan University
		Lecture	【Introduction】 High quality infrastructure development	JICA
	Tue	Lecture	【Research】 Use of digital data in social capital management	National Institute of Advanced Industrial Science and Technology, Social Infrastructure Management Research Center
		Observation	【Research】 Research facilities: DX data center, experimental field	National Institute of Advanced Industrial Science and Technology, Social Infrastructure Management Research Center
		Lecture	【Research】 Promotion of water-related disaster prevention using big data and ICT technology	Public Works Research Institute International Center for Water Hazard and Risk Management
		Lecture	【Research】 Improving the reliability of road bridge maintenance using AI technology	Public Works Research Institute Research Center for Structural Maintenance
		Lecture	【Research】 Accelerating innovation through new monitoring technologies	Public Works Research Institute Advanced Materials Technology Resource Center
	Wed	Lecture	【Survey and measurement】 Laser and photogrammetric surveying technology by drones using GNSS, etc.	Private companies and manufacturers Topcon Corporation Navigation companies

Date		Style	Content of Training (Draft)	Lecturer Request (Draft)
		Exercise	【Construction】 Operation of the latest ICT equipment and construction equipment systems, and experience creating 3D data using the latest software	Private companies and manufacturers Topcon Corporation
		Lecture	【Construction】 Next-generation construction production system through automation of construction machinery	General contractor Kajima Corporation
	Thu	Lecture	【Construction】 Basic knowledge of information-based construction	（Construction Engineering Research Institute, Japan Construction Engineering and Construction Association (Fuji City, Japan)
		Observation	【Inspection】 Demonstration of the method of workpiece control using Total Station (TS)	Construction Engineering Research Institute, Japan Construction Engineering and Construction Association (Fuji City, Japan)
	Fri	Lecture	【Maintenance Management】 Using 3D point cloud data to improve facility management efficiency	Shizuoka Prefecture, Topcon Hitachi Solutions, Ltd. Good Design Award 2020
		Observation	【Smart city/3D city model】 DX promotion of community development	Shizuoka Prefecture Atami City, etc.
		Observation	【ICT construction】 ICT earthwork, ICT dredging, and ICT slope construction sites	Within Shizuoka Prefecture
	Sat			
	Sun			
	Mon	Lecture	【Data system】 Efforts to develop information infrastructure for maintenance management database collaboration	Professor Hisada, Tohoku University Yamagata Prefecture, Daisen City
		Lecture	【Design】 Design, construction, and maintenance management using BIM/CIM 3D models	CAD Manufacturer Autodesk, Inc., and others
		Exercise	【Design】 Exercises on design, construction, and maintenance management using BIM/CIM 3D models	CAD Manufacturer Autodesk, Inc., and others
	Tue	Demonstration	【Maintenance management】 Improving the efficiency of infrastructure inspections using AI, robots, sensors, etc.	Private Companies
		Demonstration	【Construction】 Improving the efficiency of construction management using wearables and tablets	Private Companies
		Demonstration	【Construction】 Digitalization of Skilled Skills for Efficient Skill	Private Companies

Date		Style	Content of Training (Draft)	Lecturer Request (Draft)
			Acquisition Motion sensor, VR	
		Lecture	【Design, construction, maintenance and management】 Visualization technology for underwater structures (bridges and dams)	Private Companies Tokushima Prefecture
	Wed	Observation	【Maintenance management】 Remote control system for operating public infrastructure facilities	Rivers and Roads NEXCO Control Center
		Observation	【Construction machinery】 Explanation and demonstration of smart construction	Komatsu IoT Center Tokyo (Mihama-ku, Chiba City)
	Thu	Exercise	Report writing Guidance, group discussion, report writing	
	Fri	Exercise	Report Presentation	
			Evaluation meeting Closing ceremony	
	Sat		Departure from Japan	
	Sun			

10.5.4 Curriculum Content Plan

(1) 【9/●●(Mon)】

Date and time	September ●● (Monday) 13:00-14:00
Training Title	Digital Transformation Measures in the Infrastructure Sector in Japan
Instructor (Position)	Technology Research Division, Minister's Secretariat, MLIT, Japan
Purpose of lecture	Deepen knowledge through lectures on the status of Japan's efforts to realize the transformation of social capital development and public services, as well as the transformation of organizations, processes, and the construction industry, using data and digital technologies in the infrastructure sector.

(2) 【9/●●(Mon)】

Date and time	September ●● (Monday) 14:00-15:00
Training Title	Promoting i-Construction (Productivity Revolution at Construction Sites)
Instructor (Position)	Technology Research Division, Minister's Secretariat, MLIT, Japan
Purpose of lecture	Deepen knowledge through lectures on the status and prospects of the full use of ICT technology to improve productivity in construction production systems.

(3) 【9/●●(Mon)】

Date and time	September ●● (Monday) 15:00-16:00
Training Title	Promoting i-Construction (Productivity Revolution at Construction Sites)
Instructor (Position)	Professor Tateyama, Ritsumeikan University
Purpose of lecture	Deepen knowledge through lectures on the status and prospects of the full use of ICT technology to improve productivity in construction production systems.

(4) 【9/●●(Mon)】

Date and time	September ●● (Monday) 16:00-16:30
Training Title	High Quality Infrastructure Development
Instructor (Title)	JICA Social Infrastructure Department
Purpose of lecture	Deepen knowledge and understanding of the concept of infrastructure development through Japan's ODA and the significance of infrastructure development promoting DX.

(5) 【9/●●(Tue)】

Date and time	September ●● (Tuesday) 10:00-11:00

Training Title	Utilization of Digital Data in Social Capital Management
Instructor (Position)	Social Infrastructure Management Research Center, National Institute of Advanced Industrial Science and Technology
Purpose of lecture	Deepen your knowledge through lectures on the DX Data Center, digital data acquisition at construction sites, and infrastructure data platforms that are working toward the use of digital data in social capital management.

(6) 【9/●●(Tue)】

Date and time	September ●● (Tuesday) 11:00-11:30
Training Title	Research Facilities: DX Data Center, Experimental Field
Instructor (Position)	Social Infrastructure Management Research Center, National Institute of Advanced Industrial Science and Technology
Purpose of lecture	Deepen your knowledge by visiting the experimental fields and other facilities within the institute.

(7) 【9/●●(Tue)】

Date and time	September ●● (Tuesday) 13:00-14:00
Training Title	Promotion of water-related disaster prevention using big data and ICT technology
Instructor (Position)	National Institute of Public Works, Japan International Center for Water Hazard and Risk Management
Purpose of lecture	Deepen knowledge through lectures on research to support decision-making from managers to citizens, such as data-driven water-related disaster prevention through centralized management of water-related disaster information using ICT technology.

(8) 【9/●●(Tue)】

Date and time	September ●● (Tuesday) 14:00-15:00
Training Title	Improving Reliability of Road Bridge Maintenance by Using AI Technology
Instructor (Position)	National Institute of Public Works Research Center for Structural Maintenance
Purpose of lecture	Deepen knowledge through lectures on research to improve the reliability of inspections, diagnosis, and measures in the maintenance cycle, focusing on the accelerating development of AI technology.

(9) 【9/●●(Tue)】

Date and time	September ●● (Tuesday) 15:00-16:00
Training Title	Accelerating Innovation through New Monitoring Technologies
Instructor (Position)	National Institute of Public Works Advanced Materials Technology Resource Center
Purpose of lecture	Deepen knowledge through lectures on the development of new monitoring technologies to visualize invisible areas and improve efficiency.

(10) 【9/●●(Wed)】

Date and time	September ●● (Wednesday) 9:00-12:00
Training Title	Laser and photogrammetric surveying techniques using GNSS and other drones
Instructor (Position)	Private companies and manufacturers Topcon Corporation / Navigation companies
Purpose of lecture	Deepen knowledge through lectures on ICT automated construction systems that can automatically control construction equipment by utilizing 3D measurement systems and sensing control technology, and examples of productivity improvement through DX solutions that link data, such as centralized management of the workflow of “surveying, design, construction, and inspection” using 3D digital data. In the field of surveying, deepen your knowledge through lectures on measurement methods such as GPS/GNSS and aerial lasers according to the scale and scope of the measurement target.

(11) 【9/●●(Wed)】

Date and time	September ●● (Wednesday) 13:00-15:00
Training Title	Experience the operation of the latest ICT equipment and construction equipment systems

	and the creation of 3D data using the latest software
Instructor (Position)	Private companies and manufacturers Topcon Corporation / Navigation companies
Purpose of lecture	Deepen knowledge through demonstrations and direct experience in the operation of equipment and technologies related to (10) above.

(12) 【9/●●(Wed)】

Date and time	September ●● (Wednesday) 15:00-16:00
Training Title	Next generation construction production system by automation of construction machinery
Instructor (Position)	General contractor Kajima Corporation
Purpose of lecture	Through lectures on A4CSEL (Quad-Axel), a next-generation construction production system with a focus on automation of construction machinery that improves safety and productivity at job sites and ensures the stable provision of high-quality infrastructure, participants will deepen their knowledge.

(13) 【9/●●(Thu)】

Date and time	September ●● (Thursday) 10:00-1500
Training Title	Basic Knowledge of Informatization Construction
Instructor (Position)	Construction Technology Research Institute, Japan Construction Technology Association (Fuji City, Japan)
Purpose of lecture	Deepen knowledge through lectures on the basics of information-based construction in i-Construction. (1) Entry and exit to information-based construction (2) Construction industry and information-based construction (3) Civil engineering construction and construction machinery (4) Data in information-based construction (5) Positioning in information-based construction (6) Basic tools for advanced construction and surveying (7) Examples of information-based construction (8) Work form management in information-based construction (9) Application of ICT to maintenance management, etc.

(14) 【9/●●(Thu)】

Date and time	September ●● (Thursday) 15:00-17:00
Training Title	Demonstration of Work Form Management Method Using TS
Instructor (Position)	Construction Technology Research Institute, Japan Construction Technology Association (Fuji City, Japan)
Purpose of lecture	Deepen knowledge through demonstrations and direct experience of the methods of work form management using TS.

(15) 【9/●●(Fri)】

Date and time	September ●● (Friday) 10:00-11:00
Training Title	Improving Facility Management Efficiency Using 3D Point Cloud Data
Instructor (Position)	Shizuoka Prefecture, Topcon Hitachi Solutions, Ltd. Good Design Award 2020
Purpose of lecture	Deepen knowledge through lectures on the collection and utilization of 3D point cloud data, 3D point cloud open data “1VIRTUAL AHIZUOKA”, etc., which are part of the activities of the “Fuji-no-Kuni i-Construction Promotion Support Council”, a group led by Shizuoka Prefecture and consisting of the national government, local governments, construction companies, research institutes, manufacturers, software companies, etc.

(16) 【9/●●(Fri)】

Date and time	September ●● (Friday) 11:00-12:00
Training Title	DX Promotion for Community Development
Instructor (Position)	Shizuoka Prefecture Atami City, etc.
Purpose of lecture	Deepen knowledge through lectures on the examples of safe, secure, convenient, smart,

	and recycling-oriented regional development being undertaken by Atami City and Shimoda City in Shizuoka Prefecture, which have been selected as leading model projects for the Smart City Model Project by MLIT. VIRTUAL SHIZUOKA", a virtual 3D prefecture in cyberspace, is being built to support the movement of tourists and speed up disaster response through automated driving in urban areas. In Susono City, Shizuoka Prefecture, Toyota is planning a project to develop an experimental city called "Woven City.

(17) 【9/●●(Fri)】

Date and time	September ●● (Friday) 11:00-12:00
Training Title	ICT earthwork, ICT dredging, ICT slope construction site
Instructor (Position)	MLIT, local governments, highway companies, etc. in Shizuoka Prefecture
Purpose of lecture	Deepen the knowledge of ICT-implemented construction sites in Shizuoka Prefecture. Perspectives onsite inspection (draft) ・ Implementation system ・ Utilization of 3D data ・ On-site management ・ Communication ・ Information sharing ・ Deployment to maintenance management

(18) 【9/●●(Mon)】

Date and time	September ●● (Monday) 9:00-12:00
Training Title	Approaches to the development of information infrastructure for the linkage of maintenance management databases
Instructor (Position)	Professor Hisada, Tohoku University Yamagata Prefecture, Daisen City
Purpose of lecture	Deepen knowledge through lectures on efforts to develop a database information infrastructure to improve the efficiency of road maintenance and management in local governments, which are facing challenges such as a lack of technical personnel and budget.

(19) 【9/●●(Mon)】

Date and time	September ●● (Monday) 13:00-15:00
Training Title	Design, construction, and maintenance management using BIM/CIM 3D models
Instructor (Position)	CAD Manufacturer Autodesk, Inc., and others
Purpose of lecture	Deepen knowledge through lectures on the introduction of products for infrastructure that utilize BIM/CIM 3D models and examples of design, construction, and maintenance management.

(20) 【9/●●(Mon)】

Date and time	September ●● (Monday) 15:00-17:00
Training Title	Exercises on design, construction and maintenance using BIM/CIM 3D models
Instructor (Position)	CAD Manufacturer Autodesk, Inc., and others
Purpose of lecture	Deepen knowledge through demonstrations and operation exercises of the products mentioned in (19) above.

(21) 【9/●●(Tue)】

Date and time	September ●● (Tuesday) 10:00-17:00
Training Title	Introduction and demonstration of technologies promoting DX
Instructor (Position)	Private companies, etc.
Purpose of lecture	Deepen knowledge through introduction and demonstration of various modern technologies and products promoting DX. Assumed themes of modern technologies and products (1) Improving the efficiency of infrastructure inspections by using AI, robots, sensors,

	etc. (2) Improving the efficiency of construction management using wearables and tablets (3) Efficient acquisition of skills through digitization of skilled workers (motion sensors, VR) (4) Visualization technology for underwater structures (bridges and dams)

(22)【9/●●(Wed)】

Date and time	September ●● (Wednesday) 10:00-12:00
Training Title	Remote Control System for Public Infrastructure Facility Operation
Instructor (Position)	Rivers and roads (Example: NEXCO East Japan Kanto Branch Iwatsuki Road Control Center)
Purpose of lecture	Deepen knowledge by observing the remote facility system for infrastructure facility operation using the latest ICT technology. ・ Road control center ・ River management facilities, etc.

(23)【9/●●(Wed)】

Date and time	September ●● (Wednesday) 14:00-17:00
Training Title	Explanation and Demonstration of Smart Construction
Instructor (Position)	Komatsu IoT Center Tokyo (Mihama-ku, Chiba City)
Purpose of lecture	Deepen knowledge through explanations and demonstrations of the latest ICT construction equipment and drones (unmanned helicopters).

(24)【9/●●(Thu】

Date and time	September ●● (Wednesday) 9:00-17:00
Training Title	Report writing
Instructor (Position)	
Purpose of lecture	Have the participants extract two to three technologies/knowledge from those acquired in the training and prepare a report proposing measures and improvements that can be applied to their own country. [Flow of preparation] (1) Guidance for report writing (2) Group discussion for brainstorming and information sharing (3) Report writing

(25)【9/●●(Fri)】

Date and time	September ●● (Wednesday) 9:00-15:00
Training Title	Report Presentation
Instructor (Position)	
Purpose of lecture	Participants will present their reports and share their knowledge and findings through questions and comments.

Chap.11 Survey on Maintenance and Management Status of Special Bridges

11.1 Target of the Chapter

Check and analyze the actual status of achievement of AM and maintenance of special bridges constructed by JICA projects based on the materials and information provided by JICA. The survey will be conducted in two countries: the Philippines (two bridges) and Thailand (one bridge), both of which will be web-based surveys.

11.2 Overview of Technical Cooperation Project in the Philippines

Roads and bridges in Philippines are constructed, maintained, and managed by Department of Public Works and Highways (hereafter referred to as the DPWH). The extension of road management (as of October 2018) is approx. 33,000 km (Primary Road: approx. 7,000km, Secondary Road: approx. 14,000km, Tertiary Road: approx. 12,000km) and the total number of bridges is approx. 8,400. The number of special bridges is approx. 100.

Regarding organizations, this department has six 6 bureaus (Maintenance Bureau, Design Bureau, Survey Standards Bureau, Construction Bureau, Equipment Bureau, Quality Safety Bureau) in the ministry in Manila as Technical Service bureau, 16 Regional Offices (RO), and 184 District Engineering Offices (DEO).

The special bridges are maintained and managed by RO and DEO across the country and the greater part of them are constructed with the aid of foreign countries. There are a lot of bridges which have been constructed especially with the aid of Japan.

Regarding the “quality improvement project related to construction and maintenance of roads and bridges (Feb. 2007 to Feb. 2010) and the “quality improvement project related to construction and maintenance of roads and bridges phase II” (Oct. 2011 to Sep. 2014), JICA implemented the dissemination of technology related to maintenance and management of roads and bridges for DPWH ministry and 3 model regions (RO-CAR, RO-VII, RO-XI) and implemented the technology transfer related to special bridges inspections technology (formulation of inspection manual, implementation of inspections of bridges based on this manual) for 5 regions (RO-II, RO-III, RO-VII, RO-VIII, RO-XIII).

In the “quality improvement project related to construction and maintenance of roads and bridges phase III” (Apr. 2016 to Mar. 2019), JICA continuously implemented the special bridges repair pilot project based on the inspection results of special bridges, which had been implemented at the phase II and implemented the maintenance of daily maintenance and management manual and OJT based on the fact that the daily maintenance and management of special bridges are not sufficiently implemented so that maintenance and management can be continuously implemented.

The pilot project was implemented for suspension bridge: the Magapit Bridge (RO-II), cable-stayed bridge (the Diosdado Makapagal Bridge), steel arch bridge: the Bamban Bridge, steel truss bridge: the 1st Mactan Bridge (RO-VII) in the special bridges in the country. The costs required for the construction were born by DPWH and the project team implemented the preparation of repair plan and the support of construction supervision with counterpart.

Since the special bridges are long-span bridges and the structure is complicated, maintenance and management of bridges are important. Moreover, most all these bridges are constructed with support of other donners. However, proper maintenance and management are not implemented after the construction in developing countries because the inadequacy of ability related to special bridge technology.

This situation is similar in the Philippines. Most all special bridges are not properly maintained or managed. At the phase III, bridges shown below that seem to become large problems for maintenance and management were found in the target special bridges.

1) The Marcelo Fernan Bridge: PC box girder extradosed bridge
   alkali silica reaction
2) The Diosdado Makapagal Bridge: steel box girder cable-stayed bridge
   abnormal vibration of cables

11.3 The Marcelo Fernan Bridge

11.3.1 Overview

The AM evaluation of the Marcelo Fernan Bridge meets level 3 – the target of the JICA technical cooperation project – in all technical items (“Inspection”, “Diagnosis”, “Repair & Rehabilitation Plan”, “Daily Maintenance Management”, “Repair”, “Rehabilitation and Reconstruction”). The only middle item that does not meet the level 3 target for the JICA technical cooperation projects is budget financing.

If possible, a five-year repair and Rehabilitation plan should be developed, and a budget request made. In addition, it is recommended that a special bridge maintenance budget be secured.

The alkali–silica reaction (ASR) is progressing and is thought to be developing from a transitional phase into an accelerated phase. For the time being, it is necessary to extend the service life by continuing the ASR treatment, and in the long term, it will be necessary to consider large-scale reconstruction or even replacement of the bridge.

The ongoing training in inspection and diagnosis, led by engineers trained through the JICA technical cooperation project, can serve as a model for others.

11.3.2 Overview of the Loan Project for the Marcelo Fernan Bridge

Metro Cebu, the second largest economic city in the Philippines, has developed with Mactan Airport and the Mactan Export Processing Zone at its core, and has become a driving force for the Philippine growth. Prior to the construction of the Marcelo Fernan Bridge, the only bridge connecting Mactan Island to the main island of Cebu, the First Mactan Bridge, was experiencing a rapid increase in traffic (15% increase per year, at that time). However, due to the damage to the piers caused by a ship collision in 1990 and the increase in traffic, the durability of the bridge had deteriorated, and it was unable to meet the traffic demand. The construction of a new four-lane the Marcelo Fernan Bridge and the rehabilitation of the first Mactan Bridge were urgent issues.

On the other hand, traffic congestion in the central part of Cebu City was also significant, and the construction of a detour road connecting the northern part of Cebu City and the southern part of Metro Cebu was urgently needed. In addition, there was a plan to set up an export processing zone in the reclaimed land to be developed in the south of Cebu City, and the construction of an access road was essential.

Therefore, to cope with the rapid increase in traffic demand between Mactan Island and Cebu Island, it was essential to build a four-lane the Marcelo Fernan Bridge and to rehabilitate the First Mactan Bridge to improve its safety. Under these circumstances, the Marcelo Fernan Bridge (Second Mactan Bridge at the time of the project) was constructed with yen loans as Second Mactan Bridge (II) and Metro Cebu Road Improvement Project, which, together with the Cebu South Coastal Highway (Metro Cebu Road), aims to reduce traffic congestion in the city center of Metro Cebu and thereby develop the local economy of Metro Cebu.

In addition to the Mactan Bridge (II), the second Mactan Bridge (II) and the Metro Cebu Road Improvement Project were constructed with yen loans to ease traffic congestion and thereby develop the economy of the Metro Cebu region. (Table 11.1,Table 11.2)

Table 11.1 Summary of Loan Agreement (The Mactan Bridge 2 (II) and Metro Cebu Road Project)

Borrower/Implementing Organizations	Government of the Republic of the Philippines / Ministry of Public Works and Roads（DPWH）	
Amount of yen Loan Approved Execution Amount	6,593million yen 6,340million yen	
Signing of the Exchange of Notes Signing of Loan Agreement	March 1997 March 1997	
Terms and Conditions Interest Rate Repayment Period (Deferment Period) Procurement	Body part 2.7％ 30years (10years) General Untied	For consultants 2.3％ 30years (10years) General Untied
Loan Completion	June 2004.	
Start of (Construction) Work	1997.	
Completion / Opening	1999./1999.	
Main Contract	Kajima and Sumitomo Construction（JV）/ Kajima	
Consultant Contract Related	Katahira Engineering International/ Katahira Engineering	
Research	Preparation of F/S (Second Mactan Bridge Construction Project) by DPWH (December 1990). SAPROF (Central Visayas Urban Planning) prepared by JICA (July 1988), F/S (Metro Cebu Development Project (III)) prepared by DPWH (November 1989)	
Related Business	Yen Loan: Metro Cebu Development Project (I) (Signed N/A in May 1989) Metro Cebu Development Project (II) (Signed N/A in February 1990) Metro Cebu Development Project (III) E/S Loan (Signed N/A in June 1991) Mactan Bridge No. 2 Construction Project (Signed N/A in August 1993) Metro Cebu Development Project (III) Landfill/Coastal Road (Signed N/A in August 1995) Grant Aid: Construction/Materials for Local Roads and Bridges (5 rounds since 1989)	

Table 11.2 The Mactan Bridge No. 2 (II) and Metro Cebu Road Project Construction Specifications

Section (Bridge)	Various factors or elements
PC box girder extra-dose bridge	・ Total length：410m ・ Number of lanes：4 lanes (2 lanes in each direction)
Approach elevation/road	・ Total length：3,292m（overhead structure 635m、Approach road 2,657m） ・ Left turn flyover 192m
Cebu South Coast Road (Metro Cebu Road)	・ Talisay section road construction（Total length 4.5km, 4 traffic lane）

11.3.3 Overview of the Maintenance of the Marcelo Fernan Bridge

(1) Location Map of the Bridge

The bridge of interest (the Marcelo Fernan Bridge) is under the management of DPWH and connects the main island of Cebu with Mactan Island, over the sea (Figure 11.1). The other bridge connecting Cebu and Mactan Island is the First Mactan Bridge, completed in 1973, but the First Mactan Bridge is severely damaged and deteriorated, and traffic is restricted to vehicles with less than six wheels, making the Marcelo Fernan Bridge the only bridge connecting Cebu and Mactan Island that is open to heavy vehicles (Figure 11.2).

Figure 11.1 The Marcelo Fernan Bridge Location Map (left) and Photo (right)

Figure 11.2 The Marcelo Fernan Bridge Location Map (Cebu Main Island and Mactan Island)[116]

[116] JICA: Philippines No.2 Mactan Bridge (II) and Metro Cebu Road Improvement Project Post-Evaluation Report, 2012.

(2) Bridge Specifications, etc.

The specifications of the Marcelo Fernand Bridge are shown in Table 11.3 and the annual average traffic volume is shown in Table 11.4. The general view of the Marcelo Fernand Bridge is shown in Figure 11.3, the side view is shown in Figure 11.4, the girder cross section is shown in Figure 11.5,and the tower cross section and tower side view are shown in Figure 11.6. And the average daily traffic volume for the two-week period from Monday, November 23, 2020, to Sunday, December 6, 2020, is shown in Table 11.4.

Table 11.3 Specification of the Marcelo Fernan Bridge

Bridge Name	Marcelo Fernan Bridge [Second Mactan Bridge at the time of JICA project].
Bridge Type	PC box girder extra-dose bridge
Bridge Length, Span Length	Bridge length 410m, span length 185m
Purpose	Road bridge (4 lanes (2 lanes in each direction))
Start of (Construction) Work	1997.
Completion of Construction	1999.
Loan agreement	1997-(30 years)

Table 11.4 Average Daily Traffic for the Two-Week Period in 2020(11/23 to 12/6)

Vehicle Type	Vehicles/Day
Motor-Tricycle, passenger Car	14,061
Passenger Utility, goods Utility	1,609
Small bus, large bus	1,113
Rigid truck 2axles, rigid truck 3axles	2,030
Truck semi-trailer 3 and 4 axles Truck semi-trailers 5+axles Truck trailers 4 axles Truck trailers 5+axles	262
Total	19,074

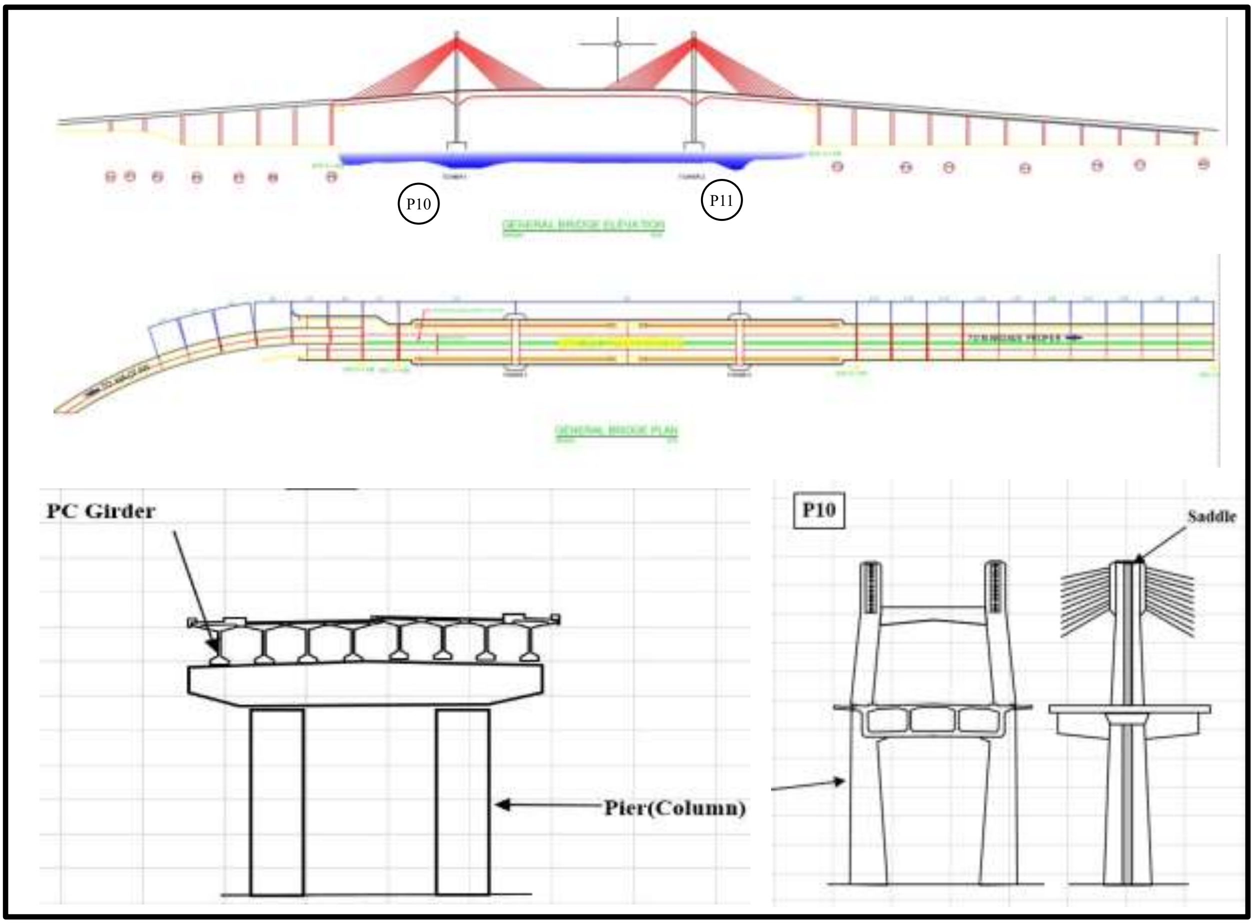


Figure 11.3 General View of the Marcelo Fernan Bridge

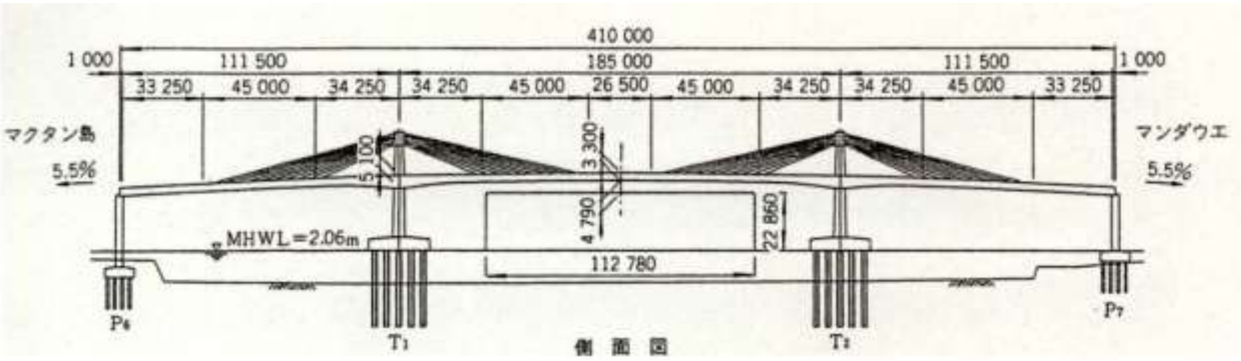


Figure 11.4 Side View of the Marcelo Fernan Bridge

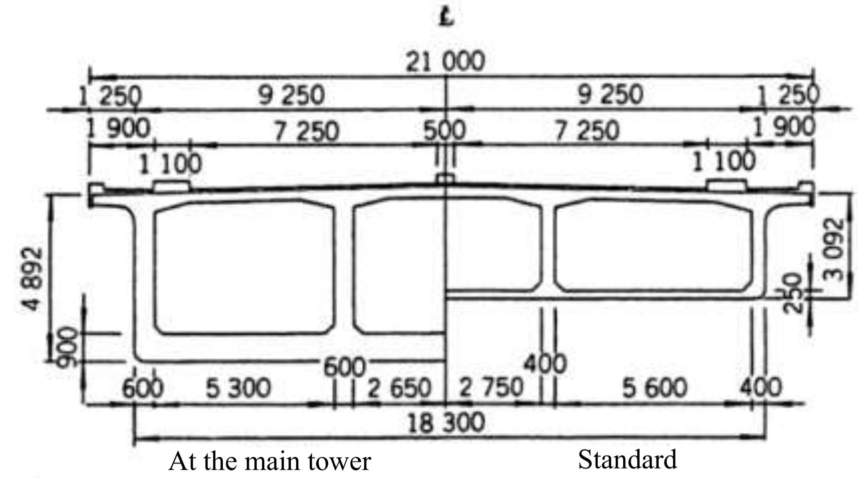


Figure 11.5 Cross-Sectional View of the Marcelo Fernan Bridge

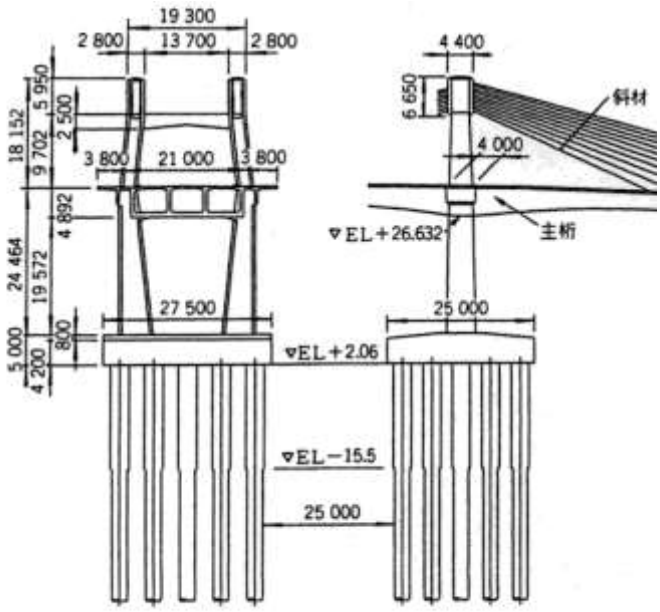


Figure 11.6 Cross Section and Side View and of Main Tower of the Marcelo Fernan Bridge

(3) Organizational Structure

The Marcelo Fernan Bridge is maintained under the jurisdiction of the Region 7 office of the Philippine Department of Public Works and Highways (DPWH) with the district office structure shown in Figure 11.39

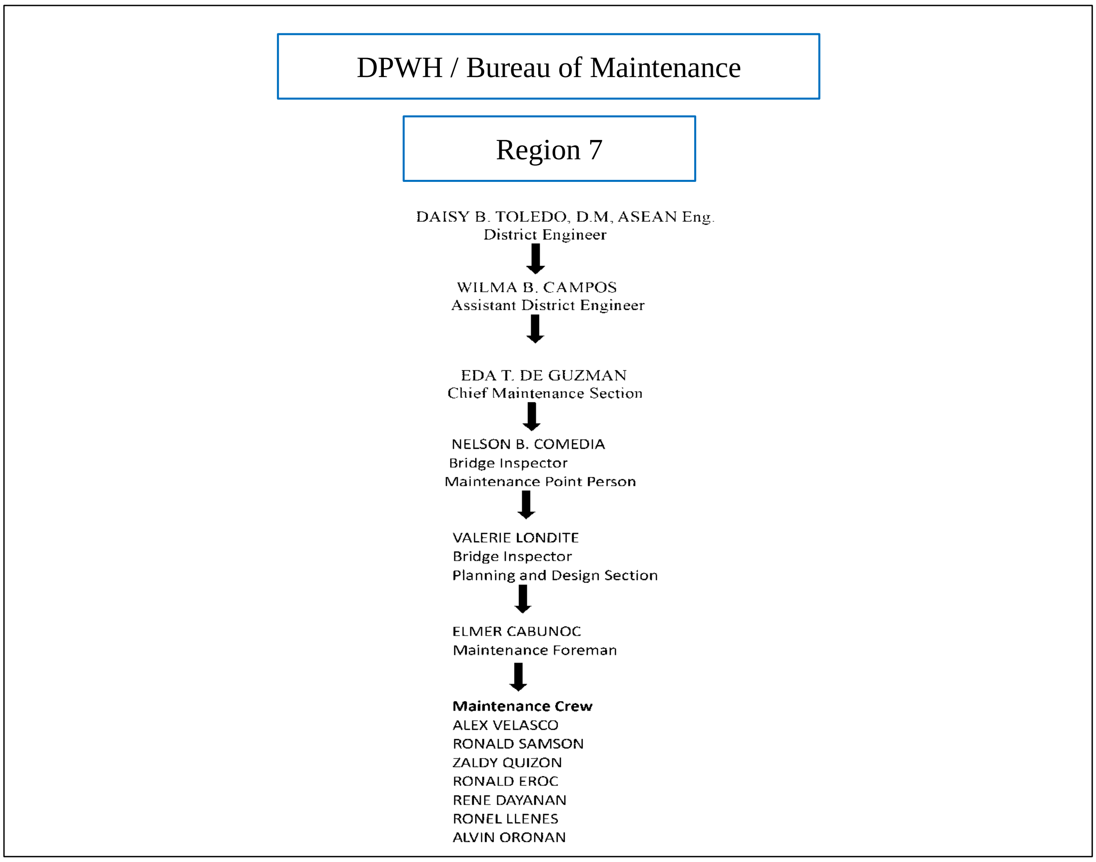


Figure 11.7 Assignment of Marcelo Fernand Bridge in the DPWH Organization

(4) Maintenance Budget

Marcelo Fernand Bridge's annual maintenance work program (AMWP) for bridges is allocated for all the 21 bridges. It is not devised to specify certain amount for each bridge. Approximately Php 3,336,044.26, Php 5,116,158.97 and Php 2,181,882.72 respectively for CY 2019, 2020 and 2021 allocated for routine activities such as patching potholes, crack sealing, repainting peeled off paint, minor repairs on concrete curbs due to ramming, repainting of faded pavement markings and the like. The said amounts cover the expenditures for the labor, equipment, and materials during maintenance activities for each year.

(5) Technical Standard

There is an inspection manual, namely "Bridge Engineering Inspection Manual (2014)", but for special bridges specifically, "Bridge Inspection Manual for Extradosed Bridges (2014) "is in operation for the Marcelo Fernand Bridge. They are developed through JICA technical cooperation project, and they have not yet been revised.

11.3.4 Technical Challenges of the Marcelo Fernan Bridge

11.3.4.1 History of Project in the Past

The communication related to "alkali silica reaction" between project team and DPWH are summarized in chronological order as shown below.

As a result of inspection survey by project team found a crack indicating the alkali silica reaction at the pillar section of pier of main tower. The aggregate for concrete at the construction was transported from Leyte because there was no good-quality aggregate in Cebu. Since the soil of the Philippines frequently causes alkali silica reaction because the Philippines is volcanic region.

Table 11.5 History of Project in the Past

Year and Month	Item	
Mar. 2016	TCP-III project started	
Apr. 2016	Project team found ASR by implementing the visual inspection	Project team
May 2017	Implementation of detailed inspection was requested	From DPWH to JICA office
Jan. 2018	Inspection utilizing NDT was implemented	Project team
Mar. 2018	A sample was collected from pier of main tower	Project team
Jun. 2018	ASR repair method was suggested	From Project team to DPWH
Jul. 2018	ASR test was implemented for the sample	Project team
Sep. 2018	Test result report was submitted to DPWH	Project team
Mar. 2019	ASR repair was implemented	DPWH

Figure 11.8 Situation of Crack Caused by ASR

The project team made a comment and suggested the repair method for ASR as shown below.

a) Comment

- For the bridge, the concrete aggregate in Leyte is selected and used. Since Cebu is mainly made of limestone, the quality of aggregate is not good.
- Since Philippines is in volcanic terrain, the aggregate used for concrete may cause Alkali-silica aggregate reaction.
- Use of reactive aggregate or existence of water, and use of extremely alkaline substance encourages or generates crack to deteriorate concrete.

Most all of cracks form grid-like or turtle shell-like crack pattern. Now, it is difficult to clearly classify

the process of bridge performance degradation due to ASR in stages to forecast the period of each stage. However, the process of degradation can be classified into 4 stages: initial stage, expansion stage, acceleration stage, degradation stage because the degree of performance degradation changes upon the process of degradation. Since the effect of degradation phenomenon on the performance of a bridge varies for each stage, process of degradation, evaluation, and repair method vary for each stage. b) Suggestion of repair The project team suggested the response in the figure as shown below. - Carry out the detailed inspections and investigation for whole bridge including PC box girder in addition to pier as early as possible. - Repair piers 10 and 11 early. As a repair method, the method using Lithium Silicate Modifier is suggested. For the detailed repair procedure, refer to the previously suggested report.

11.3.4.2 Result of Hearing

(1) Alkali-Silica Aggregate Reaction (ASR)

Question: Was the ASR countermeasure construction implemented? If it was implemented, please introduce the construction method. Please let us know supplier of materials and construction company too.
Answer: It is being implemented. - 2020: it was already implemented at the lower surface of main girder (PC box girder) shown in page 9 (implemented by DEO) - 2021: it was already implemented at the pier of main tower shown in pages 10 and 11 (implemented by RO) - 2022: planned to be implemented at the main girder (PC box girder) (planned to be implemented by RO) The construction has been implemented since 2020 and planned to be terminated in 2022. For the construction method, a method, which is introduced in TCP-III, lithium nitrite + lithium silicate system surface impregnation material application method (lithium ions, especially the lithium nitrite and lithium silicate) was adopted. After applying the impregnation material additionally, polymer cement mortar containing lithium was applied as a measure against salt damage. For the material, a Japanese product is used. The construction company is a local contractor in Philippines who has experience of repair pilot project in TCP-III.
Question: Did you find any suspicious ASR point in addition to a point where the countermeasure construction was implemented?
Answer: The symptom of ASR is found at the main girder PC box girder as shown above. The construction is planned to be implemented in 2022.
Question: Is there a continuous repair plan?
Answer: Yes, there is. We have ensured the budget for carrying out ASR countermeasure construction at main girder part in 2022 to terminate the countermeasure construction within all ranges affected by ASR.

(2) Problems Related to Maintenance and Management

Question: Are there problems related to maintenance and management of bridges?
Answer:

It is difficult to carry out maintenance and management because there is no equipment (example: lift car) for carrying out inspections and repair at high place such as main tower and cables. (Supplement from investigation team) With TCP-III, an inspection method utilizing a drone is introduced for the inspections of special bridges. It is additionally shown in the manual. Please reference it.
Question: Are daily maintenance and management implemented periodically?
Answer: Yes. We are carrying out daily maintenance and management to find out damage etc. as early as possible and ensure the safety of traffic. (Supplement from investigation team) What is the concrete work? -> We are carrying out cleaning, repair of pavement pothole, paint application, cleaning of expansion device etc.
Question: Is there budget for daily maintenance and management?
Answer: There is budget for daily maintenance and management, but it is not sufficient for maintenance and management of this bridge. However, the minimum budget for maintenance and management is ensured.
Question: Is there a plan for repairing the bridge in the future?
Answer: The repair work is planned to be implemented by RO as a budget in FY2022 based on National Expenditure Program / bridge repair and reinforcement policy construction.

(3) Inspections of Special Bridges

Question: Are daily inspections implemented periodically?
Answer: The daily inspections are implemented twice a month.
Question: Were the periodical inspections implemented after TCP-III?
Answer: The periodical inspections were implemented every year; 2019, 2020, 2021. It was especially implemented for measures against ASR and examination of repair of crack.
Question: Are there other damages?
Answer: As it now stands, ASR is generated in and out of box girder of main tower and main girder, but it is the major damage.

(4) Other

Question: Damage situation of typhoon ODETTE

Answer:
Damage of cables, damage of cover at the cable anchorage zone, damage of road lighting, damage of guard fence

(Supplement from investigation team)
a.) Damage of cables:
Since the details are unknown, it is necessary to inspect the damage early to confirm the situation. If a PC cable is exposed depending on the situation of damage, water may enter the PC cable and whole cable may get flooded. If water penetrates in a cable, we have to carry out temporary repair (covering the damaged part with polymer mortar) early to prevent water from entering as an emergency repair.
b.) Damage of cover at cable anchorage zone
If there is a gap at the joint etc., carry out repair with polymer mortar to prevent water from entering.
c.) Damage on bridge surface asphalt pavement
When carrying out replacement of next pavement, it is recommended to construct waterproof layer to prevent degradation of PC box girder of main girder.

11.3.5 AM Maturity Level of the Marcelo Fernan Bridge

11.3.5.1 How to Conduct Maturity Evaluations

The maturity evaluation was conducted through web interviews with the participants according to the schedule shown in Table 11.6. Content of the Maturity Evaluation Hearing In the hearings, we asked them to explain the reasons and background behind the low and high items that they graded. In addition, if the other party offered to revise the level during the hearing, the revision was made on the spot. The evaluation sheet was distributed in advance, and the grading procedure was explained during the kick-off meeting.

In the hearings, we asked them to explain the reasons and background behind the low and high items that they graded. In addition, if the other party offered to revise the level during the hearing, the revision was made on the spot.

Table 11.6 Content of the Maturity Evaluation Hearing

Title	Date / Time	Participants	Notes
JICA Kick-off	November 10, 2021 /11:30-12:00	JICAHQ, JEXWAY	Explanation of aim
	November 25, 2021 /11:00-12:00	JICAHQ, JICA Philippines office、JEXWAY	Explanation of aim
DPWH Kick-off	January 6, 2022 /13:00-14:00(PST)	• Engr. Teofila SF. Borlongan (OIC-Assistant Director, Bureau of Maintenance) • Engr. Krezia M. Tactac (Engineer II, National Building Services Division, Bureau of Maintenance) • Engr. Noe O. Bonga (Engineer II, National Building Services Division, Bureau of Maintenance) • Engr. Nenita R. Jimenez (Chief, Development Planning Division, Planning Service) • Engr. Justino Jaime T. Surot (Engineer III, Development Planning Division, Planning Service) • Engr. Rosario C. Calves (JICA TWG Member – Engineer III, Maintenance Division, Region VII) • Engr. Bryan James C. Pitos (JICA CWG Member – Engineer II, Planning and Design Division, Region XIII) • Engr. Irewil D. Flores (JICA CWG Member – Engineer II, Maintenance Division, Region XIII) • Engr. Faustino A. De La Cruz, Jr. (Chief, Maintenance Division, Region VII) • Engr. Daisy B. Toledo (District Engineer, Cebu VI District Engineering Office) • Engr. Eda T. De Guzman (Chief, Maintenance Section, Cebu VI District Engineering Office) • Engr. Cristina Luz R. Cacayan, Chief (Maintenance Division, Region XIII) • Engr. Jose Caesar A. Radaza (District Engineer, Butuan City District Engineering Office) • Engr. Reynaldo A. Canlas (Chief, Maintenance Section, Butuan City District Engineering Office) • Engr. Marc Joseph M. Brutas (Engineer II, Office of the Undersecretary Carvajal)	Explanation of aim, date and time schedule

Title	Date / Time	Participants	Notes
DPWH 1st interview	January 19, 2022 /13:00-15:30(PST)	• Engr. Rosario C. Calves (Engineer III, Maintenance Division, Region VII) • Engr. Nelson, Comedia (District 6) • Engr. Justino Jaime T. Surot (Engineer III, Development Planning Division, Planning Service) • Engr. Teofila SF. Borlongan (OIC- Assistant Director, Bureau of Maintenance) • Engr. Krezia M. Tactac (Engineer II, National Building Services Division, Bureau of Maintenance)	Marcelo Fernan Bridge: Evaluation sheet scoring
DPWH 2nd interview	January 26, 2022 /13:00-16:00(PST)	• Engr. Noe O. Bonga (National Building Services Division, Bureau of Maintenance) • Engr. Krezia M. Tactac (Engineer II, National Building Services Division, Bureau of Maintenance) • Engr. Eda T. De Guzman (Chief, Maintenance Section, District 6) • Engr. Nelson, Comedia (Bridge Inspector, District 6) • Engr. Justino Jaime T. Surot (Development Planning Division, Planning Service) • Engr. Rosario C. Calves (Maintenance Division, Region VII) • Engr. Bryan James C. Pitos (Planning and Design Division, Region XIII)	Questions on individual issues, Additional Questions
DPWH Feedback	February 9, 2022 /13:00-15:05(PST)	• Engr. Noe O. Bonga (National Building Services Division, Bureau of Maintenance) • Engr. Krezia M. Tactac (Engineer II, National Building Services Division, Bureau of Maintenance) • Engr. Eda T. De Guzman (Chief, Maintenance Section, District 6) • Engr. Nelson, Comedia (Bridge Inspector, District 6) • Valerie Londite (District 6) • Engr. Rosario C. Calves (Maintenance Division, Region VII) • Engr. Bryan James C. Pitos (Planning and Design Division, Region XIII) • Vincent Montrix Calapre (Region VII)	
JICA Report	February 16, 2022 From 16:00	JICA Headquarters	

11.3.5.2 Maturity Evaluation Results

(1) Radar Chart

The radar chart (level evaluation) by major and medium items is shown in Figure 11.9 Major and Medium Item Radar Chart (Level). Red is the result of the evaluation of the Marcelo Fernan Bridge in DPWH, and the gray dotted line indicates a perfect score. The radar chart based on the level evaluation of the Marcelo Fernan Bridge in DPWH is partly asymptotic to the case of a perfect score, and to show the situation clearly, Figure 11.10 shows the radar chart based on the achievement rate evaluation, which shows the evaluation result of each item as a percentage of its perfect score.

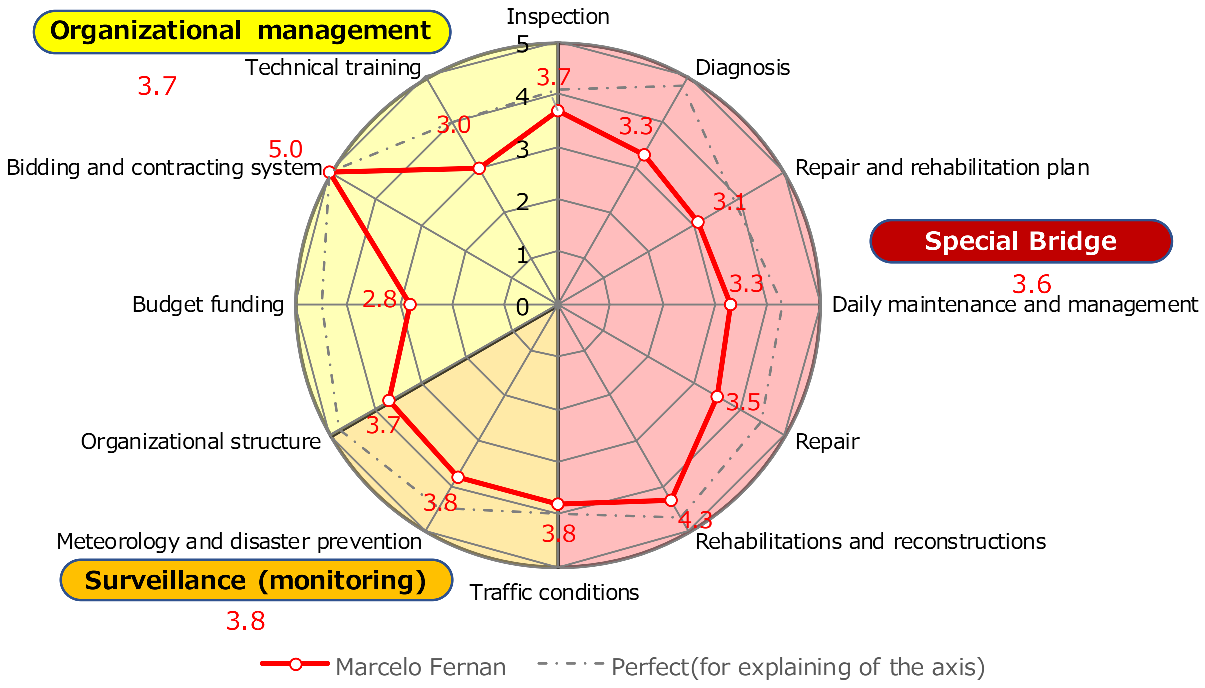


Figure 11.9 Major and Medium Item Radar Chart (Level)

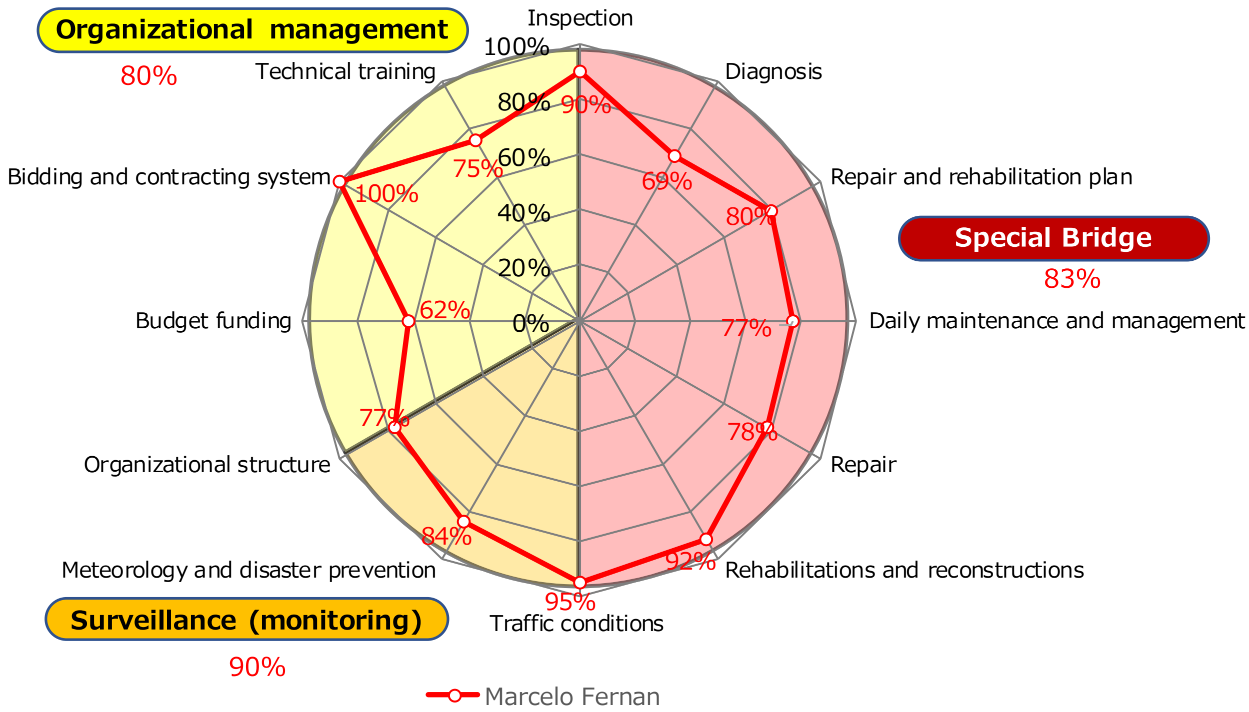


Figure 11.10 Major and Medium Item Radar Chart (Achievement Rate)

(2) Overall Evaluation

The AM evaluation of the Marcelo Fernan Bridge meets level 3 – the target of the JICA technical cooperation project – in all technical items (“Inspection”, “Diagnosis”, “Repair & Rehabilitation Plan”, "Daily Maintenance Management", "Repair, "Rehabilitation and Reconstruction"). The only middle item that does not meet the level 3 target for the JICA technical cooperation projects is Budget Financing.

1) The overall average level of the technical item "Special Bridges" is 3.6 (83%), and all of the middle items met the JICA technical cooperation target of level 3. As for the sub-items, Level 2.9 (71%) was for "Diagnostic Manual", level 2.6 (71%) for "Formulation of Repair and Reconstruction Plan", and level 2.5 (63%) for "Cleaning".
2) The overall average AM rating for "Surveillance (Monitoring)" is 3.8 (90%), which meets level 3 of the JICA technical cooperation target for the middle and sub-items.
3) The overall average AM rating for "Organizational Management" is level 3.7 (80%). Among the middle items, "Bidding and Contracting System" scores the perfect, but "Budget Funding" is at level 2.8 (62%), which is below the JICA technical cooperation target of level 3.

11.3.5.3 Current Status and Challenges of the Marcelo Fernan Bridge

(1) Inspection and Diagnosis

1) There are four types of inspections: Routine, Periodic, Engineering, and Emergency inspections. Basically, in-house engineers carry out the inspections, but there are cases where they are outsourced.
2) The above four inspections are basically carried out by qualified engineers of the DPWH. If there is a special need, the inspections may be outsourced and implemented by a hired consultant.
3) The subcontracting of inspections is handled by a different department, which is not under the jurisdiction of the bridge maintenance department, but they evaluate the contractor's capabilities and conduct pre-qualifications.
4) There are about four qualified engineers in the district office. Two are from the Planning Division and two are from the Maintenance Division.
5) There is ongoing training on inspection and repair of special bridges. The JICA Counterpart and project managers in charge of repairs serve as training instructors. Training will be held annually, and eligible persons will be trained as they arise.
6) Inspection equipment is all that is needed.
7) There is an inspection manual, but it has not yet been evaluated or revised.
8) The contents of the diagnostic manual are included in the inspection manual.
9) The diagnostic procedure is specifically created to fit the Marcelo Fernan Bridge. The damage evaluation criteria used in the diagnosis were those developed by JICA's technical professionals.
10) The first manuals were created by the World Bank when BMS was introduced. The inspection manual was reviewed by JICA's technical professionals.
11) Routine inspections are conducted once a week and Periodic inspections are conducted on an annual basis. Engineering inspections are conducted as needed, but often at five-year intervals.
12) Periodic inspections are conducted at an appropriate frequency. Even after the completion of the JICA technical cooperation project, inspections of special bridges are conducted once a year (2018, 2019, 2020, 2021). Periodic inspections in 2018 were conducted jointly by the District Office and the Regional Office, during which cracks in the box girders were discovered.

13) Inspection results are shared between the headquarters and regional offices. Every month, the inspection data along with the results of the activities will be sent to the headquarters. In addition, the headquarters updates the data of the inspection results once a year.
14) The diagnosis is not outsourced but is done directly by qualified technicians at the DPWH.
15) Diagnosis of extradosed bridges and ASR is technically difficult, so the level of "Diagnosis" is not high.

(2) Repair and Rehabilitation Plan

1) BMS was introduced by the World Bank in 2004. Then, four years after its introduction, a manual for inspection, diagnosis, and repair was introduced by the JICA technical cooperation project.
2) The MIRB (Maintenance Information System on Road Slope Protection & Bridge Repair), which manages data based on the manual introduced by the JICA technical cooperation project, has been introduced and is being operated separately from the World Bank's BMS. In addition, although the BMS system has not been updated, data such as inspection results continues to be updated.
3) Records of inspections, diagnosis, and repairs are updated and shared.
4) The repair plan is reviewed on a rolling three-year basis.

(3) Daily Maintenance and Management, Repair, Rehabilitation and Reconstruction

1) 10 DPWH staff including workers and supervisors.
2) Some small repairs are done directly by the organization, but larger scale repairs are outsourced.
3) There is sufficient machinery for maintenance and repair.
4) The budget for daily maintenance and management is being cut due to COVID 19.
5) There is a lack of specialized training required by maintenance managers for maintenance management due to technical difficulties. We believe that the level of maintenance management needs to be raised, and there are plans to hold specialized training sessions in maintenance management.
6) ASR is occurring in the main tower and box girder. The repair of the ASR is scheduled to be completed in 2022. The budget has been secured by the National Expenditure Program, Retrofitting/Strengthening.
7) For the repair method, two layers of lithium nitrite and lithium silicate were applied as recommended by the JICA technical cooperation, and then lithium mixed polymer cement mortar was applied as a protective layer. The repair material is a Japanese product, made by Alphatec.
8) Potholes were discovered in the bridge surface pavement and were repaired with general asphalt pavement.
9) Rehabilitation and reconstruction are outsourced. The technical level of the contractors is sufficient, and their work is appreciated.

(4) Surveillance (Monitoring)

1) The traffic volume is automatically measured and stored on the server for 24 hours, and the data can be shared. However, there is no traffic control center.
2) Wind speed and temperature are automatically measured at the regional office. Rainfall and temperature are measured by other agencies. This data is available upon request.

(5) Organizational Management

1) The AM cycle (Goal setting/Internal audit/Review) is established.
2) The number of staff in the department in charge of AM is insufficient.
3) The budget has been planned for two to three years. In addition, it is believed that the budget is unbalanced in many cases where budget requests are never secured.
4) An analysis of the gap between the current budget and the required budget amount is being conducted.
5) Corruption, contracting methods, procurement, and contract changes are assessed and continuously improved.

11.3.5.4 Maturity and Findings of the Marcelo Fernan Bridge AM

(1) Inspection and Diagnosis

1) Maturity of Inspection and Diagnosis

a) The AM rating for the middle item is 3.7 (90%) for "Inspection" and 3.3 (69%) for "Diagnosis"
b) The small items with full marks are the "Implementation of Daily Inspections and the Implementation of Periodic Inspections".
c) "Diagnostic Manual" is rated 2.9 (71%) in the small item category. The achievement rate is 71%, which is not low since it includes two detail items with a full score of level 3, but it does not meet the level 3 target of the JICA technical cooperation project. The main reason for this is that investigation of the cause of damage is incomplete (level 2) in the detail items, and the difficulty in diagnosing ASR, which is progressing substantially on this bridge, is one of the causes of this.
d) Inspection records for both daily and periodic inspections are shared and continuously updated. MIRB (Maintenance Information System on Slope Protection & Bridge Repair) is a stand-alone system.
e) The frequency of inspection, the method of inspection, and the series of inspection equipment should be evaluated from a more objective perspective by checking the local conditions and actual activity.

2) Findings of Inspection and Diagnosis

a) Continued training, led by engineers trained in technical cooperation projects, serves as a model for others.
b) Since not much time has passed since the completion of the JICA technical cooperation project, it will be sufficient to evaluate and revise the manuals as necessary.
c) Since the ASR in the box girder was found through the steady implementation of the periodic

inspections, the inspection system is functioning well and is a model for others.
d) Updating inspection records is now firmly established at the DPWH.
e) Since the repair technologies for extradosed bridges and ASR are at a high technical level, it is considered necessary to raise the technical level of the DPWH by dispatching JICA experts.

(2) Repair and Rehabilitation Plan

1) Maturity of Repair and Rehabilitation Plan

a) The AM rating for the middle term “ Repair and Rehabilitation Plan “ is 3.1 (80%).
b) The AM rating for the small item is a perfect score for “Bridge Asset Ledger/DB”, 3.5 (90%) for “Bridge Management System” and 2.6 (71%) for “Planning”.
c) The main reason why the sub-item “Planning” does not meet level 3, which is the target of JICA technical cooperation projects, is because the sub-item “Predicting the Degree of Health” is incomplete (level 2) and the sub-item for “Understanding the Cost of Repair and Reconstruction” is also incomplete (level 2) due to difficulties in predicting the progress of ASR.

2) Findings of Repair and Rehabilitation Plan

a) Since the repair technologies for extradosed bridges and ASR are at a high technical level, it is considered necessary to raise the technical level of the DPWH by dispatching JICA experts.
b) It is desirable to develop a repair plan for at least three years, and preferably five years.

(3) Daily Maintenance and Management, Repair, Rehabilitation and Reconstruction

1) Maturity of Daily Maintenance and Management, Repair, Rehabilitation, and Reconstruction

a) The AM rating of the middle items is 3.3 (77%) for “Daily Maintenance Management” , 3.5 (78%) for “Repair”, and 4.3 (92%) for “Rehabilitation and Reconstruction.”
b) In the small items, “Cleaning” is 2.5, which does not meet the level 3 target of the JICA technical cooperation project. This is due to the partial scope of the cleaning.
c) Other than “Cleaning”, both small items and details meet the level 3 target of the JICA technical cooperation project.

2) Findings of Daily Maintenance and Management, Repair, Rehabilitation, and Reconstruction

a) It is necessary to prioritize and secure the minimum necessary budget for Daily Maintenance and Management.
b) Since there are many cases of ASR repair techniques in Japan, it may be necessary for JICA to investigate the possibility of similar cases occurring on other bridges.
c) Special bridge maintenance budgets will need to be secured as the damage progresses in the future. (For details, please refer to the supplementary explanatory materials.)
d) Since this bridge has concrete slabs, it is recommended that slab waterproofing be applied when the pavement is fully repaired to protect the quality of the concrete main girders.

(4) Surveillance (Monitoring)

1) Maturity of Surveillance (Monitoring)

a) The AM ratings for the middle items are 3.8 (95%) for “Traffic Conditions” and 3.8 (84%) for weather and disaster prevention.
b) All sub-items and details items meet level 3, which is the target of the JICA technical cooperation project.
c) In details items, “Information Sharing”, and Utilization of Monitoring Results is level 5 (full score), with records being appropriately stored, shared, and updated.

2) Findings of Surveillance (Monitoring)

(None)

(5) Organizational Management

1) Maturity of Organizational Management

a) The AM rating of middle items is a perfect score for “Bidding and Contracting System”. others include “Organizational Structure” (3.7 (77%)), “Budget Funding”(2.8 (62%)), and “Technical Training” (3.0 (75%)). Throughout the entire project, the only middle item under “Organizational Management” that fell below JICA’s level 3 threshold is “Budget Funding”.
b) The main reason for this is that the full score for the small item “Funding” is set at level 3, and in the details “Budget Allocation” section, the necessary budget allocation is assessed to be partially unbalanced (level 2). In fact, no budget request has been approved for the detailed investigation of abnormal cable vibrations and the required budget has not been allocated for the period of 2018-2022.

2) Findings of Organizational Management

a) It is desirable to secure the necessary personnel.
b) It is desirable to request a budget of at least three years, preferably five years, along with a repair plan. It is also necessary to secure a budget for special bridge maintenance and management.

11.3.6 List of the Marcelo Fernan Bridge Evaluation Results

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Bridges	4.1	95.1%	Inspection	4.0	98%	Inspection system	4.2	83%	System	4.5	90%
									Technical level of inspectors	3	60%
									Use of inspection equipment	5	100%
						Inspection manual	4.2	100%	Existence of daily inspection manual	5	100%
									Use of daily inspection manual	3	100%
									Existence of periodic inspection manual	5	100%
									Periodic inspection manual operation	3	100%
									Technical level of the manual	5.0	100%
						Implementation of daily inspections	3.7	100%	Inspection range	3	100%
									Frequency of inspections	3	100%
									Storage and sharing of inspection records	5	100%
						Implementation of periodic inspections	3.7	100%	Inspection range	3	100%
									Frequency of inspections	3	100%
									Storage and sharing of inspection records	5	100%
			Diagnosis	4.7	98%	Diagnostic system	4.8	95%	System	4.5	90%
									Technical level of diagnosis	5	100%
						Diagnostic manual (Specific bridge)	4.3	100%	Existence of diagnostic manual	5	100%
									Use of diagnostic manual	3	100%
									Technical level of the manual	5.0	100%
						Diagnosis of soundness (Specific bridge)	5.0	100%	Investigation of the cause of damage	5	100%
									Ranking of damage level	5	100%
									Storage and sharing of diagnostic records	5	100%
			Repair and rehabilitation plan	3.7	95%	Bridge assets ledger/DB	3.5	90%	Existence of bridge assets ledger/DB	4	80%
									Use of bridge assets	3	100%
						Bridge management system	3.5	90%	Existence of bridge management system	4	80%
									Use of bridge management system	3	100%
						Development of the plan	3.8	100%	Planning	5	100%
									Scope of the plan	3	100%
									Prediction of soundness	3	100%
									Understanding of the cost of repairs and rehabilitation	3	100%
									Preventive maintenance	5	100%

Figure 11.11 List of the Marcelo Fernan Bridge Evaluation Results【Bridge】(1/2)

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
			Daily maintenance and management	3.3	77%	System for daily maintenance and management	3.7	73%	System	3.0	60%
									Technical level of the person responsible for maintenance and management	3	60%
									Operation of maintenance and management work equipment (bridges)	5	100%
						Cleaning (bridge)	2.5	63%	Cleaning range	2	67%
									Frequency of cleaning	3	60%
						Emergency measures	3.5	90%	Management of response to deformation and damage	3	60%
									Small repair of deformation (temporary repair)	3	100%
									Emergency restoration of failures, etc.	3	100%
									Storage and sharing of emergency measure records	5	100%
			Repair	3.5	78%	Repair system	3.8	77%	System	3.5	70%
									Technical level of repair	4	80%
									Procurement of materials and equipment	4	80%
						Quality standards (Specific bridge)	3.3	80%	Existence of quality standards	3	60%
									Application of quality standards	3	100%
									Quality control	4	80%
						Repair (Design) manual	3.2	79%	Existence of repair (design) manuals	3	60%
									Use of repair (design) manual	3	100%
									Technical level of the manual	3.6	78%
						Implementation of repairs	3.8	85%	Repair planning and process management	4	80%
									Repair (radical repair)	3	100%
									Management of changes	3	60%
									Storage and sharing of repair records	5	100%
			Rehabilitations and reconstructions	4.3	92%	System for rehabilitations and reconstructions	4.3	87%	System	5.0	100%
									Level of technology for rehabilitations and reconstructions	4	80%
									Procurement of materials and equipment	4	80%
						Implementation of rehabilitations and reconstructions	4.3	95%	Implementation plan	5	100%
									Rehabilitation and reconstruction	3	100%
									Management of changes	4	80%
									Storage and sharing of records of rehabilitations and reconstructions	5	100%

Figure 11.12 List of the Marcelo Fernan Bridge Evaluation Results【Bridge】(2/2)

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Surveillance (monitoring)	3.8	90.0%	Traffic conditions	3.8	95%	Traffic volume	3.8	95%	Monitoring range	3	100%
									Monitoring frequency	3	100%
									Monitoring sites	4	80%
									Information sharing and utilization of monitoring results	5	100%
			Meteorology and disaster prevention	3.8	84%	Precipitation, temperature, wind	3.8	85%	Monitoring range	3	100%
									Monitoring frequency	3	60%
									Monitoring sites	4	80%
									Information sharing and utilization of monitoring results	5	100%

Figure 11.13 List of the Marcelo Fernan Bridge Evaluation Results【Surveillance(Monitoring)】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Organizational management	3.7	80.0%	Organizational structure	3.7	77%	Asset management cycle	5.0	100%	Setting management goals	5	100%
									Conducting internal audits	5	100%
									Implementation of management review	5	100%
						Organization	2.5	50%	Role-sharing	3	60%
									Manpower allocation	2	40%
						Control	3.0	73%	Commitment from the top	3	100%
									Influence of the organization	3	60%
									Motivation and ability of counterpart	3	60%
						Business continuity	4.3	87%	Responding to accidents	3	60%
									Responding to rainfall	5	100%
									Responding to earthquakes	5	100%
						Operational support facilities	3.0	60%	Training facility	3	60%
									Communication facilities	3	60%
			Budget funding	2.8	62%	Budget	2.5	50%	Budget planning	3	60%
									Budgetary allocation	2	40%
						Raising funds	3.0	80%	Short-term financing	3	100%
									Long-term financing	3	60%
			Bidding and contracting system	5.0	100%	Bidding and contracting system	5.0	100%	Cost estimation standard	5	100%
									Prevention of collusion	5	100%
									Contract method	5	100%
									Procurement process	5	100%
									Contract change	5	100%
			Technical training	3.0	75%	Pavement training	3.0	80%	Training plan	3	100%
									Contents of training	3	60%
						Bridge training	3.0	80%	Training plan	3	100%
									Contents of training	3	60%

Figure 11.14 List of the Marcelo Fernan Bridge Evaluation Results【Organizational Management】

11.4 The Diosdado Macapagal Bridge

11.4.1 Overview

The AM evaluation of the Diosdado Macapagal Bridge does not meet the level 3 target of the JICA technical cooperation project in the middle technical items ("Repair and Rehabilitation Planning" and "Daily Maintenance and Management") and in the middle item of organizational management (Budget Financing).

In the repair and rehabilitation plan phase, engineering inspections should be carried out promptly, diagnoses should be made, and a repair and rehabilitation plan should be formulated for not only a single year but also three and five years, if possible. Additionally, a budget request should be made, and it is recommended that a special bridge maintenance budget be secured.

Ongoing training in inspections and diagnosis, led by engineers trained in the JICA technical cooperation projects, should serve as a model for others.

11.4.2 Overview of the Loan Project for the Diosdado Macapagal Bridge [117]

The road network is the largest means of transportation in the Philippines, and at the time of the screening of this project, the road network was responsible for about 90% of passenger transportation and about 50% of cargo transportation. The island of Mindanao, the target of this project, has one of the lowest economic levels in the Philippines, and there is a strong need for development from the perspective of poverty alleviation, and the road pavement rate is low compared to other regions, so there are many issues to be addressed in the development of the road network.

The Butuan-Cagayan de Oro-Iligan Road, which is a trunk road in the northeastern part of the island, plays an extremely important role in the distribution of goods within the island and to neighboring areas, and is a fundamental road for the economic and social development of the island.

The road passes through the Agusan River, the largest river on the island, in the center of Butuan City, the main city in the northeastern part of the island. At the time of the inspections, the area around the existing bridge was extremely congested due to the increased traffic volume, and the existing bridge, which was built in 1957, was deteriorating and needed to be repaired drastically.

Under these circumstances, the Diosdado Macapagal Bridge (the Second Magsaysay Bridge at the time of the project) was constructed with yen loans as the Second Magsaysay Bridge and Bypass Road Construction Project to relieve traffic congestion in and around Butuan City and to facilitate transportation and traffic among major cities in the northeastern part of Mindanao, thereby contributing to the economic and social development of the northeastern part of Mindanao (Table 11.7,Table 11).

[117] JICA: Project Evaluation Report of the Second Magsaysay Bridge and the Bypass Road Construction Project, 2012.

Table 11.7 Summary of Loan Agreement (The Second Magsaysay Bridge and Butuan City Bypass Road Construction Project)

Borrower/Implementing Organizations	Government of the Republic of the Philippines / Ministry of Public Works and Roads （DPWH）	
Amount of yen Loan Approved Execution Amount	3,549 million yen 3,506 million yen	
Signing of the Exchange of Notes Signing of Loan Agreement	August 2000 August 2000	
Terms and Conditions Interest Rate Repayment Period (Deferment Period) Procurement	body part 0.95％ 40years (10years) Japan tide[118]	For consultants 0.75％ 40years (10years) Bilateral tide
Loan Completion	December 2008	
Start of (Construction) Work	2004	
Completion / Opening	2007 / 2007	
Main Contract	Nippon Steel Corporation (Japan) and Toa Corporation (Japan) (JV)	
Consultant Contract	Katahira Engineering International (Japan), Sogo Engineering Inc. (Japan), Proconsult, Inc.(Philippines), TCGI Engineers(Philippines)/DCCD Engineering(Philippines)(JV)	
Related Research	Basic Ventures Consultants (1992), Katahira Engineering International, PROCONSULT,INC.・TCGIEngineers・DCCD Engineering(JV)(1999)	
Related Business	None	

Table 11.8 The Second Magsaysay Bridge and Butuan City Bypass Road Construction Project Construction Specifications

Section (Bridge)	Various factors or elements
Steel Cable-Stayed Bridge	･Total length：360m ･Number of lanes：2 lanes (1 lane in each direction)
Approach	･Steel plate girder bridge：548m
Bypass road	･Length: 9,430m（Bypass road construction 8,100m+Maguinda-Las Nieves Road rehabilitation 1,330m）Two lanes of two-way traffic

11.4.3 Overview of the Maintenance of the Diosdado Macapagal Bridge

[118] This project was implemented under the Special Yen Loan Program. The Special Yen Loan Program was introduced by the Japanese government in 1998 to support Asian countries in their early recovery from the Asian currency crisis and provides financial assistance for infrastructure development in areas such as improving logistics efficiency, strengthening production infrastructure, and countermeasures against large-scale disasters. Under this program, the terms, and conditions of loan contracts (interest rates and repayment periods) are moderate, the contractors are limited to Japanese companies, and the procurement of products and services using loan funds is limited to those originating in Japan (procurement from other countries is limited to 50% or less of the total loan amount). This is also intended to expand business participation opportunities for Japanese companies.

(1) Location Map of the Bridge

The bridge of interest (the Diosdado Macapagal Bridge,, which was the 2nd Magsaysay Bridge at the time of JICA project.) is under the management of DPWH and is a steel cable-stayed bridge that crosses the Agusan River in Butuan City, northeastern Mindanao.(Figure 11.15). In Butuan City in the northeastern part of Mindanao Island, there is an old bridge near the city center that crosses the Agusan River on the Butuan - Cagayan de Oro-Iligan Road, which is a major highway, but it was built in 1957 and is aging, and the surrounding roads are congested. The Diosdado-Macapagal Bridge is part of the bypass road of the Butuan-Cagayan de Oro-Iligan Road (Figure 11).

Figure 11.15 Diosdado Macapagal Bridge Location Map (left) and Photo (right)

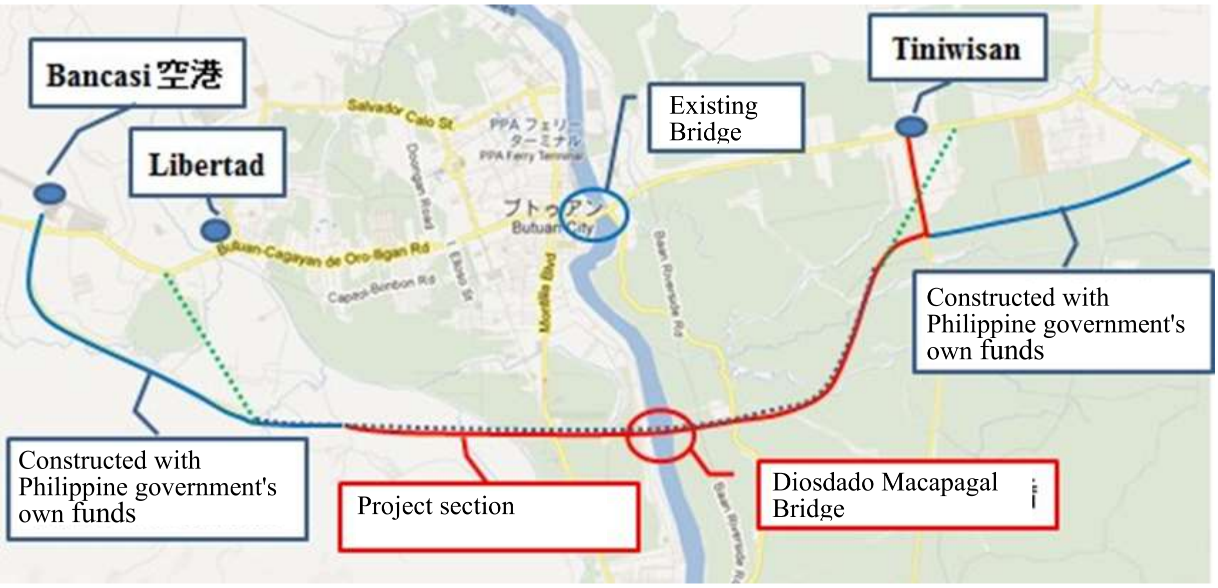


Figure 11.16 Location Map of Diosdado Macapagal Bridge (around Butuan City)

(2) Bridge Specifications, etc.

The specifications of the Diosdado Macapagal Bridge are shown in Table 11.9and the annual average traffic volume is shown in Table 11.10. The general view of the Diosdado Macapagal Bridge is shown in Figure 11.17, the side view is shown in Figure 11.18, the girder cross section is shown in Figure 11.19.

Table 11.9 Specification of the Diosdado Macapagal Bridge

Bridge Name	Diosdado Macapagal Bridge [Second Magsaysay Bridge at the time of JICA project]
Bridge Type	Steel Cable-Stayed Bridge (Steel slab, steel box girder)
Bridge Length, Span Length	Bridge length 360m、span length 160m + 200m
Purpose	Road bridge (2 lanes (1 lane in each direction))
Start of (construction) Work	2004
Completion of Construction	2007
Loan agreement	2000-(40 years)

Table 11.10 Annual Average Daily Traffic Volume

Annual Average Traffic Volume in 2019 (Vehicles/Day)		
MOTOR-TRICYCLE	2,480	(1,737 in 2020)
PASSENGER CAR	2,204	(740 in 2020)
PASSENGER UTILITY	290	(349 in 2020)
GOODS UTILITY	741	(635 in 2020)
SMALL BUS	176	(46 in 2020)
LARGE BUS 11 or 12	169	(114 in 2020)
RIGID TRUCK (2 axles) 11	3	(4 in 2020)
RIGID TRUCK (3+ axles) 12 or 22 or 13	199	(461 in 2020)
TRUCK SEMI-TRAILER (3 and 4 axles) 12-1t	112	(93 in 2020)
TRUCK SEMI-TRAILER (5+ axles) 12-2	84	(108 in 2020)
TRUCK TRAILERS (4 axles) 11-11	38	(25 in 2020)
TRUCK TRAILERS (5+ axles) 11-12	10	(6 in 2020)
Total	6,506	(4,318 in 2020)

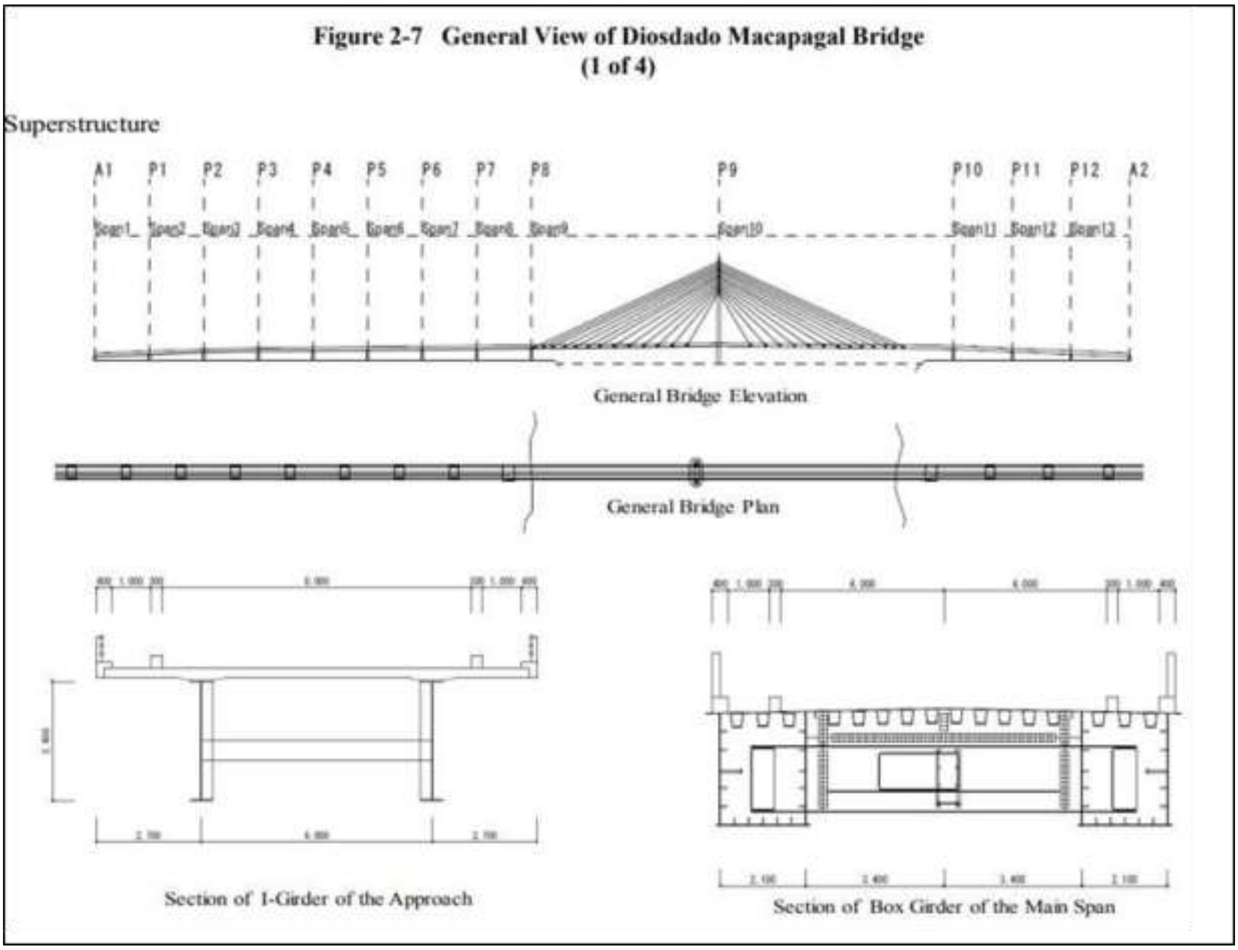


Figure 11.17 General View of the Diosdado Macapagal Bridge

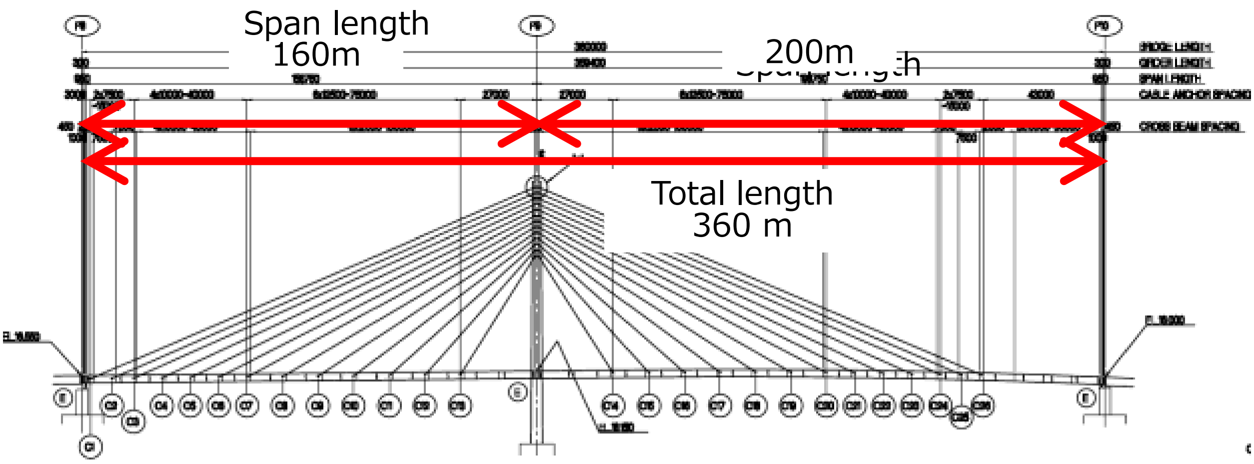


Figure 11.18 Side View of the Diosdado Macapagal Bridge

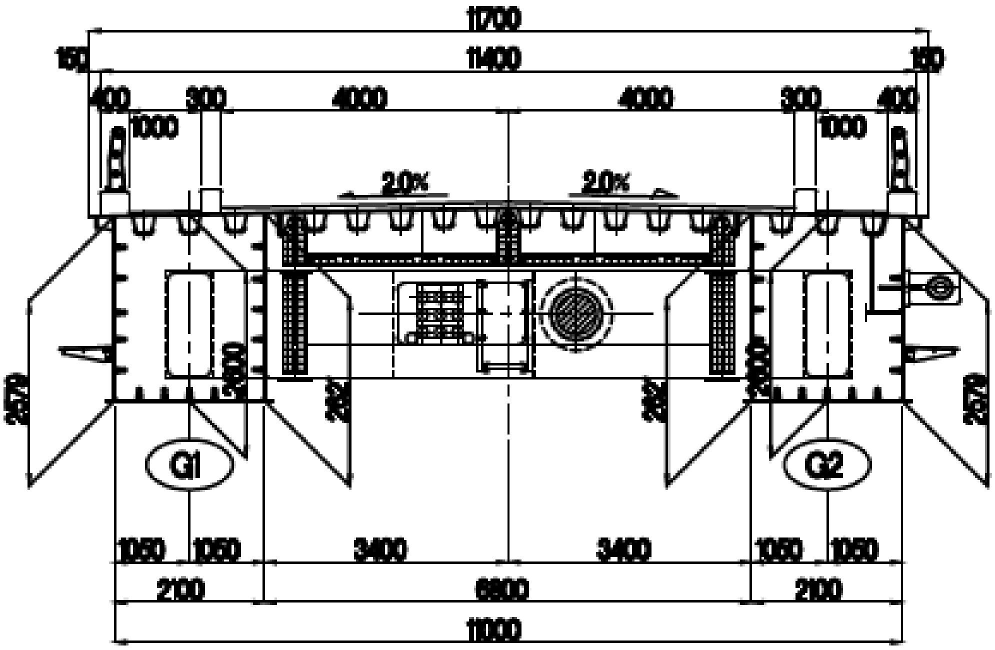


Figure 11.19 Girder Cross Section of the Diosdado Macapagal Bridge

(3) Organizational Structure

The Diosdado Macapagal Bridge is maintained under the jurisdiction of the Regional Office XIII of Department of Public Works and Highways (DPWH) and the Butuan City District Engineering Office (BCDEO), as shown in Figure 11.20.

The Diosdado Macapagal Bridge is under the direct maintenance, inspections of Butuan City District Engineering Office particularly the Maintenance Section and Planning and Design Section with the assistance and monitoring of Regional Office XIII.

The Maintenance Section of Butuan City District Engineering Office (BCDEO) will be the overall in charge of the routine Maintenance work of the said bridge with the assistance from representative of regional office while on the other hand, the Planning and Design Section of the same office under Bridge Management System will be the in charge for diagnostic and inspections annually with also the assistance of Bridge Inspector coming from the Planning and Design Division of Regional Office XIII.

The Maintenance Division, Regional office XIII will be the in charge of monthly monitoring on the routine maintenance work of the BCDEO and the BMS Regional Office XIII also for the annual condition report.

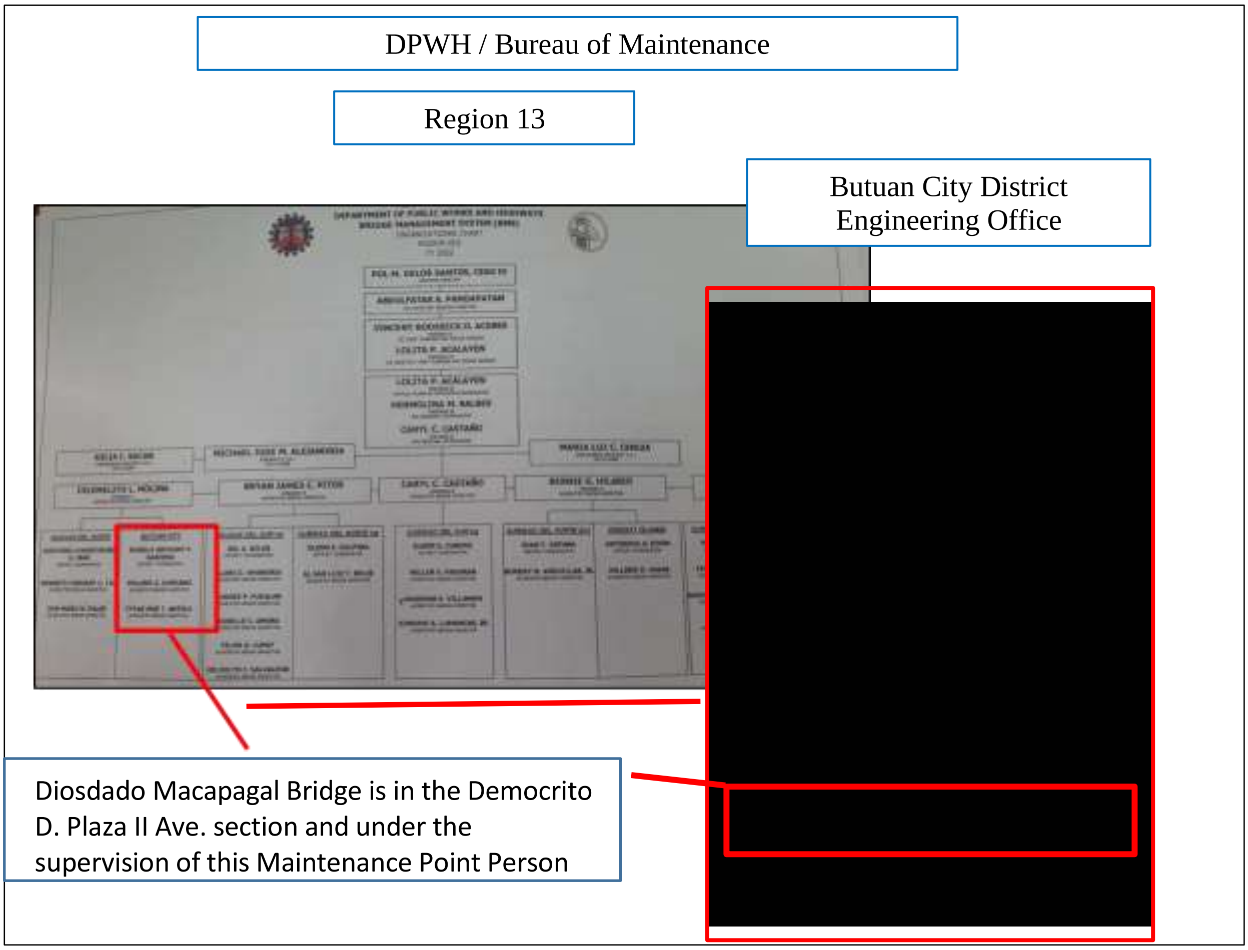


Figure 11.20 Assignment of Diosdado Macapagal Bridge in the DPWH Organization

(4) Maintenance Budget

The Maintenance Budget for cleaning, inspections of the Diosdado Macapagal Bridge is under Annual Maintenance Budget Program shown as Table 11.11.

Table 11.11 The Most Recent Budget for Maintenance and Management

Year	Detail	Type of Work	Budget
2019	Bridge Routine Maintenance	Cleaning, pothole patching	P2,499,506.12
2020	Bridge Routine Maintenance	Cleaning, pothole patching	P3,878,565.80
2021	Bridge Routine Maintenance	Cleaning, pothole patching	P3,469,820.69

Additional information about Table 11.11 is as follows.

1) Photo of Pothole Repair

Figure 11.21 shows the implementation status of the pothole repairs carried out in the daily maintenance of the Diosdado Macapagal Bridge.

Figure 11.21 Implementation of Pothole Repairs Diosdado Macapagal Bridge

2) Photo of Cleaning

Figure 11.22 shows the implementation status of cleaning carried out in the daily maintenance of the Diosdado Macapagal Bridge.

Figure 11.22 Status of Cleaning at Diosdado Macapagal Bridge

(5) Technical Standard

There is an inspection manual, namely "Bridge Engineering Inspection Manual (2014)", but for special bridges specifically, "Bridge Inspection Manual for Cable Stayed Bridge (2014)" is in operation for Diosdado Macapagal Bridge. They are developed through JICA technical cooperation project, and they have not yet been revised.

11.4.4 Technical Challenges of the Diosdad Macapagal Bridge

11.4.4.1 History of Project in the Past

The communication related to "abnormal vibration of cables" between project team and DPWH are summarized in chronological order as shown below.

Table 11.12 History of Project in the Past

Year and month	Item	
Mar. 2016	TCP-III project started	
Apr. 2016	Field investigation by project team, abnormal vibration of cables was confirmed	Project team
July 2016	Measurement of vibration was implemented using a simple device	Project team C/P
Nov. 2016	A report on cable measurement and analysis was submitted to DPWH	Project team
Mar. 2017	The detailed investigation implementation plan report related to abnormal vibration of cables was submitted to DPWH based on the inspections and investigation result utilizing a drone	Project team
During this period, a region reported the investigation and requested support to the ministry Design Bureau and Construction Bureau of the ministry request support to assistance administrator		
Mar. 2017	Detailed investigation was requested to DPWH and Sadain assistance administrator	Project team
May 2017	DPWH asked head of JICA for support for implementing the investigation	DPWH
Jan. 2019	JICA office asked DPWH.PM to confirm the consultant and construction company that implemented design and construction	JICA Philippines office
Mar. 2020	The project team asked DPWH for implementation of detailed investigation again	Project team
Mar. 2020	DPWH and PM ordered the examination of implementation of detailed investigation and elimination of overloaded vehicles to the regional office	DPWH, ministry

(1) Investigation of Vibration of Cables

The project team implemented visual inspections for the vibration of cables at the field and confirmed the abnormal vibration. The vibration investigation was implemented using a device based on this result.

1) Vibration investigation

In July 2016, the vibration was measured to comprehend the cause of vibration and degree of vibration.

2) Equipment used for the measurement

iPod touch (hereafter, "device") in which application for obtaining the vibration measurement data was installed was used.

3) Measured cable / Measurement point

The measurement was implemented for 8 cables per surface, total 16 cables on both surfaces (upstream side, downstream side) as shown in Figure 11.23.

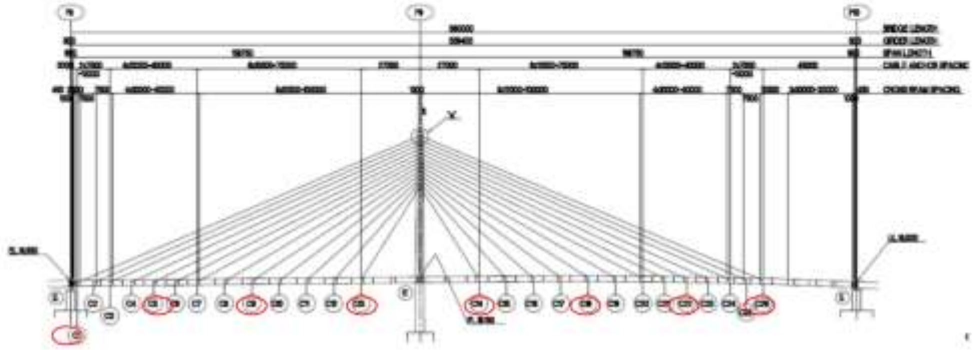


Figure 11.23 Measurement Point

4) Measurement Result

The measurement result is shown below.

① As a result of vibration measurement of cable and beam, the vibration of cables near 2.45Hz, 2.78Hz, and 4.22Hz is outstanding. The cause of vibration of these cables is thought of as resonance with vibration of beam.

② The cause of resonance is thought of as that the character frequencies of beam and cable are close and a device that gives attenuation such as damper is not attached to a cable.

③ Regarding the size of vibration, the amplitude could not be obtained because of the accuracy of the device, but the average size is about 0.5m/sec2 and the maximum size is about 1.5m/sec2. The acceleration level is comparatively large.

(2) Misalignment of Cable Anchorage Axis Line

In November 2017, this bridge was inspected using a drone. The observation result of drone images clarified that the waterproof rubber cover, which had been attached to both ends of cable to prevent rainwater from entering the cable anchorage zone, was deformed / rotating at a high rate. This type of defect is rarely reported in Japan. The monitoring was implemented because it may be caused by a decrease in tension of a cable.

As a result of monitoring, the point of cable where rotation or deformation of cover tends to increase.

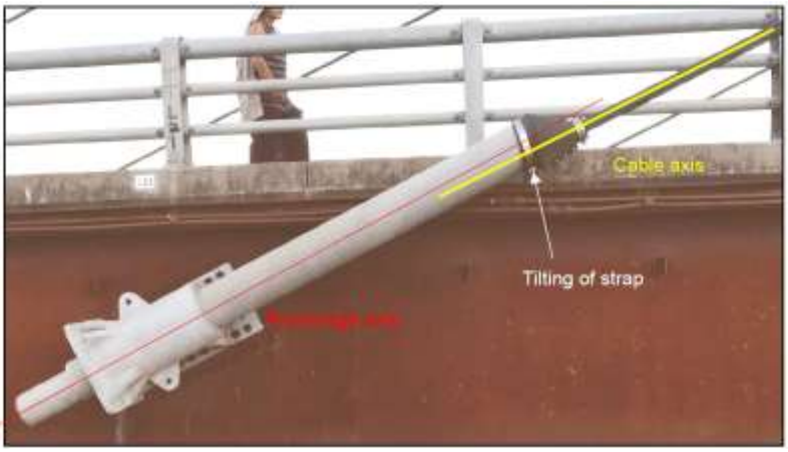


Figure 11.24Misalignment of Cable Anchorage Axis Line

(3) Disconnection of Cable Cover at the Main Tower

As a result of inspections of a bridge utilizing a drone, the rubber cover attached to the anchorage zone on tower side of C1 cable (downstream side) had been disconnected and had a slide on the cable to remain.

The rubber cover is fixed by cable cover (SGP) and cable strap.

The strap must be orthogonal to cable axis in a normal situation; however, the image shows that it is not orthogonal to the peripheral cables and some of straps are almost disconnected.

With C1 cable from which a rubber cover is disconnected, the center line of the cable is misaligned from the center line of cable cover in a downward direction.

Figure 11.25 Disconnection of Cable Cover at the Main Tower

(4) Abnormal Phenomenon and Consideration Obtained from Preliminary Vibration Measurement Result

1) Abnormal Vibration of Cables and Beams

a) All cables are vibrating all the time. Beams are also vibrating all the time. The vibratory phenomenon was observed in a calm state when the traffic of vehicles is not restricted.

b) The character frequency measurement result of a cable measured by a simple device corresponds to the predominant frequency measurement result of a beam. Thus, it is considered that the vibration of cable and beam resonates.

c) The vibration level was a comparatively large value; the maximum value of acceleration of a cable was 1.5m/sec2 (when a large vehicle runs) and the value when a private passenger vehicle run was 0.5m/sec2.

2) Deformation of Cable Anchorage Zone

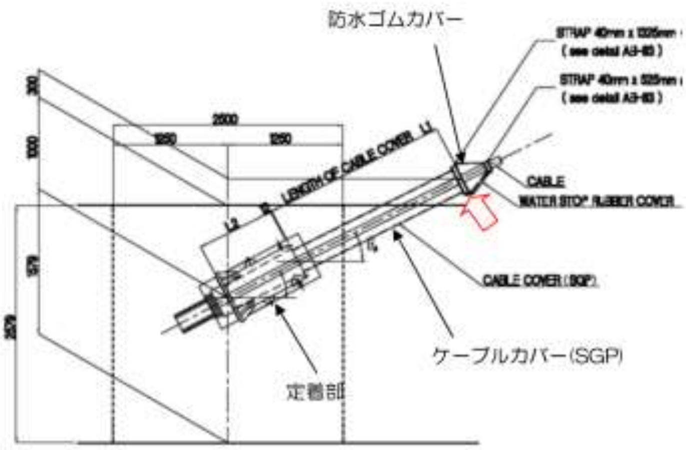
a) At the anchorage zone on beam side, misalignment is generated in between cable axis line and cable cover axis line. The tension of a cable may be loosened.

b) Deformation or tilt of strap for fixation is found in most of rubber covers on beam side and tower side.

c) Disconnection of rubber cover from the pipe cover is found (1 point on tower side, 2 points on beam side).

d) Rotation of rubber cover is found on beam side.

e) The wire stranding state emerges on the polyethylene cover near anchorage zone on beam side of several cables. When the cable received large tensile stress and the polyethylene as film was pulled toward the axis direction, it may have contracted toward the cross-section direction and the contact with wire may have been improved.



図ー３　桁側ケーブル定着構造

Figure 11.26 Structure of Anchorage Zone and Consideration

(5) Recommendations to DPWH in the Past

At the end of project, the project team delivered following recommendations to DPWH to encourage DPWH to solve the problems of maintenance and management.

1) Continuance of monitoring Carry out the monitoring with eyes such as rotation and disconnection of cover at the cable anchorage zone continuously. The cover on the main tower side has come off. An instruction was issued to DBWH to carry out the periodical monitoring 2) Continuance of monitoring Carry out the monitoring with eyes such as rotation and disconnection of cover at the cable anchorage zone continuously. The cover on the main tower side has come off. An instruction was issued to DBWH to carry out the periodical monitoring 3) Suggestion of detailed investigation of cables To check the cause of abnormal vibration shown above, the project team gave a suggestion to DPWH to carry out the detailed investigation. As content of investigation, carry out close investigation of deformation of each member of bridge with eyes, measurement of tension of cables, and observation of state of vibration due to traffic vehicles to infer the relationship with abnormal vibration based on these investigation results. The details are shown below. 4) Detailed investigation of cable anchorage zone on beam side Install scaffold near cable anchorage zone and remove the tap bolts fixing the cable pipe to the anchorage zone on beam side and move the cable pipe to expose the cable, and then observe the amplitude of cable at the tip of anchorage zone. By this, estimate the stress amplitude and number of repetitions accompanied with secondary bending of cable. b) Additionally, anchorage zone and peripheral member are not deformed. 5) Detailed investigation of vibration characteristics

For all cables and major points of beam, measure the vibration using a portable FFT analyzer and an acceleration sensor. b) Carry out measurement of cable and beam at the same time and comprehend the relationship of them correctly. c) Calculate the amount of displacement. d) When possible, install a sensor at the cable position and measure the vibration in low order mode.

11.4.4.2 Result of Hearing

(1) Measures Against Overloaded Vehicles

Question: Is the traffic enforcement implemented for overloaded vehicles? If it is implemented, please explain the content of the implemented traffic enforcement. If it is not implemented, is there any problem?
Answer: It is implemented. The policy against DPWH overloaded vehicles complies with the regulation of republic law 8794 as the “law charging a fee for vehicle users for owners of all models of vehicles and other purposes”. This is consensus among three parties: DPWH, DILG (Department of the Interior and Local Government) and DOTr (Department of Transportation). DPWH identifies an overloaded truck passing the measurement station immediately anterior to a bridge according to axle category and corresponding GVW (gross vehicle weight). National Bureau of Investigation and DILG arrest an overloaded truck and LTO issues a ticket to a truck driver who is charged for a corresponding fee designated by the law. (Supplement from investigation team) How is the current situation of overloaded vehicles? Answer: The data shows that 55.6% of vehicles are overloaded vehicles as of December 2021. The overloaded vehicles are measured every month. Although the overloaded vehicles are policed by the law shown above, it does not function effectively. A vehicle that is evaluated as an overloaded vehicle can directly pass the bridge. Unloading is not implemented. The current guideline has problems, and we cannot let drivers get unloaded. DPWH can identify the overloaded vehicles at the vehicle weight measurement station but giving drivers a warning and letting them get unloaded shall be implemented by other government department. (Supplement from investigation team) The technical cooperation project team asked DPWH for the policing of overloaded vehicles after coordination with other departments. How is the result? Answer: Policing is not implemented so frequently. (Supplement from investigation team) If the overloaded vehicles are not reduced, they may adversely affect the abnormal vibration of cables etc. as noted by technical cooperation project team.
Question: Is there a problem related to overloaded vehicles in Philippines?
Answer: When operating the regulation 8794, a vehicle that is evaluated as an overloaded vehicle can pass a bridge without unloading as shown above and the loading is not restricted. DPWH can identify overloaded vehicles at the vehicle weight measurement station but giving drivers a warning and letting them get unloaded shall be implemented by other government department.
Question: If there is a traffic management improvement plan for national roads, please introduce it.
Answer: DOTr implements the traffic management and encourages other departments to have consultations on overloading, but it is not promoted. (Supplement from investigation team) The project team ask the government to implement resolution of overloading and detailed investigation early at the end of project and Sadain assistance administrator issues instructions to the local region to respond to it.

Answer: Since the problem of abnormal vibration of cables cannot be solved, the budget for detailed inspections and investigation has been continuously requested to the ministry since 2019, but it is not accepted. We are continuously requesting the budget in FY2022.

(2) Asphalt Pavement

Question: Is the monitoring of bridge surface pavement continuously implemented?
Answer: Yes, it is implemented. The MPP (Maintenance Point Person) in charge of maintenance and management implements the monitoring twice a week at the annual periodical inspections and based on the ministerial ordinance No.41, s.2016DEO. (Supplement from investigation team) Which kind of work implemented? For the technical cooperation project, implementation of cleaning by high-pressure washing is described in the manual. Answer: Only the cleaning is implemented.
Question: Is there a new damage?
Answer: No damage is found newly in the result of inspections implemented by DEO at this moment.
Question: How are maintenance and management of bridge surface pavement implemented?
Answer: Maintenance and management are implemented based on the repair manual prepared by TCP-III.

(3) Vibration of Cables

Question: Is the monitoring of abutment on beam side of cable and cable vibration continuously implemented? If it is continuously implemented, is there new damage?
Answer: It is implemented based on the instructions of JICA's expert. A new damage is not found.
Question: Is the cable cover made of rubber detached from the cable on tower side repaired?
Answer: No, it is not repaired. We are waiting for the approval of budget for detailed inspections and investigation.
Question: Is there a plan for implementing detailed inspections and investigation recommended by project team?
Answer: Yes. We are requesting the budget.

(4) Problems on Maintenance and Management

Question: Is there any problem for implementing maintenance and management of bridges?
Answer: There is no sufficient budget for adequate maintenance and management.
Question: Are daily maintenance and management implemented periodically?
Answer: The cleaning of bridge surface is periodically implemented.
Question: Is repair planned?
Answer: There is no repair plan at this moment. First, we are planning to implement the detailed inspections and

investigation of cables and prepare the repair plan based on the result.

(5) Inspection of Special Bridges

Question: Are the daily inspections implemented periodically?
Answer: It is implemented, but only on the bridge surface.
Question: Are the periodical inspections continuously implemented after the technical cooperation project?
Answer: It is implemented every year based on the BMS program.
Question: Is there other damage?
Answer: Pavement potholes are generated on the bridge surface. These potholes are repaired in each case.

11.4.5 AM Maturity Level of the Diosdado Macapagal Bridge

11.4.5.1 How to Conduct Maturity Evaluations

The maturity evaluation was conducted through web interviews with the participants according to the schedule shown in Table 11.13, we asked them to explain the reasons and background behind the low and high items that they graded. In addition, if the other party offered to revise the level during the hearing, the revision was made on the spot. The evaluation sheet was distributed in advance, and the grading procedure was explained during the kick-off meeting.

In the hearings, we asked them to explain the reasons and background behind the low and high items that they graded. In addition, if the other party offered to revise the level during the hearing, the revision was made on the spot.

Table 11.13 Content of the Maturity Evaluation Hearing

Iteme	Date / Time	Atendees	Notes
JICA Kick-off	November 10, 2021 /11:30-12:00	JICAHQ, JEXWAY	Explanation of aim
	November 25, 2021 /11:00-12:00	JICAHQ, JICA Philippines office、JEXWAY	Explanation of aim
DPWH Kick-off	January 6, 2022 /13:00-14:00(PST)	・ Engr. Teofila SF. Borlongan (OIC-Assistant Director, Bureau of Maintenance) ・ Engr. Krezia M. Tactac (Engineer II, National Building Services Division, Bureau of Maintenance) ・ Engr. Noe O. Bonga (Engineer II, National Building Services Division, Bureau of Maintenance) ・ Engr. Nenita R. Jimenez (Chief, Development Planning Division, Planning Service) ・ Engr. Justino Jaime T. Surot (Engineer III, Development Planning Division, Planning Service) ・ Engr. Rosario C. Calves (JICA TWG Member – Engineer III, Maintenance Division, Region VII) ・ Engr. Bryan James C. Pitos (JICA CWG Member – Engineer II, Planning and Design Division, Region XIII) ・ Engr. Irewil D. Flores (JICA CWG Member – Engineer II, Maintenance Division, Region XIII) ・ Engr. Faustino A. De La Cruz, Jr. (Chief, Maintenance Division, Region VII) ・ Engr. Daisy B. Toledo (District Engineer, Cebu VI District Engineering Office) ・ Engr. Eda T. De Guzman (Chief, Maintenance Section, Cebu VI District Engineering Office) ・ Engr. Cristina Luz R. Cacayan, Chief (Maintenance Division, Region XIII) ・ Engr. Jose Caesar A. Radaza (District Engineer, Butuan City District Engineering Office) ・ Engr. Reynaldo A. Canlas (Chief, Maintenance Section, Butuan City District Engineering Office) ・ Engr. Marc Joseph M. Brutas (Engineer II, Office of the Undersecretary Carvajal)	Explanation of aim, date and time schedule
DPWH 1st	January 19, 2022	・ Engr. Cristina Luz R. Cacayan (Chief, Maintenance Division, Region XIII)	Diosdado Macapagal

Iteme	Date / Time	Atendees	Notes
interview	/15:30-17:00(PST)	・ Engr. Reynaldo A. Canlas (Chief, Maintenance Section, Butuan City District Engineering Office) ・ Engr. Teofila SF. Borlonga (OIC-Assistant Director, Bureau of Maintenance) ・ Engr. Krezia M. Tactac (Engineer II, National Building Services Division, Bureau of Maintenance)	Bridge: Evaluation sheet scoring
DPWH 2nd interview	January 26, 2022 /13:00-16:00(PST)	・ Engr. Noe O. Bonga (National Building Services division, Bureau of Maintenance) ・ Engr. Krezia M. Tactac (Engineer II, National Building Services Division, Bureau of Maintenance) ・ Engr.Eda T. De Guzman (Chief, Maintenance Section, District 6) ・ Engr. Nelson, Comedia (Bridge Inspector, District 6) ・ Engr. Justino Jaime T. Surot (Development Planning Division, Planning Service) ・ Engr. Rosario C. Calves (Maintenance Division, Region VII) ・ Engr. Bryan James C. Pitos (Planning and Design Division, Region XIII)	Questions on individual issues, Additional Questions
DPWH Feedback	February 9, 2022 /13:00-15:05(PST)	・ Engr. Noe O. Bonga (National Building Services Division, Bureau of Maintenance) ・ Engr. Krezia M. Tactac (Engineer II, National Building Services Division, Bureau of Maintenance) ・ Engr. Eda T. De Guzman (Chief, Maintenance Section, District 6) ・ Engr. Nelson, Comedia (Bridge Inspector, District 6) ・ Valerie Londite (District 6) ・ Engr. Rosario C. Calves (Maintenance Division, Region VII) ・ Engr. Bryan James C. Pitos (Planning and Design Division, Region XIII) ・ Vincent Montrix Calapre (Region VII)	
JICA Report	February 16, 2022 From 16:00	JICA Headquarters	

11.4.5.2 Maturity Evaluation Results

(1) Radar Chart

The radar chart (level evaluation) by major and medium items is shown in Figure 11.27. Red is the result of the evaluation of the Diosdado Macapagal Bridge in DPWH, and the gray dotted line indicates a perfect score. The radar chart based on the level evaluation of the Diosdado Macapagal Bridge in DPWH is partly asymptotic to the case of a perfect score, and to show the situation clearly, Figure 11.28 shows the radar chart based on the achievement rate evaluation, which shows the evaluation result of each item as a percentage of its perfect score.

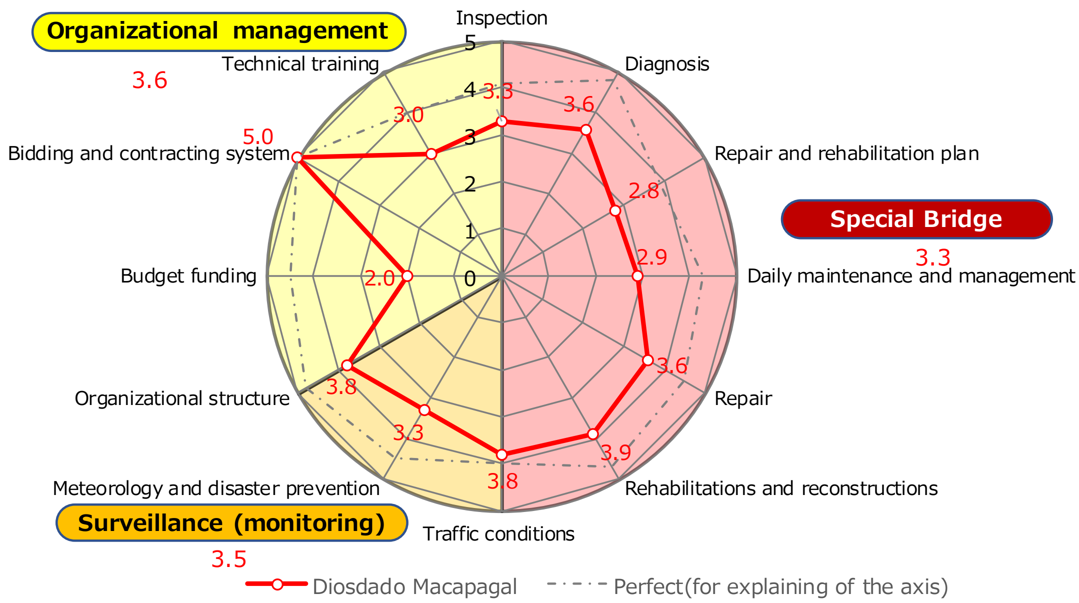


Figure 11.27 Major and Medium Item Radar Chart (Level)

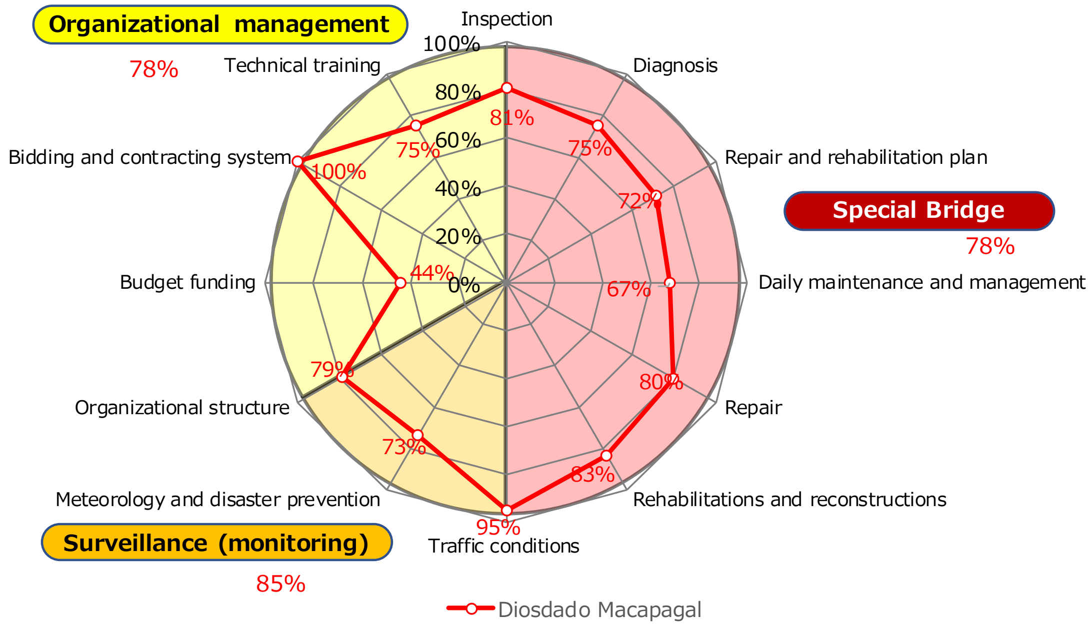


Figure 11.28 Major and Medium Item Radar Chart (Achievement Rate)

(2) Overall Evaluation

The AM evaluation of the Diosdado Macapagal Bridge does not meet the level 3 target of the JICA technical cooperation project in the middle technical items (“Repair and Rehabilitation Planning” and “Daily Maintenance and Management”) and in the middle item of “Organizational Management (Budget Financing)”.

1) Regarding the AM evaluation of the Diosdado Macapagal Bridge, the overall average is 3.3 (78%), but in the middle items, the level of “Repair and Reconstruction”, “Planning” is 2.8 (72%), and

"Daily Maintenance" is 2.9 (67%), which is lower than the JICA technical cooperation target of level 3.

2) The overall average AM rating for "Surveillance (Monitoring)" is 3.5 (85%), which is higher than the level 3 of JICA technical cooperation target in the middle and small items.
3) The overall average AM rating for "Organizational Management" is level 3.6 (79%). Among the middle items, "Bidding and Contracting System" received a perfect score, but "Budget Funding" is at level 2.0 (44%), which is below the JICA technical cooperation target of level 3.

11.4.5.3 Current Status and Challenges of the Diosdado Macapagal Bridge

(1) Inspection and Diagnosis

1) There are four types of inspections: routine, periodic, engineering, and emergency inspections. In-house engineers are conducting the inspections.
2) The above four inspections are basically carried out by qualified engineers of DPWH.
3) There are plans for engineering inspections of bridges, but there is no budget for outsourcing.
4) There are a total of 10 qualified engineers. Three of them are district office staff and seven are regional office staff.
5) There is ongoing training on inspections and repair of special bridges. The JICA Counterpart and project managers in charge of repairs serve as training instructors. Training will be held annually, and eligible persons will be trained as they arise
6) As for the inspection equipment, one of the rebar probes is out of order and cannot be used. In addition, other departments oversee the management of inspection equipment. It is unknown if repairs have been requested.
7) The underside of the box girder at the main span has not been inspected because the working machines cannot reach it.
8) There is an inspection manual, but it has not yet been evaluated or revised.
9) The contents of the diagnostic manual are included in the inspection manual.
10) The diagnostic procedure is specifically created to fit the Diosdado Macapagal Bridge. The damage evaluation criteria used in the diagnosis were those developed by JICA's technical professionals.
11) The first manuals were created by the World Bank when BMS was introduced. The inspection manual was reviewed by JICA's technical experts.
12) Routine inspections are conducted once a week and Periodic inspections are conducted on an annual basis.
13) Periodic inspections are carried out at an appropriate frequency.
14) The underside of the box girder cannot be reached by bridge inspection vehicles, so there is a need to rely on drone inspections. Drones have been used for inspections once during the implementation of the project, but no drone inspections have been conducted since the completion of the JICA technical cooperation project.
15) Abnormal vibration of cables on the cable-stayed bridge was confirmed. A detailed investigation to determine the cause of the problem has been proposed by the JICA technical cooperation project team but has not been carried out. The budget for that detailed study has not been approved for 2019-2022. It

will continue to be requested in the 2023 budget.

16) The main girder, which is made of weather-resistant steel, is recommended by the JICA technical cooperation project to be inspected periodically, with particular attention to the underside of the girder, near the bearings, expansion joints and drainage facilities.
17) Inspection results are shared between the headquarters and regional offices. Every month, the inspection data along with the results of our activities will be sent to the headquarters. In addition, the headquarters updates the data of the inspection results once a year.
18) The diagnosis is not outsourced but is done directly by qualified technicians at the DPWH.
19) There is a plan to conduct an overall structural diagnosis after the engineering inspections are implemented.
20) Diagnosis skills are high due to continuous training as well as inspection training.
21) The underside of the box girder at the main span was not inspected and therefore not diagnosed.

(2) Repair and Rehabilitation Plan

1) BMS was introduced by the World Bank in 2004. Then, four years after its introduction, a manual for inspection, diagnosis, and repair was introduced by the JICA technical cooperation project.
2) The MIRB (Maintenance Information System on Road Slope Protection & Bridge Repair), which manages data based on the manual introduced by the JICA technical cooperation project, has been introduced and is being operated separately from the World Bank's BMS. In addition, although the BMS system has not been updated, data such as inspection results continues to be updated.
3) Records of inspections, diagnosis, and repairs are updated and shared.
4) The repair plan is only planned for the next year. In addition, as mentioned earlier, the underside of the superstructure has yet to be inspected, so the repair plan is only partial.
5) The repair costs are also only partially known for the reasons mentioned above.

(3) Daily Maintenance and Management, Repair, Rehabilitation and Reconstruction

1) Daily maintenance and management are handled by eight DPWH employees, including workers and supervisors. The underside of the box girder on the main span is not accessible by work equipment, so maintenance work is not being done.
2) The cleaning for daily maintenance and management covers the pavement surface; the high-pressure cleaning of the expansion joints recommended by JICA technical project is not implemented.
3) Some small repairs are done directly by the organization, but larger scale repairs are outsourced. The level of repair technology is satisfactory, and evaluations are being conducted.
4) There is a lack of machinery for maintenance and repair. In particular, the range of work is limited due to the lack of elevated work vehicles.
5) The budget for daily maintenance and management is being cut due to COVID 19.
6) Rehabilitation and reconstruction are outsourced. The technical level of the contractors is sufficient, and their work is appreciated.

(4) Surveillance (Monitoring)

1)	The traffic volume is automatically measured and stored on the server for 24 hours, and the data can be shared. However, there is no traffic control center.
2)	Wind speed and temperature are measured manually at the regional office. Rainfall and temperature are measured by other agencies. This data is available upon request. However, they are not located within the Diosdado Macapagal Bridge.
3)	Regarding the abnormal cable vibrations, the cable cover on the main tower side was detached and the cable cover on the main girder side was displaced during the inspection of the JICA technical cooperation project, after which monitoring was conducted. Regarding the current situation, the detached cover on the main tower side has moved downward.
4)	Measurement of overloaded vehicles is being conducted, but more than half of the vehicles are still overloaded. The DPWH can identify overloaded vehicles at the vehicle weight measurement station, but they cannot unload them and let them pass. Through the National Economic Development Agency, approaches have been made to the Ministry of Transportation, which oversees traffic management, about this issue, but there has been no progress.

(5) Organizational Management

1)	The AM cycle (Goal setting/Internal audit/Review) is established.
2)	The number of staff in the department in charge of AM is insufficient.
3)	The networks between training facilities and headquarters are being evaluated and improved.
4)	The budget only plans for the next year. In addition, it is believed that the budget is unbalanced in many cases where budget requests are never secured.
5)	The budget for a detailed inspections to determine the status and cause of the abnormal cable vibration identified in the JICA technical cooperation project has not been approved until 2019-2022.
6)	No long-term budget planning has been done, and no analysis of the gap between the current budget and the required budget amount has been done.
7)	Corruption, contracting methods, procurement, and contract changes are assessed and continuously improved.

11.4.5.4 Maturity and Findings of the Diosdado Macapagal Bridge AM

1. Inspection and Diagnosis

1) Maturity of Inspection and Diagnosis

a)	The AM ratings of the middle items are 3.3 (81%) for “Inspection” and 3.6 (75%) for “Diagnosis”.
b)	There is a perfect score in the sub-items, which is Diagnostic System.
c)	As a sub-item, Diagnostic Manual is rated 2.9 (71%). The achievement rating is 71%, which is not low since it includes two detail items with a full score of level 3, but it does not meet the level 3 target of the JICA technical cooperation project. The reason for this is that the diagnostic manual has not been applied to the entire bridge because there are areas that cannot be inspected, such as the underside of the box girder and the main towers.

d)	In the detail items, investigation of the cause of damage is rated as level 2 (the cause of damage is partially investigated), which does not meet the level 3 target of the JICA technical cooperation project. This is because there has been no progress in investigating the causes of abnormal cable vibration.
e)	Inspection records for both routine and periodic inspections are shared and updated on an ongoing basis; both MIRB and BMS data are updated.
f)	Frequency of inspections, inspection methods and series of inspection equipment should be evaluated from a more objective perspective by checking local conditions and actual activity.

2) Findings of Inspection and Diagnosis

a)	Ideally, engineering inspections should be carried out at intervals of about five years. Since it has been more than 10 years since the completion of construction and there are more than vibrations in the cables, the bridge needs immediate inspection and diagnosis.
b)	Continued training, led by engineers trained in the technical cooperation projects, serves as a model for others
c)	Necessary equipment such as rebar probes need to be installed as soon as possible.
d)	The use of drones and other equipment is recommended to carry out inspections of the underside of the main span.
e)	Since not much time has passed since the completion of the project, it will be sufficient to evaluate and revise the manuals as necessary.
f)	It is necessary to proceed with inspections of areas that have not yet been inspected, such as the underside of the box girder, the top of the main tower and cables.
g)	After the JICA technical cooperation project was completed, Katahira Engineering inspected the bridge and found it to be in good working order, but it needs to be checked on a continuous basis.
h)	Updating inspection records is now firmly established at the DPWH.
i)	Ideally, Engineering inspections should be conducted at intervals of about five years. Since it has been more than 10 years since the completion of construction and there are abnormal vibrations in the cables, immediate inspections and diagnosis is necessary. (For details, please refer to the supplementary explanatory materials.)

(2) Repair and Rehabilitation Plan

1) Maturity of Repair and Rehabilitation Plan

a)	The AM rating for the middle item, “Repair and Rehabilitation Plan”, is 2.8 (72%), which does not meet the level 3 target of the JICA technical cooperation project. The main reason for this is that the rating for the sub-item Formulation of Plans is 2.2 (60%).
b)	As for the other sub-items, “Bridge Asset Ledger/DB” received a perfect score and Bridge Management System received 3.0 (73%).
c)	The main reason for the low rating of 2.2 (60%) for the sub-item Planning is that the detail “Planning, Scope of Planning”, “Prediction of Soundness”, and “Understanding of Repair and Rehabilitation Costs” are rated as incomplete (level 2) because there are areas that cannot be inspected, such as the underside

of the box girder and the main tower.

2) Findings of Repair and Rehabilitation Plan

a) The inspections, diagnosis and repair manuals are in operation, and the MIRB inspection, diagnosis and repair data is being updated, so it can be said that the MIRB is functioning.
b) It is desirable to develop a repair plan for at least three years, and preferably five years.

(3) Daily Maintenance and Management, Repair, Rehabilitation and Reconstruction

1) Maturity of Maintenance and Management, Repair, Rehabilitation, and Reconstruction

a) The AM rating of the middle item, "Daily Maintenance Management", is 2.9 (67%), which does not meet the level 3 target of the JICA technical cooperation project. The other two are Repair (3.6 (80%)) and Rehabilitations and reconstructions (3.9 (83%)).
b) In the sub-items, the score of 2.3 of the system for "Daily Maintenance and Management" and 2.5 of "Cleaning" don't meet the level 3 target set by the JICA technical cooperation project. Those reasons are largely because the person in charge of maintenance management is considered to have only partial knowledge of the professional education required for maintenance management work (level 2). Also, maintenance management work machines are in short supply (level 2).

2) Findings of Maintenance and Management, Repair, Rehabilitation, and Reconstruction

a) Cleaning should be carried out because clogging of the expansion joints may lead to deterioration of the drainage function and damage to the girder ends.
b) It is necessary to reduce the number of areas that have not been inspected by renting elevated work vehicles, for example. Owning or leasing a bridge inspection vehicle is recommended if it will be used constantly for routine inspections and daily maintenance and management.
c) It is necessary to prioritize and secure the minimum necessary budget for daily maintenance and management.
d) Special bridge maintenance budgets will need to be secured as the damage progresses in the future. (For details, please refer to the supplementary explanatory materials.)

(4) Surveillance (Monitoring)

1) Maturity of Surveillance (Monitoring)

a) The rating of the middle items is 3.8 (95%) for "Traffic Conditions" and 3.3 (73%) for "Weather and Disaster Prevention".
b) In the detail items on "Meteorology and Disaster Prevention", "Surveillance (Monitoring) Frequency I"s irregularly monitored (level 2), which does not meet the level 3 target of the JICA technical cooperation project.
c) For the detail items, "Information Sharing" and "Utilization of Surveillance (Monitoring) Results", the level is 5 (full score), and records are stored, shared, and updated.

2) Findings of Surveillance (Monitoring)

a) Investigation of the cause and immediate implementation of temporary repairs are required. (For details, please refer to the supplementary explanatory materials.)
b) The vehicle weight measuring station is owned by the DPWH. One of the possible causes of abnormal cable vibrations is overloaded vehicles. It is necessary not only to monitor overloaded vehicles but also to crack down on them.

(5) Organizational Management

1) Maturity of Organizational Management

a) The AM rating of the middle item is a perfect score for “Bidding and Contracting System”. others included “Organizational Management” (3.8 (79%)), “Budget Funding” (2.0 (44%)), and “Technical Training” (3.0 (75%)).
b) The main reason why it does not meet the level 3 target of JICA technical cooperation project is that only the budget plan for the following year is developed (level 2 in details), the required budget allocation is partially unbalanced (level 2 in the detail items), and the gap between the required and available funds for long-term funding and financing has not been identified (level 1 in the detail items). In fact, from 2018-2022, no budget request has been approved for the detailed investigation of abnormal vibration of cables and the required budget has not been allocated and is unbalanced, thus resulting in no repair plan or bridge health prediction.

2) Findings of Organizational Management

a) It is desirable to secure the necessary personnel.
b) It is desirable to request a budget of at least three years, preferably five years, along with a repair plan. It is also necessary to secure a budget for special bridge maintenance and management.

11.4.6 List of the Diosdado Macapagal Evaluation Results

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Bridges	3.3	78.1%	Inspection	3.3	81%	Inspection system	4.0	80%	System	5.0	100%
									Technical level of inspectors	5	100%
									Use of inspection equipment	2	40%
						Inspection manual	2.9	75%	Existence of daily inspection manual	3	60%
									Use of daily inspection manual	3	100%
									Existence of periodic inspection manual	3	60%
									Periodic inspection manual operation	3	100%
									Technical level of the manual	2.7	53%
						Implementation of daily inspections	3.3	89%	Inspection range	2	67%
									Frequency of inspections	3	100%
									Storage and sharing of inspection records	5	100%
						Implementation of periodic inspections	3.3	89%	Inspection range	2	67%
									Frequency of inspections	3	100%
									Storage and sharing of inspection records	5	100%
			Diagnosis	3.6	75%	Diagnostic system	5.0	100%	System	5.0	100%
									Technical level of diagnosis	5	100%
						Diagnostic manual (Specific bridge)	2.9	71%	Existence of diagnostic manual	3	60%
									Use of diagnostic manual	3	100%
									Technical level of the manual	2.7	53%
						Diagnosis of soundness (Specific bridge)	3.3	67%	Investigation of the cause of damage	2	40%
									Ranking of damage level	3	60%
									Storage and sharing of diagnostic records	5	100%
			Repair and rehabilitation plan	2.8	72%	Bridge assets ledger/DB	4.0	100%	Existence of bridge assets ledger/DB	5	100%
									Use of bridge assets	3	100%
						Bridge management system	3.0	73%	Existence of bridge management system	4	80%
									Use of bridge management system	2	67%
						Development of the plan	2.2	60%	Planning	2	40%
									Scope of the plan	2	67%
									Prediction of soundness	2	67%
									Understanding of the cost of repairs and rehabilitation	2	67%
									Preventive maintenance	3	60%

Figure 11.29 List of the Diosdado Macapagal Bridge Evaluation Results【Bridge】(1/2)

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
			Daily maintenance and management	2.9	67%	System for daily maintenance and management	2.3	47%	System	3.0	60%
									Technical level of the person responsible for maintenance and management	2	40%
									Operation of maintenance and management work equipment (bridges)	2	40%
						Cleaning (bridge)	2.5	63%	Cleaning range	2	67%
									Frequency of cleaning	3	60%
						Emergency measures	3.5	90%	Management of response to deformation and damage	3	60%
									Small repair of deformation (temporary repair)	3	100%
									Emergency restoration of failures, etc.	3	100%
									Storage and sharing of emergency measure records	5	100%
			Repair	3.6	80%	Repair system	4.7	93%	System	5.0	100%
									Technical level of repair	5	100%
									Procurement of materials and equipment	4	80%
						Quality standards (Specific bridge)	3.3	80%	Existence of quality standards	3	60%
									Application of quality standards	3	100%
									Quality control	4	80%
						Repair (Design) manual	3.1	78%	Existence of repair (design) manuals	3	60%
									Use of repair (design) manual	3	100%
									Technical level of the manual	3.4	75%
						Implementation of repairs	3.5	80%	Repair planning and process management	3	60%
									Repair (radical repair)	3	100%
									Management of changes	3	60%
									Storage and sharing of repair records	5	100%
			Rehabilitations and reconstructions	3.9	83%	System for rehabilitations and reconstructions	4.3	87%	System	5.0	100%
									Level of technology for rehabilitations and reconstructions	4	80%
									Procurement of materials and equipment	4	80%
						Implementation of rehabilitations and reconstructions	3.5	80%	Implementation plan	3	60%
									Rehabilitation and reconstruction	3	100%
									Management of changes	3	60%
									Storage and sharing of records of rehabilitations and reconstructions	5	100%

Figure 11.30 List of the Diosdado Macapagal Bridge Evaluation Results【Bridge】(2/2)

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Surveillance (monitoring)	3.5	85.0%	Traffic conditions	3.8	95%	Traffic volume	3.8	95%	Monitoring range	3	100%
									Monitoring frequency	3	100%
									Monitoring sites	4	80%
									Information sharing and utilization of monitoring results	5	100%
			Meteorology and disaster prevention	3.3	73%	Precipitation, temperature, wind	3.3	75%	Monitoring range	3	100%
									Monitoring frequency	2	40%
									Monitoring sites	3	60%
									Information sharing and utilization of monitoring results	5	100%

Figure 11.31 List of the Diosdado Macapagal Bridge Evaluation Results【Surveillance(Monitoring)】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Organizational management	3.6	78.5%	Organizational structure	3.8	79%	Asset management cycle	5.0	100%	Setting management goals	5	100%
									Conducting internal audits	5	100%
									Implementation of management review	5	100%
						Organization	3.0	60%	Role-sharing	4	80%
									Manpower allocation	2	40%
						Control	3.0	73%	Commitment from the top	3	100%
									Influence of the organization	3	60%
									Motivation and ability of counterpart	3	60%
						Business continuity	3.0	60%	Responding to accidents	3	60%
									Responding to rainfall	3	60%
									Responding to earthquakes	3	60%
						Operational support facilities	5.0	100%	Training facility	5	100%
									Communication facilities	5	100%
			Budget funding	2.0	44%	Budget	2.0	40%	Budget planning	2	40%
									Budgetary allocation	2	40%
						Raising funds	2.0	60%	Short-term financing	3	100%
									Long-term financing	1	20%
			Bidding and contracting system	5.0	100%	Bidding and contracting system	5.0	100%	Cost estimation standard	5	100%
									Prevention of collusion	5	100%
									Contract method	5	100%
									Procurement process	5	100%
									Contract change	5	100%
			Technical training	3.0	75%	Pavement training	3.0	80%	Training plan	3	100%
									Contents of training	3	60%
						Bridge training	3.0	80%	Training plan	3	100%
									Contents of training	3	60%

Figure 11.32 List of the Diosdado Macapagal Bridge Evaluation Results【Organizational Management】

11.5 Rama IX Bridge (Expressway Authority of Thailand (EXAT))

11.5.1 Overview

The maturity level of the asset management of the Rama IX Bridge is very high, and as a result of the maturity evaluation, it meets level 3 of the JICA technical cooperation project objectives.
Repairs and preventive maintenance are carried out in a planned manner.

In addition, daily inspections, diagnosis and simple repairs are basically carried out directly by Expressway Authority of Thailand(EXAT).

The design, main repairs, rehabilitation and reconstruction are done by Thai companies, and foreign technology is adopted as needed within the budget of EXAT.
Periodic inspections are outsourced to Thai companies, but the inspection cycle is long, on the order of 10 years, and it is doubtful whether the evaluation of health and the associated repair and budget plans are updated in a timely manner.

Fatigue crack damage due to repeated loading appeared on the steel slab. The repair is being carried out by a company in Thailand, and EXAT is planning the repair by itself.

EXAT has a desire to participate in JICA training on specialized technologies such as inspections and diagnosis in Japan and to visit training facilities.

11.5.2 Overview of the Loan Project for Rama IX Bridge [119]

The metropolitan area around Bangkok has grown rapidly since the 1970s as the political and economic center of Thailand, with an average population growth rate of 3.4% between 1975 and 1980, much higher than the world average growth rate of 2.1%.
In 1980, with a population of 5.15 million people, the number of registered vehicles in the Bangkok Metropolitan Region grew dramatically, reaching 620,000 vehicles in 1980, an average annual growth rate of 9%.

On the other hand, road conditions in Bangkok are poor in terms of both road area and paving rate, and there are some problems with traffic conditions. The Chao Phraya River was blocking the flow of traffic in Bangkok, forcing vehicles to divert to nearby bridges to cross the river. Furthermore, due to the lack of a ring road, transit traffic had to pass through the center of Bangkok once. Against this backdrop, the traffic situation in the Bangkok metropolitan area was becoming increasingly congested.

To deal with these traffic problems, the Transport Masterplan for Greater Bangkok was formulated in September 1975, and the construction of the first Metropolitan Expressway was planned as a pillar of the mid-term plan. The main objectives of the project were 1) to speed up traffic by directly connecting the center of Bangkok with the main arterial roads, and 2) to ease congestion in the center of Bangkok by creating a new dedicated route for transit traffic.

Under these circumstances, the Rama IX Bridge was implemented with yen loans in accordance with

[119] JICA: Metropolitan Expressway Construction Project (III) (Chao Phraya River Bridge Section Construction) Evaluation Report, October 2001.

Phase III-1 of the Third Stage Route Plan (construction of bridges connecting Bangkok City and the southwest peripheral areas) of the First Metropolitan Expressway Project. The scope of this loan covers the construction of 1) cable-stayed bridge on the Chao Phraya River overpass, 2) approach bridge on the Thonburi side, and 3) approach bridge on the Bangkok side.

The borrower/implementing agency is the Kingdom of Thailand/Expressway and Rapid Transit Authority of Thailand (ETA), now the Expressway Authority of Thailand (EXAT) (Table 11.14,Table 11.15). The construction of this bridge started in 1984 and was completed in 1987, and it was opened to traffic in 1987 as a road bridge.

Table 11.14 Summary of Loan Agreement (The Rama IX bridge)

Borrower/Implementing Organizations	Expressway and Rapid Transit Authority of Thailand (ETA)
Amount of yen Loan Approved Execution Amount	25,900 million yen 11,097 million yen
Signing of the Exchange of Notes Signing of Loan Agreement	June 1982 July 1982
Terms and Conditions Interest Rate Repayment Period (Deferment Period) Procurement	 30% p.a. 30 years (10 year) General Untied
Loan Completion	September 1989
Main Contract	Hitachi Zosen, Tokyu Construction, Cho Kan Chang (Thai company), Kobe Steel, Nissho Iwai

Table 11.15 The Rama IX Bridge Project Construction Specifications

Section (Bridge)	Specifications
Main cable-stayed bridge	Main spacing: 450 m Main tower: 2 Number of lanes: 6 (3 lanes in each direction) Suspension material: Lock, coil, and cable Auxiliary steel girder: Box girder Two piers each are placed on both side spans as anti-pullers.
Bangkok side approach bridge	Length: 650 m Normal post-tensioned T-girder bridge: 50 m x 13 spans Concrete piles: 746 Steel piles: 376
Thonburi side approach bridge	Length: 650 m Normal post-tensioned T-girder bridge: 50 m x 13 spans Concrete piles: 777 Steel piles: 392

11.5.3 Overview of the Maintenance of the Rama IX Bridge

(1) Location Map of the Bridge

The bridge of interest (the Rama IX Bridge) is a cable-stayed bridge over the Chao Phraya River that crosses Bangkok, the capital of Thailand (Figure 11.33[120]). The Rama IX Bridge is part of the Bang Phli-Suk Sawat Expressway, which is a heavy-traffic route under the management of EXAT that connects Bangkok City and Thonburi District with an annual average daily traffic volume of over 100,000 vehicles. (Figure 11.34).

Figure 11.33Rama IX Bridge Location Map (left) and Photo (right)

Figure 11.34 Rama IX Bridge Location Map (Bangkok)[121]

(2) Bridge Specifications, etc.

The specifications of the Rama IX Bridge are shown in Table 11.16and the annual average traffic volume is shown in Table 11.17. This traffic volume is a cross-sectional traffic volume calculated from the volume of traffic handled at nearby toll booths and is different from the volume of traffic handled itself shown in the annual report. It is also the average daily traffic volume for each year from 2013-2019 before the COVID-19 pandemic. The traffic volume is 124,113 vehicles/day, but the actual traffic volume in 2021 is 90,195 vehicles/day, a decrease of about 30%.

[120] JICA: Metropolitan Expressway Construction Project (III) (Chao Phraya River Bridge Section Construction) Evaluation Report, October 2001.
[121] Expressway Authority of Thailand (EXAT): Annual Report 2020

The side, plan, and main tower cross-sections of the Rama IX Bridge are shown in Figure 11.35Figure 14.3, the support cross-sections in Figure 11.36, and the side cross-sections in Figure 11.37.

Table 11.16 Specifications of the Rama IX Bridge

Bridge Name	Rama IX Bridge
Bridge Type	Steel cable-stayed bridge (Steel slab, steel box girder)
Bridge Length, Span Length	Bridge length: 781.2 m, span length: 450 m
Purpose	Road bridge (6 lanes (3 lanes in each direction))
Start of Construction	1984
Completion	1987-(30 years)
Loan Contract	1982-(30 years)

Table 11.17 Specifications of the Rama IX Bridge

	Traffic Volume (Vehicles/Day)	Notes
Small Cars	120,337	4 axes (2013-2019 results)
Mid-size Cars	3,058	6 to 10 axes (2013-2019 results)
Large Vehicles	718	Over 10 axes (2013-2019 results)
Total	124,113	(Actual figure for 2021 is 90,195 units/day)

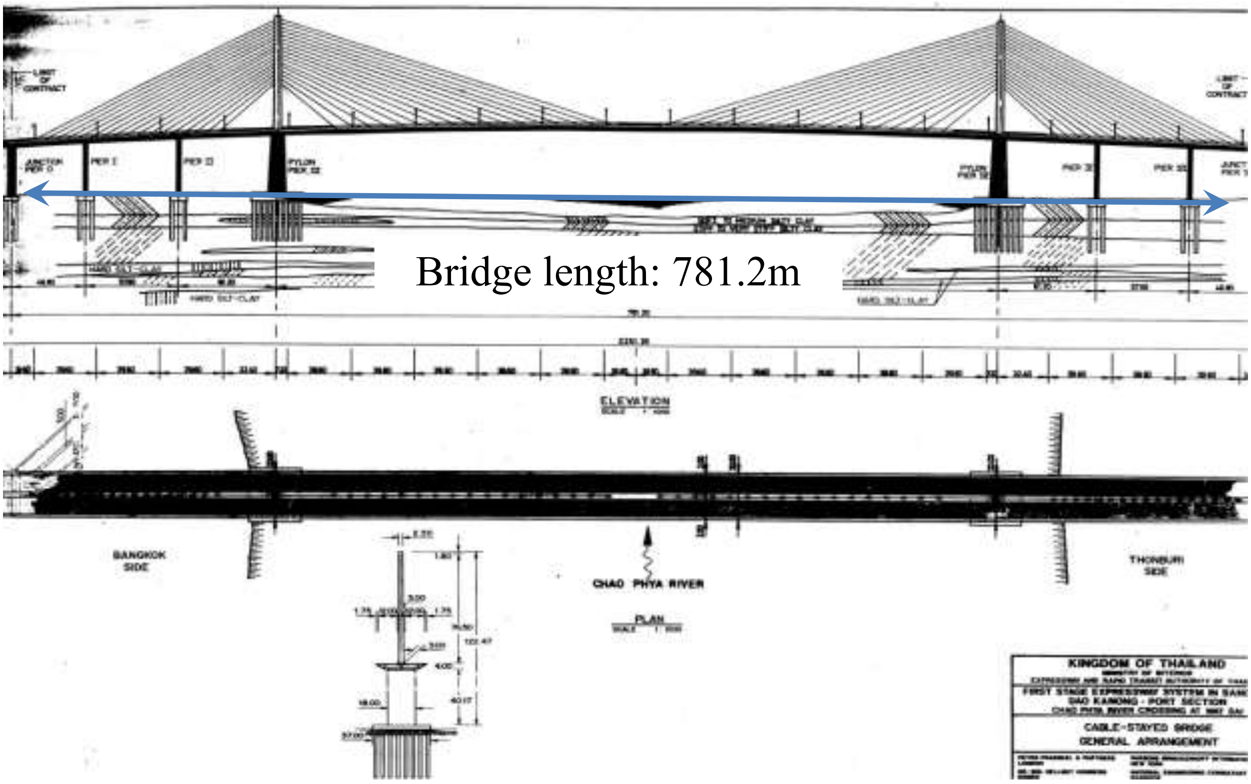


Figure 11.35 Rama IX Bridge: Side view, Plan, Cross Section of Main Tower

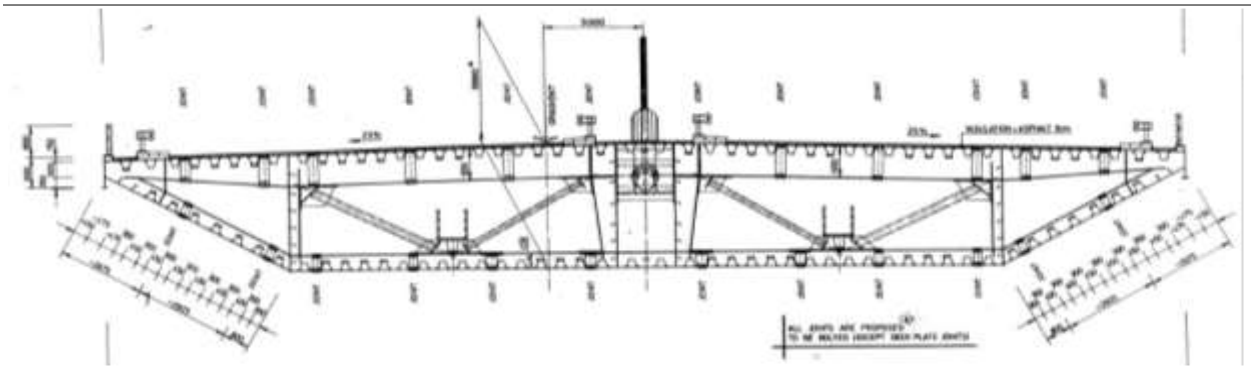


Figure 11.36 Cross Section of the Rama IX Bridge

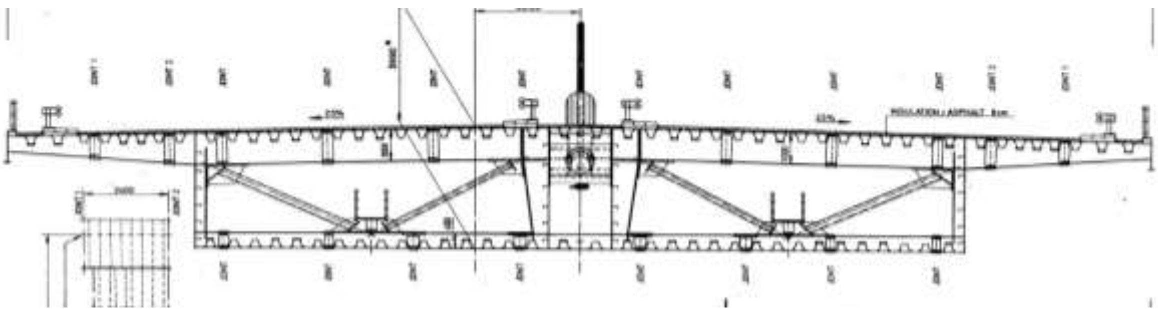


Figure 11.37 Cross-Sectional View of the Side Sections of the Rama IX Bridge

(3) Organizational Structure

As shown in Chapter 5, EXAT manages intra-city highways, which are about 225 km out of the total 700,000 km of roads in Thailand (Table 5.1). As of 2019, the annual average daily handled traffic volume was about 1.8 million vehicles, while in 2020 it was about 1.63 million vehicles.[122]
As of October 2021, EXAT has 5322 employees, of which 829 are assigned to the maintenance department. Of these, 158 are assigned to the Highway Maintenance Department, with 513 permanent staff and 316 temporary staff. Of these regular employees, 37 are assigned to the Bridge Maintenance Section, which oversees the maintenance of the Rama IX Bridge.
Four engineers and seven specialized technicians are assigned to bridge maintenance and are in charge of daily inspections and diagnosis. In addition to the Rama IX Bridge, the Kanchanapisek Bridge and other steel structures are being handled by three separate teams.

(4) Maintenance Budget

No subsidies have been received from foreign countries, foundations, other donors, or the government within the last 10 years. The most recent maintenance budget (investment budget) is shown in Table 11.18, and maintenance costs are steadily being invested.

[122] Thai Highway Corporation (EXAT): Annual Report 2020 (Annual Report 2020)

Table 11.18 Maintenance Budgets (Investments) at EXAT in the Last Three Years

No.	Year	Contents	Events	Budget (Excluding value added tax)	
				(Baht)	(Yen equivalent)
1	2018	Bridge health monitoring system (installation)	Inspection	49,428,037.38	14,462thousand yen
2	2018	Replacement of anchor bolts fixing the foundations of the steel columns (1 location)	Repair	700,747.66	205thousand yen
3	2018	Improvement of side walkways	Repair	1,741,085.38	509thousand yen
4	2019	Replacement of anchor bolts fixing the base of the steel pillars (31 places)	Repair	19,164,485.98	5,457thousand yen
5	2019	Replacement of drainage system	Repair	11,802,803.74	3,361thousand yen
6	2019	Sub-bridge inspection road replacement	Repair	4,626,168.22	1,317thousand yen
7	2019	35-year inspection (consultant)	Inspection	33,644,859.81	9,581thousand yen
8	2020	Replacement of surface layer (Para slurry seal method)	Repair	1,181,171.03	346thousand yen
9	2020	Painting of handrails and guardrails	Repair	3,093,457.94	906thousand yen
10	2020	Repair of surface layer and telescopic equipment on side spans	Repair	17,009,336.45	4,983thousand yen
				Total value 142,392,153.59	41,127 thousand yen

2018: 3.4178 Baht/yen, 2019: 3.5118 Baht/yen, 2020: 3.4132 Baht/yen [123]

Additional information on Figure 11.18 is given below.

1) Bridge Health Monitoring System

The bridge health monitoring system, which was completed in 2021, measures the actual strain and cable tension on the bridge. The monitoring system has been in place since the beginning of the construction, but was upgraded because it was no longer viable. The system was designed by a Thai company, but some of the equipment was purchased from abroad. The installation of the system was supervised by an advisor from a Thai company.

2) Replacement of Anchor Bolts Fixing the Foundations of Steel posts

In 2018 and 2019, the anchor bolts fixing the foundations of the steel pillars, which were rusted by water, were replaced. The Thai contractor sourced and installed the materials locally (Figure 11.37).

[123] World Economy Factbook: Thai Baht-Yen Exchange Rate Trends (https://ecodb.net/exchange/thb_jpy.html)

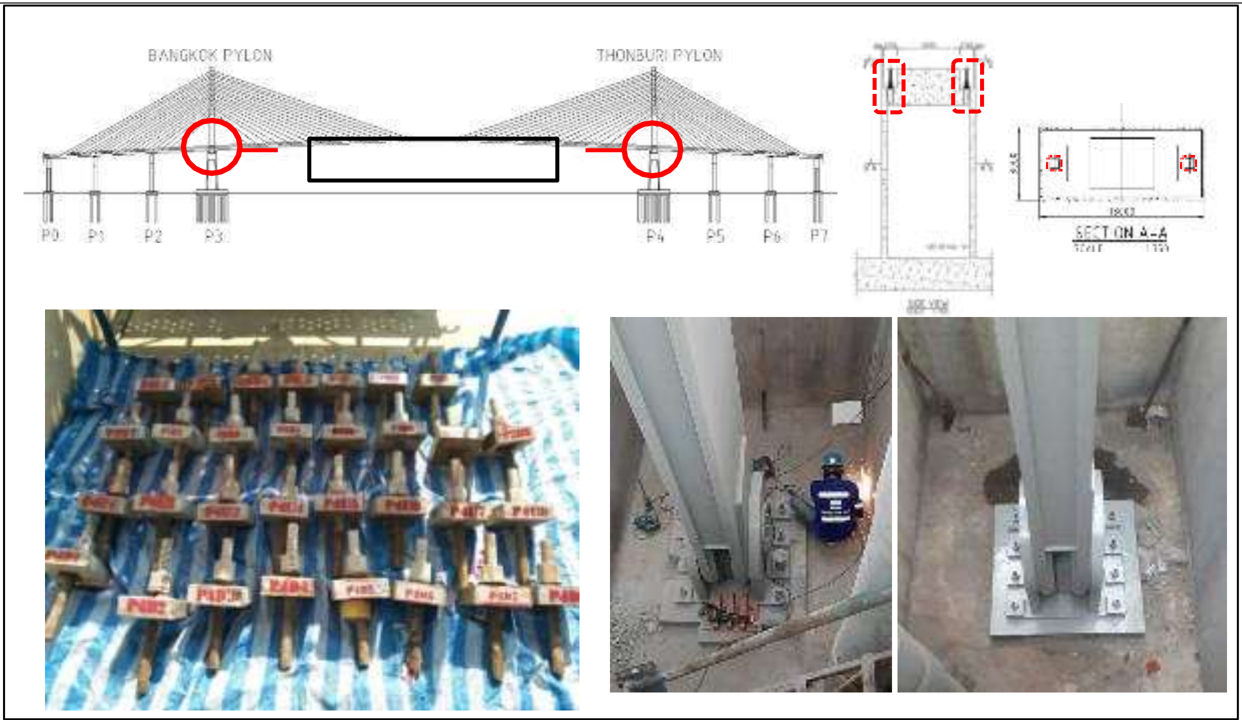


Figure 11.38 Replacing the Anchor Bolts that Secure the Base of a Steel Support Column

3) 35-Year Inspection

The 35-year inspection, budgeted for 2019, was ordered and carried out by a consultant in Thailand and completed in 2021.

(5) Technical Standard

As for inspection manuals, “Expressway Inspection and Maintenance Manual (2006 revision)” is used for general bridges, and “Rama IX Bridge Inspection Manual (2005 revision)” and “Kanchanaphisek Bridge Inspection Manual” are used only for special bridges.

“The Rama IX Bridge Inspection Manual” was developed in 1994 with the support of the JICA team and was revised by Thai consultants in 2005 (Table 11.19). In addition, EXAT itself is planning to revise it in 2022.

The revision of the second edition was based on the first edition, mainly to facilitate the work of the maintenance department by mentioning a database called MAXIMO, which was not described in the first edition. However, MAXIMO is no longer in use because the process of recording and reading data is complex and time-consuming. The revision scheduled for 2022 will remove the reference to MAXIMO.

For “Kanchanaphisek Bridge Inspection Manual”, the first edition was prepared by a Thai consultant in 2017 in collaboration with the Metropolitan Expressway Company. The manual also includes, for example, “AASHTO Guide Manual for Bridge Element Inspection”, “AASHTO Manual for Condition Evaluation and Load and Resistance Factor Ration of Highway Bridges”.

Table 11.19 EXAT's Original Manual for Special Bridges

	Version	Time		Notes
		Revision	Execution	
Rama IX Bridge InspectionManual	First edition 2nd 3rd	1994/09 2005/04 (2022/ plan)	1994-2004 2005-Present	First edition published with JICA support
Kanchanaphisek Bridge Inspection Manual	First Edition	2017/09	2017-Present	In cooperation with Metropolitan Expressway Co.

11.5.4 Technical Challenges of the Rama IX Bridge

(1) Expansion and Contraction Device Replacement (2010)

The expansion and contraction of the telescopic device did not work properly with temperature changes, and the excessive stress generated caused U-rib buckling (Figure 11.39,Figure 11.40).It was repaired by reinforcing with carbon fiber, but the telescopic device was replaced in 2010. The contractor in Thailand procured the materials from abroad and installed them.

Figure 11.39 Replacement of an Expansion joint (2010)

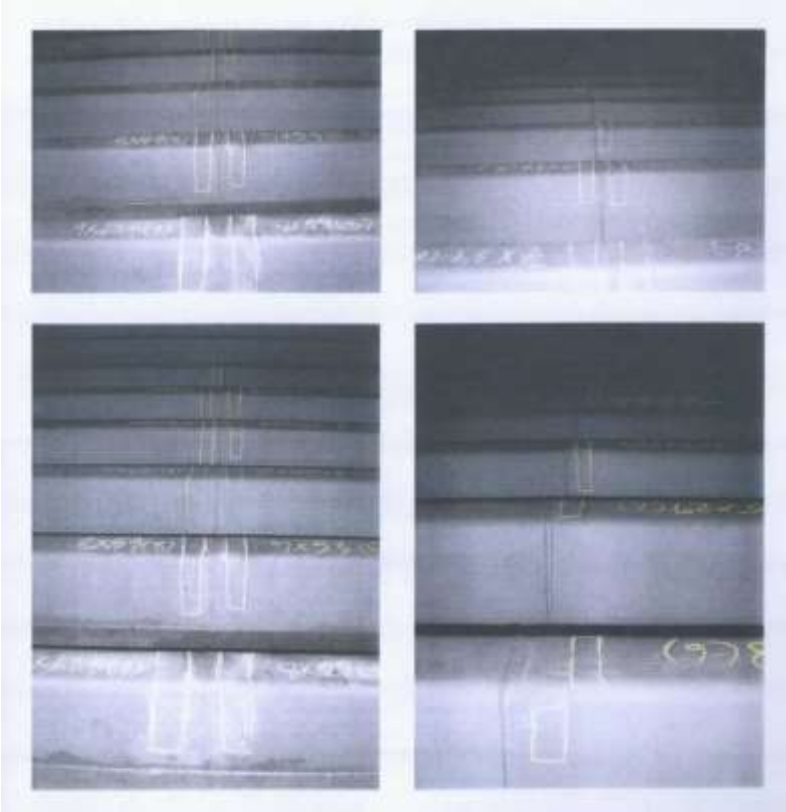


Figure 11.40 Buckling of U-Ribs due to a Defective Expansion Joint

(2) Repainting of the Outside of the Superstructure (2012) and Corrosion of the Inside

The outside of the superstructure was repainted in 2012, but the inside of the superstructure is rusting in some places due to water leakage caused by deterioration of the drainage function (Figure 11.41). The repainting of the cables was carried out in 2016.

Figure 11.41 Corrosion of Steel Inside the Steel Superstructure

(3) Pavement Replacement (2014)

Potholes are occasionally occurring on the pavement surface (Figure 11.42). The thickness of the asphalt pavement is 6cm, and the pavement is to be completely replaced every 10 years (Figure 11.43).

In the meantime, patching and other repairs are being carried out. The pavement repair standards include rutting, IRI, etc. Potholes are to be repaired within 24 hours, and the surface layer replacement in 2020 used modified asphalt, which was procured in Thailand. The asphalt plant is located within 80 km of the project site.

Figure 11.42 Pothole Occurrence (left) and Repair (right)

Figure 11.43 Pavement Replacement

(4) Cracks in the Steel Slab

Cracks in the steel slabs are recognized as a major issue (Figure 11.44).EXAT is working on solving the problem by themselves and working with a consultant in Thailand. The cracks in the steel slabs are considered to be fatigue cracks caused by repeated loading, and countermeasures are being considered based on the results of periodic inspections. The new bridge parallel to the Rama IX Bridge is scheduled to be completed in 2024, so the plan is to wait until then to close the Rama IX Bridge to traffic and repair it. In the 2024 repair, the thickness of the cracked steel slabs will be increased, which will naturally increase the dead load, but since only the damaged areas will be repaired by spot repairs, the entire bridge will not be affected.

Figure 11.44 Cracks in steel slab and U-rib reinforcement

11.5.5 AM Maturity Level of the Rama IX Bridge

11.5.5.1 How to Conduct Maturity Evaluations

The maturity evaluation was conducted through web interviews with the participants according to the schedule shown in Table 11.20 Content of the Maturity Evaluation Hearing In the hearings, we asked them to explain the reasons and background behind the low and high items that they graded. In addition, if the other party offered to revise the level during the hearing, the revision was made on the spot.. The evaluation sheet was distributed in advance, and the grading procedure was explained during the kick-off meeting.
In the hearings, we asked them to explain the reasons and background behind the low and high items that they graded. In addition, if the other party offered to revise the level during the hearing, the revision was made on the spot.

Table 11.20 Content of the Maturity Evaluation Hearing

Item	Date and Time	Attendance	Contents
JICA Kickoff	November 10, 2021 11:30-12:00.	JICA Headquarters, JEXWAY	Explanation of purpose
EXAT Kickoff	November 25, 2021 10:00-11:00 (ICT)	Supapat Mahadthai (Engineer, Construction Division) Sarawut Pornmard (Maintenance Engineer) Tanaporn Moungchoo (Junior Engineer)	Explanation of purpose and setting of hearing date
Hearing 1st Time	December 2, 2021 10:00-12:00 (ICT)	Supapat Mahadthai (Engineer, Construction Division) Jarupong Jitprawes (Chief, Highway Inspection and Maintenance Section 1) Sun Punurai (Director, Highway Maintenance Planning Division) Manoch Chimrak (Bridge Maintenance Section Chief) Tanaporn Moungchoo (Junior Engineer)	Evaluation sheet scoring

Item	Date and Time	Attendance	Contents
	December 3, 2021 9:00-11:00 (ICT)		Evaluation sheet scoring
Hearing 2st Time	December 16, 2021 10:00-11:00 (ICT)		Additional questions
Feedback to EXAT	January 20, 2022 10:00-11:30 (ICT)	Jarupong Jitprawes (Chief of Highway Inspection and Maintenance Section 1) Sun Punurai (Director, Highway Maintenance Planning Division) Manoch Chimrak Bridge Maintenance Section Chief) Tanaporn Moungchoo (Junior Engineer)	
JICA Report	January 28, 2022 From 16:00	JICA Headquarters	

11.5.5.2 Maturity Evaluation Results

(1) Radar Chart

The radar chart (level evaluation) by major and medium items is shown in Figure 11.45. Red is the result of the evaluation of the Rama IX bridge in EXAT, and the gray dotted line indicates a perfect score. The radar chart based on the level evaluation of the Rama IX Bridge is asymptotic to the case of a perfect score, and to show the situation clearly, Figure 11.46shows the radar chart based on the achievement rate evaluation, which shows the evaluation result of each item as a percentage of its perfect score.

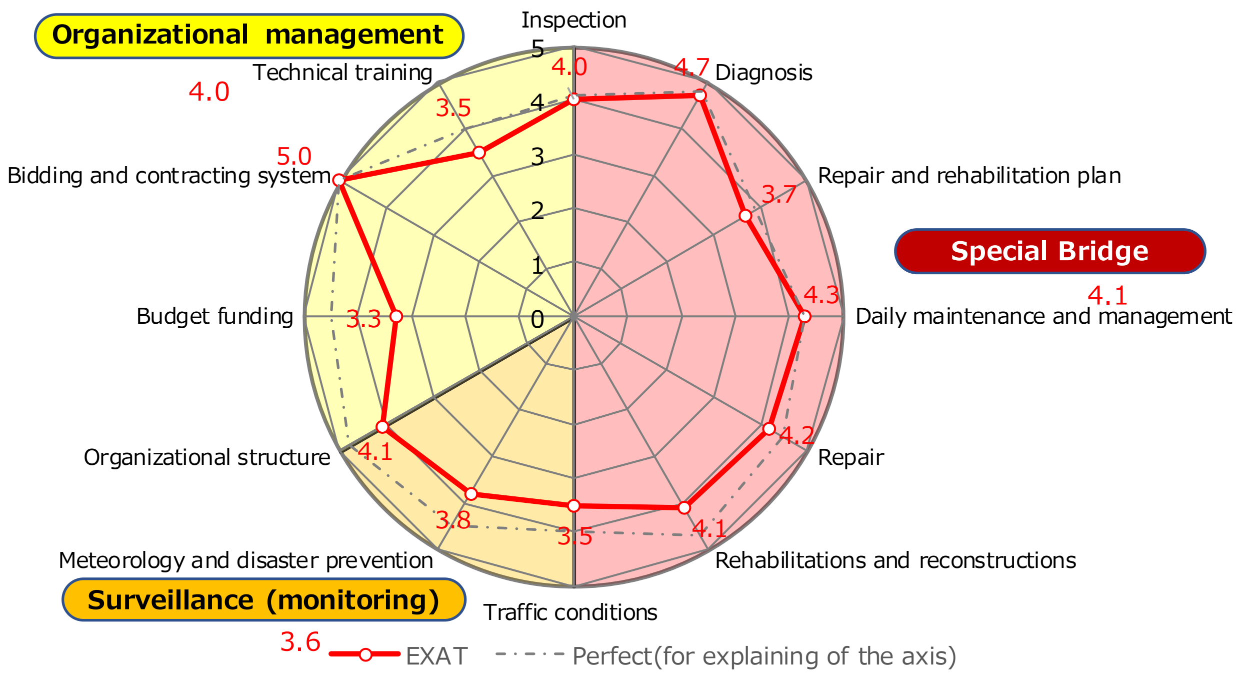


Figure 11.45 Major and Medium Item Radar Chart (Level)

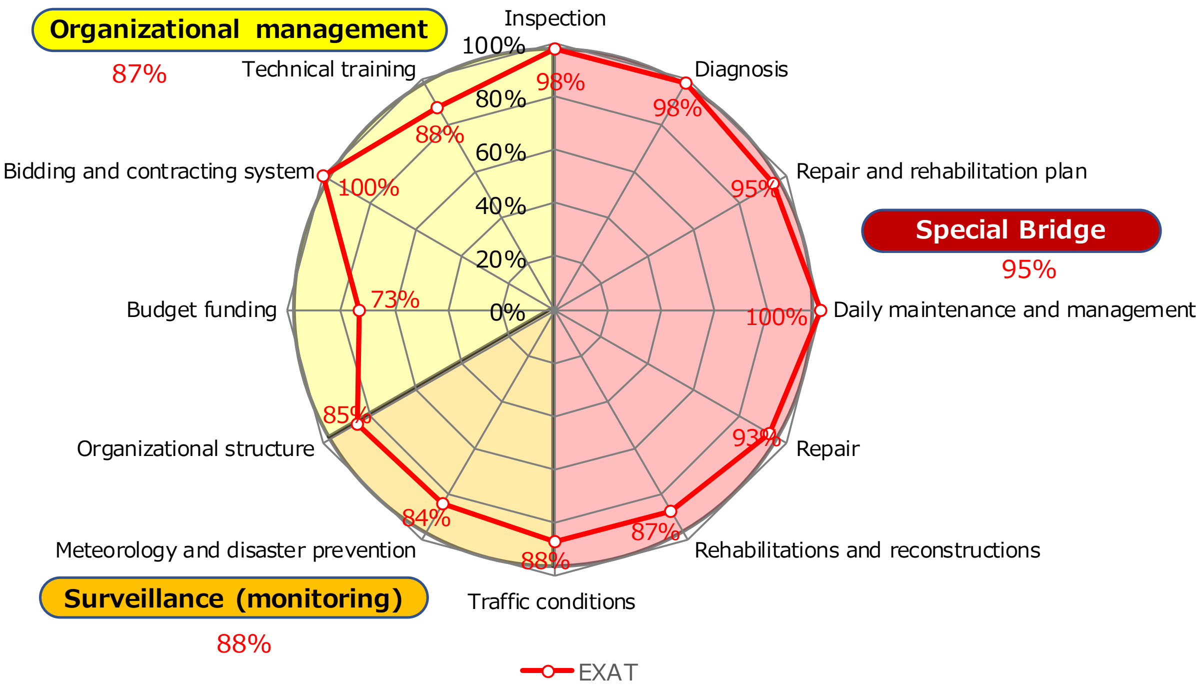


Figure 11.46 Major and Medium Item Radar Chart (Achievement Rate)

(2) Overall Evaluation

1) The overall average evaluation of the Rama IX Bridge is level 4.1 (95.1%), and none of the middle and sub-items are below level 3 of the JICA technical cooperation project target. No problematic technical items are found in the special bridge AM evaluation.

2) There is an inspection and diagnosis manual specifically for the Rama IX Bridge, and the fact that EXAT itself is continuously revising the manual based on the first edition formulated with JICA's support is worthy of emulation by other developing countries. However, the frequency of periodic inspections is considered to be less than once every 10 years, as it affects the repair plan of the bridge.

3) The overall average for the evaluation of “Surveillance (Monitoring)” is level 3.6 (88%), and none of the middle or sub-items are below level 3 of the JICA technical cooperation target. In the future, it is expected that the information from these monitoring will be used to contribute to safe and smooth traffic.

4) As for the evaluation of “Organizational Management”, the overall average is level 4.0 (89%), and none of the middle and sub-items are below level 3 of the JICA technical cooperation project target. However, when looking at the details, “Training Facilities and Budget Allocation” is at level 2. It is important that the skills necessary for bridge maintenance and management are passed on and that young engineers are trained. EXAT wishes to receive specialized training in inspection and repair, and may participate in JICA's group training programs.

5) The budget required for maintenance of bridges can be minimized in the long term by proper asset

management. It is necessary to continue to carry out appropriate asset management, and to make the necessary repairs and preventive maintenance to extend the service life.

(3) Findings

In the maturity evaluation of the Rama IX Bridge, the following sub-items received a perfect score and could be best practices for other developing countries, but there are some points to keep in mind. Notes are given in 11.5.5.3

Table 11.21 Sub-Items that Received Full Marks on the Rama IX Bridge

Major items	Middle items	Small items
Bridges	Inspection	Inspection system and manual
		Implementation of daily inspections
		Implementation of periodic inspections
	Diagnosis	Diagnostic manual
		Diagnosis of soundness
	Repair and Rehabilitation Plan	Diagnosis of plan
	Daily Maintenance and Management	Daily maintenance system
		Cleaning (Bridges)
		First aid measures
	Repair	Repair systems
		Quality standards
	Rehabilitation and Reconstruction	none
Surveillance (Monitoring)	Traffic Conditions	none
	Meterology and Disaster Prevention	none
Organization and Structure	Organizational Structure	Business continuity
	Budget Funding	none
	Bidding and Contracting System	Bidding and Contracting System
	Technical Training	none

11.5.5.3 Current Status and Challenges of the Rama IX Bridge

(1) Inspection and Diagnosis

1) The inspection manual for the Rama IX Bridge was originally prepared by a JICA team in September 1994 and revised by a Thai consultant in April 2005. It is an EXAT original. It is also scheduled to be revised in 2022.
2) Inspection equipment is fully equipped at EXAT, properly maintained, and defective inspection

equipment is repaired and updated as needed. EXAT also owns a bridge inspection vehicle.

3) Diagnosis will be determined directly by the organization when urgent action is required, such as damage that needs to be repaired within 24 hours. If an emergency response is not required, the work is outsourced as necessary. The diagnosis is made by seven inspectors who have received the necessary specialized training, and after evaluations are done based on the inspection manual, four engineers will make the final decision based on their expertise in their respective fields.
4) Inspection results are referred to in the field for routine maintenance and are also used for periodic inspections.
5) Daily inspections arecarried out directly by seven inspectors and four other specialized technicians on a cycle of no more than one year.
6) Periodic inspections will be outsourced to an engineering consultant once every 10 years.
7) Damage is assessed and ranked by structure. The integrity of the structure is assessed based on the results of periodic inspections at 10-year intervals for large components such as slabs, girders, and substructures.

(2) Repair and Rehabilitation Plan

1) The inspection results of the Rama IX Bridge are managed by a stand-alone system, which will be migrated to the BMS currently in operation in early 2022. Once the data is transferred to the BMS, the repair plan creation function of the BMS can be used.
2) The causes of all damages have been identified and their repair methods are being studied by EXAT.
3) Predictions of structural integrity are based on a comprehensive evaluation of the inspection results for each component.
4) A 10-year repair plan is developed based on periodic inspections every 10 years, but due to budget allocations, only a 5-year medium-term plan is allowed.

(3) Daily Maintenance Management,Repair, Rehabilitation, and Reconstruction

1) Daily maintenance management work is carried out by EXAT in three groups of four people per group (12 people in total).
2) Repairs are outsourced, except when partially performed directly by the organization, such as touch-up painting. Reconstraction work is outsourced.
3) The quality standards are original to EXAT, and for the Rama IX Bridge, they are unique and distinct from other bridges. Some of these individual standards are set by applying external standards, such as those provided by Thailand, the United States, and JICA.
4) The repair manual for the Rama IX Bridge was originally prepared by JICA and revised in 2005, and is the original of EXAT. It is currently under review and is expected to be revised in 2022.
5) Repairs due to traffic accidents and other emergency measures are also recorded in the database.
6) A repair plan is developed prior to the repair and is updated whenever there is a change in conditions.
7) The results of repairs are recorded and updated for each repair. The same applies to records of

	rehabilitations and updates.
8)	Repainting, which is carried out as preventive maintenance, was carried out in 2010 on the exterior of the superstructure of the entire Rama IX Bridge and in 2016 on the cables only.
9)	The painting condition is checked by visual observation during daily inspections and by the use of equipment when necessary, and the time for repainting is determined.

(4) Surveillance (Monitoring)

1)	Traffic volume is measured 24 hours a day by laser and other machines.
2)	EXAT directly measures wind, but obtains measurements of rain and temperature from outside agencies.
3)	Deflection, strain, etc. are measured for monitoring of structures.

(5) Organizational Management

1)	Management objectives and decision-making criteria for achieving them are established in each sector, internal audits are conducted regularly, and management reviews are carried out.
2)	Standardized response systems for accidents, rainfall, and earthquakes have been established and are continually reviewed. Traffic control due to wind speed is enforced, but traffic control due to rainfall is not enforced.
3)	The bidding and contracting system, including costing standards, bid rigging prevention, contracting methods, procurement processes, and contract modification procedures, are all properly implemented and are continuously evaluated and reviewed.
4)	There are no dedicated training facilities for internal training, but classroom lectures are conducted using existing conference rooms, on-site training is conducted in the field when necessary, and on-the-job training is also conducted. External training has been conducted by private bridge manufacturers and government road departments. There is no long-term training plan, but the content of the training changes from year to year, and the content of past training is evaluated and analyzed in order to enhance the training in areas that are lacking.
5)	Since there are no specialized training facilities for inspection and repair, there is a desire for engineers to visit training facilities in Japan to learn about the level and structure of training.
6)	Although the budget plan is on a 5-year basis, the actual allocation of the required budget is partially skewed. The maintenance management budget is funded entirely by tarrif revenue, there are no government subsidies, and the organization has a certain budget limit and may not be able to raise sufficient funds. Therefore, maintenance starts with projects that have the highest priority.

11.5.5.4 Maturity and Findings of the Rama IX Bridge AM

(1) Inspection and Diagnosis

1) Maturity of Inspection and Diagnosis

a)	The medium item “Inspection” is 4.0 (98%) and the “Diagnosis” is 4.7 (98%).
b)	These sub-items are “Inspection Manuals”, “Implementation of Daily Inspection”,

“Implementation of Periodic Inspection”, “Diagnosis Manuals”, and “Diagnosis of Soundness” with full marks.

c) The reason why “Inspection and Diagnosis Systems” receive a score of 4.5, which is not a perfect score, is because they are rated as level 5 (perfect score) when directly managed, but level 4 when outsourced.

d) The frequency of inspections, the method of inspection and the maintenance and operation of inspection equipment are superficial evaluations based on interviews. In practice, it is necessary to check the local conditions and actual activities and evaluate them from a more objective perspective.

2) Findings of Inspection and Diagnosis

a) The fact that EXAT itself is continuously revising the inspection and diagnosis manual based on the first edition developed with JICA's support is worthy of emulation by other developing countries.

b) “Periodic Inspections” are at a perfect score, assuming a 10-year interval. periodic inspections are conducted to obtain the necessary information to determine the need for countermeasures until the next periodic inspection. As the bridge ages, the structure deteriorates further, so for the Rama IX Bridge, which has been completed for more than 30 years, the periodic inspection at 10-year intervals is considered to be slightly longer.

c) Future periodic inspections should be conducted at five-year intervals, but may be shorter than five years depending on the needs of the components. In this case, it is not necessary to align all of them with 5-year intervals. For example, depending on the importance of the material, it is possible to combine 3-year, 6-year, and 10-year intervals.

(2) Repair and Rehabilitation Plan

1) Maturity of the Repair and Rehabilitation Plan

a) The rating for the middle item, “Repair and Reconstruction Plan” is 3.7 (95%). The rating for that sub-item is a perfect score for Planning, and 3.5 (90%) for both “Bridge Asset Register/DB” and “Bridge Management System”.

2) Findings of the Repair and Rehabilitation Plan

a) The inspection results are recorded and operated as a stand-alone system. The system is scheduled to be integrated with the BMS currently in operation on other bridges in 2022, and efficient operation is expected in the future.

b) The formulation of a plan for the middle item is given full marks, but the sub-items that are a prerequisite for its evaluation include prediction of health and preventive maintenance. If these are to be implemented based on the results of periodic inspections, it is necessary to confirm whether the system can promptly reflect the results of detailed inspections and structural monitoring conducted as needed, because periodic inspections once every 10 years may deviate significantly from the actual situation.

(3) Daily Maintenance Management, Repair, Rehabilitation, and Reconstruction

1) Maturity of Daily Maintenance Management, Repair, Rehabilitation, and Reconstruction

a) The rating for the middle item, “Daily Maintenance Management”, is a perfect score.
b) The rating for the middle item, “Repair”, is 4.2 (93%).The evaluation of those sub-items is 3.7 (90%) for “Repair (Design) Manual” and 3.8 (82%) for the “Implementation of the Repair”, with the repair system and quality standard receiving full marks.
c) The details that fell below level 3 are “Repair (Main repair) and “Rehabilitation and “Reconstruction” at level 2, but the full score for these is level 3. These have also been partially implemented.
d) The middle item, “Rehabilitation and Reconstruction”, is 4.1 (87%). The rating for that sub-item is 4.7 (93%) for “System for Rehabilitations and Reconstruction” and 3.8 (82%) for the “Implementation of Rehabilitations and Reconstruction”.

2) Findings of Daily Maintenance Management, Repair, Rehabilitation, and Reconstruction

a) Quality standards are important and need to be continuously revised as technology advances. In particular, since special components are used in such bridges, special quality control based on the characteristics and aging of individual structures is required.
b) “Repair(main repair)” in the detail of the middle item “Implementation of Repairs” and “Rehabilitation, and reconstruction” in the detail of the middle item “Implementation of Rehabilitations and Reconstructions” do not meet the level 3 target set by the JICA technical cooperation project because they are only partially implemented, but the full score is level 3 and all other detals of these middle items are above level 3, so there is no problem.
c) It is difficult to fully implement repairs due to budget constraints. In order to extend the life of the structure and make the minimum necessary repairs, it is recommended that periodic inspections, including partial detailed inspections and monitoring of the structure, are carried out more frequently, depending on the state of damage.
d) When repair work is started based on the repair plan, unexpected damage may be found. In such cases, change management is important and the repair method should be flexible according to the newly found damage.

(4) Surveillance (Monitoring)

1) Maturity of Surveillance (Monitoring)

a) The rating for the middle item, “Traffic Conditions”, is 3.5 (88%). The evaluation of the details is a perfect score (level 5) for the monitoring scope, monitoring frequency, and information sharing and utilization of monitoring results, and level 3 for the monitoring points.
b) The score for the middle item, “Weather and Disaster Prevention”, is 3.8 (84%). The evaluation of the details is a perfect score (level 5) for the monitoring scope and monitoring frequency, level 3

for "Monitoring Points", and level 4 for "Information Sharing and Utilization of Monitoring Results".

2) Findings of Surveillance (Monitoring)

a) It is a very busy section with six lanes and more than 100,000 vehicles per day. It is expected that the results of traffic monitoring will be used to provide users with traffic information that contributes to safe and smooth traffic, and to continuously assess the future risks and life cycle costs of structures.
b) The Rama IX Bridge is located in a tropical monsoon climate, with heavy squalls during the rainy season. EXAT's highways are mainly urban, elevated bridges that are not affected much by rain. However, it is important to obtain weather-related information necessary to ensure the safety of road traffic, such as wind, and the results of weather-related monitoring are useful in providing traffic regulations and road traffic information according to wind and traffic conditions.
c) Monitoring of structures, such as deflections and strains, has been conducted on the Rama IX Bridge. This is an important complement to the regular inspection intervals and requires continuous evaluation of the observed data.

(5) Organizational Management

1) Maturity of Organizational Management

a) The middle item, "Bidding and Contracting System", receives a perfect score, while the other items are "Organizational Structure" 4.1 (85%), "Budget Funding" 3.3 (73%), and "Technical Training" 3.5 (88%).
b) In the sub item of "Organizational Structure, Business Continuity" is given a perfect score, and the other sub items are "Asset Management Cycle" at 3.7 (73%), "Organization" at 4.0 (80%), and "Control" at 4.0 (93%).
c) In detail, "Training Facilities and Budget Allocation" is at level 2. These are the only organizational management items that fell below level 3.

2) Findings of Organizational Management

a) If internal audits or management reviews find no need for improvement, there may be problems with the way it is implemented, or with the setting of standards and targets.
b) Regarding the continuation of the project, traffic control due to rainfall has not been implemented, but this is not a particular problem since the EXAT expressway is an elevated bridge and it is unlikely to be closed due to rainfall.
c) The middle item, the bidding and contracting system, which received a perfect score, can serve as a model for other developing countries as a fair and efficient bidding and contracting system.
d) It is important that the skills necessary for bridge maintenance and management are passed on and that young engineers are trained. EXAT has an agreement with a Japanese expressway company and training has been provided in Japan, but they would like specialized training in inspections

and repair, and may participate in JICA's country-specific subject-specific training.

e) The budget required for maintenance of bridges can be minimized in the long term by proper asset management. It is necessary to continue to carry out appropriate asset management, and to make the necessary repairs and preventive maintenance to extend the service life.

11.5.6 List of the Rama IX Bridge Evaluation Results

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Bridges	4.1	95.1%	Inspection	4.0	98%	Inspection system	4.2	83%	System	4.5	90%
									Technical level of inspectors	3	60%
									Use of inspection equipment	5	100%
						Inspection manual	4.2	100%	Existence of daily inspection manual	5	100%
									Use of daily inspection manual	3	100%
									Existence of periodic inspection manual	5	100%
									Periodic inspection manual operation	3	100%
									Technical level of the manual	5.0	100%
						Implementation of daily inspections	3.7	100%	Inspection range	3	100%
									Frequency of inspections	3	100%
									Storage and sharing of inspection records	5	100%
						Implementation of periodic inspections	3.7	100%	Inspection range	3	100%
									Frequency of inspections	3	100%
									Storage and sharing of inspection records	5	100%
			Diagnosis	4.7	98%	Diagnostic system	4.8	95%	System	4.5	90%
									Technical level of diagnosis	5	100%
						Diagnostic manual (Specific bridge)	4.3	100%	Existence of diagnostic manual	5	100%
									Use of diagnostic manual	3	100%
									Technical level of the manual	5.0	100%
						Diagnosis of soundness (Specific bridge)	5.0	100%	Investigation of the cause of damage	5	100%
									Ranking of damage level	5	100%
									Storage and sharing of diagnostic records	5	100%
			Repair and rehabilitation plan	3.7	95%	Bridge assets ledger/DB	3.5	90%	Existence of bridge assets ledger/DB	4	80%
									Use of bridge assets	3	100%
						Bridge management system	3.5	90%	Existence of bridge management system	4	80%
									Use of bridge management system	3	100%
						Development of the plan	3.8	100%	Planning	5	100%
									Scope of the plan	3	100%
									Prediction of soundness	3	100%
									Understanding of the cost of repairs and rehabilitation	3	100%
									Preventive maintenance	5	100%

Figure 11.47 List of the Rama IX Bridge Evaluation Results【Bridge】(1/2)

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
			Daily maintenance and management	4.3	100%	System for daily maintenance and management	5.0	100%	System	5.0	100%
									Technical level of the person responsible for maintenance and management	5	100%
									Operation of maintenance and management work equipment (bridges)	5	100%
						Cleaning (bridge)	4.0	100%	Cleaning range	3	100%
									Frequency of cleaning	5	100%
						Emergency measures	4.0	100%	Management of response to deformation and damage	5	100%
									Small repair of deformation (temporary repair)	3	100%
									Emergency restoration of failures, etc.	3	100%
									Storage and sharing of emergency measure records	5	100%
			Repair	4.2	93%	Repair system	5.0	100%	System	5.0	100%
									Technical level of repair	5	100%
									Procurement of materials and equipment	5	100%
						Quality standards (Specific bridge)	4.3	100%	Existence of quality standards	5	100%
									Application of quality standards	3	100%
									Quality control	5	100%
						Repair (Design) manual	3.7	90%	Existence of repair (design) manuals	4	80%
									Use of repair (design) manual	3	100%
									Technical level of the manual	4.1	90%
						Implementation of repairs	3.8	82%	Repair planning and process management	5	100%
									Repair (radical repair)	2	67%
									Management of changes	3	60%
									Storage and sharing of repair records	5	100%
			Rehabilitations and reconstructions	4.1	87%	System for rehabilitations and reconstructions	4.7	93%	System	4.0	80%
									Level of technology for rehabilitations and reconstructions	5	100%
									Procurement of materials and equipment	5	100%
						Implementation of rehabilitations and reconstructions	3.8	82%	Implementation plan	5	100%
									Rehabilitation and reconstruction	2	67%
									Management of changes	3	60%
									Storage and sharing of records of rehabilitations and reconstructions	5	100%

Figure 11.48 List of the Rama IX Bridge Evaluation Results【Bridge】(2/2)

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Surveillance (monitoring)	3.6	87.5%	Traffic conditions	3.5	88%	Traffic volume	3.5	90%	Monitoring range	3	100%
									Monitoring frequency	3	100%
									Monitoring sites	3	60%
									Information sharing and utilization of monitoring results	5	100%
			Meteorology and disaster prevention	3.8	84%	Precipitation, temperature, wind	3.8	85%	Monitoring range	3	100%
									Monitoring frequency	5	100%
									Monitoring sites	3	60%
									Information sharing and utilization of monitoring results	4	80%

Figure 11.49 List of the Rama IX Bridge Evaluation Results【Surveillance(Monitoring)】

Major item	Lv	Achv	Middle item	Lv	Achv	Subitem	Lv	Achv	Details	Lv	Achv
Organizational management	4.0	86.9%	Organizational structure	4.1	85%	Asset management cycle	3.7	73%	Setting management goals	4	80%
									Conducting internal audits	3	60%
									Implementation of management review	4	80%
						Organization	4.0	80%	Role-sharing	3	60%
									Manpower allocation	5	100%
						Control	4.0	93%	Commitment from the top	3	100%
									Influence of the organization	4	80%
									Motivation and ability of counterpart	5	100%
						Business continuity	5.0	100%	Responding to accidents	5	100%
									Responding to rainfall	5	100%
									Responding to earthquakes	5	100%
						Operational support facilities	3.5	70%	Training facility	2	40%
									Communication facilities	5	100%
			Budget funding	3.3	73%	Budget	3.0	60%	Budget planning	4	80%
									Budgetary allocation	2	40%
						Raising funds	3.5	90%	Short-term financing	3	100%
									Long-term financing	4	80%
			Bidding and contracting system	5.0	100%	Bidding and contracting system	5.0	100%	Cost estimation standard	5	100%
									Prevention of collusion	5	100%
									Contract method	5	100%
									Procurement process	5	100%
									Contract change	5	100%
			Technical training	3.5	88%	Pavement training	3.5	90%	Training plan	3	100%
									Contents of training	4	80%
						Bridge training	3.5	90%	Training plan	3	100%
									Contents of training	4	80%

Figure 11.50 List of the Rama IX Bridge Evaluation Results【Organizational Management】