incorporated into the system. It is necessary to make it possible to automatically incorporate inspection sheets into the system in order to improve system efficiency and prevent human error.

### 6.4.2 The technical elements necessary for improving BMMS

The technical elements necessary to improve BMMS are as follows, based on the issues raised in 6.4.1(1).
Examples for reference are offered in (2) of the use of these technical elements in Japan. It is preferable that improvements be made to the system based on the reference examples in order to achieve bridge maintenance that utilizes BMMS.

#### (1) Technical elements

a) Establishing a method of evaluating bridge healthiness
It is necessary to be able to quantitatively understand the healthiness of a bridge (members) in order to propose a long-term bridge maintenance plan. It is necessary to establish a method of evaluating bridge healthiness that can comprehensively evaluate the differences and scope of damage based on damage evaluation results gained according to the inspection and evaluation manual.
It is necessary to target high priority members in order to achieve bridge safety when determining the bridge healthiness. The optimal determination must be made in consideration of the trends for damage in rural bridges in Thailand.
Thorough consideration must also be made of risk management policies, because the risk exists that severe damage might be missed if bridge healthiness is evaluated mechanically based on inspection results.

b) Determining management levels
It is illogical to manage all of the bridges according to the same level when the bridges being managed possess a variety of characteristics. This leads to the risk of increased maintenance costs and possesses the potential for resulting in the prevention of appropriate maintenance.
It is essential that management levels be adopted appropriate for the characteristics of the bridge such as its importance and application in order to efficiently and effectively manage all of the bridges as a whole. Management levels can also be restated as maintenance targets for bridges. It is possible to express the greater concept for bridge maintenance by setting different management targets for individual bridges.

c) Determining a priority evaluation index
It is necessary to determine the management levels for each bridge in consideration of the conditions of the bridge and calculate a point evaluation using a priority evaluation index that

evaluates the importance of the bridge. It is possible to clearly indicate the justification for determining management levels by quantitatively evaluating the importance of the bridge.

d) Establishment of predicting method for deterioration

A method of predicting deterioration based on the theoretical formula is applicable under limited conditions for specific members. However, this is not suitable for proposing a maintenance plan based on inspection results because this method requires a variety of tests in order to apply the theoretical formula.

Conversely, a method of predicting deterioration using inspection results could be a data analysis method. Appropriate methods could include PONTIS which is in use in the US or the "Markov Model of transition probability" that is in use by many local governments in Japan.

In these methods it is possible to reflect the differences in the conditions of construction and environmental conditions of each bridge in order to calculate the predicted deterioration of a single bridge (by individual member). While inspection data is currently limited, and it can be said that prediction accuracy is low, it is possible to make improvements to the prediction accuracy as more data is accumulated.

e) Determining repair methods appropriate for the level of bridge healthiness

By determining the repair methods appropriate for the level of bridge healthiness, it is possible to clearly indicate the increased costs if the level of health of the bridge deteriorates (deterioration progresses) when the damage is not dealt with. This can then be used as the basis of an explanation of the necessity for preventative maintenance.

f) The method of prioritizing in a logical way that takes the risk of damage into consideration

A method is necessary for assigning priority that has the purpose of achieving bridge healthiness and reducing maintenance costs in the future and which makes attaining safety and reliability the highest priority.

g) Incorporating the concept of equalization in order to propose an effective maintenance plan

Even as budgets encounter limitations resulting from the current severe economic conditions, it is possible to propose an effective and realistic maintenance plan through eualization. This involves extracting the bridges for which countermeasures will be implemented within the confines of budget limitations and determining the timing for implementing countermeasures based on management levels, evaluations of importance and priority.

The use of deterioration predictions to track bridge healthiness over time and tracking maintenance conditions according to management levels makes it possible to explain the risks presented when countermeasures are delayed as a result of budget limitations.

h) A form that provides output which enables an explanation of the appropriateness of cost required for maintenance

It is preferable to provide information on the following items in the documents used to explain the appropriateness of maintenance costs during budget negotiations with the finance bureau.

- Quantitatively indicate the cost reduction effectiveness of implementing preventative maintenance by comparing the maintenance costs required for the responsive and preventative maintenance.
- Illustrate a graph of single year operating costs and cumulative operating costs from the results of a simulation of the future based on the scale of the budget.
- Illustrate a graph of changes in the distribution of the healthiness of all bridge elements totaled together based on a simulation of the future.
- Illustrate a graph of the proportion of bridges that satisfy the management level in order to understand the current state of maintenance of the bridges.
- By summarizing these results, it is possible to easily understand conditions such as if the budget is insufficient and if the maintenance targets are being achieved. This makes it possible to explain quantitatively the appropriateness of maintenance costs and the risk, etc., projected to bridges when repairs are delayed.

### (2) Reference examples of the use of these technical elements in Japan

Appendix-7 introduces an example case of the establishment of a long-term maintenance plan for rural bridges in Japan. This summary is a reference document based on case examples adopted by local governments in Japan of long-term maintenance plans which were proposed after applying the technical elements described in (1).

## 6.4.3 The direction of efforts aimed towards improving basic data

a) Training of engineers

One reason that can be given for the decay of rural bridges is the lack of technical skill level amongst engineers for correctly determining the condition of bridges. It is necessary to make further progress on efforts towards cooperation between government and academia (inspection training, training about repair techniques, etc.), as was similarly pointed out in our interviews with academic experts.

In response to the low level of awareness amongst the entities responsible for bridge maintenance, it is likely also necessary to make consistent efforts to raise awareness of the necessity of bridge maintenance.

The development of engineers is not something that can be achieved overnight. However, engineers must be rapidly developed by clarifying the priority of maintenance work within DRR, raising technical skill levels and increasing the number of personnel, and it is necessary to take preventative maintenance measures for aging bridges.

b) Unifying the format of inspection forms

It's important to improve efficiency during system input and prevent human error during input by unifying the format of inspection forms. The suggested formats are displayed in Report 2.

# Chapter 7 Technology Transfer

## 7.1 Details of OJT programs

### 7.1.1 Sharing techniques to conduct bridge inspections and evaluations

Our JICA study team successfully completed an OJT-based technology transfer project (one of the team's missions).We thanks to the cooperation rendered by the DRR.
The OJT programs can be classified mainly into two categories. One is to require trainees to conduct bridge inspections on an on-site basis; the other is to offer lectures to give in-depth explanations about matters related to the inspection work so that trainees can deepen understanding through discussions.
The on-site inspections and lectures were attended by a total of 75 and 43 DRR officers respectively. The details of these OJT programs are summarized in Appendix 10. It should be noted that *Chapter 3 Inspections, investigations, and evaluations of the Chao Phraya River Bridges* was drafted in collaboration with the DRR based on the above-mentioned discussions.

#### (1) On-site inspection programs

The team inspected the bridges throughout the three-month period of the Survey (Phase 2).
The inspections were successfully completed. On-site inspection training programs were offered on about 45 days (from September 24 to November 8) to participants selected by the DRR in advance. During this period, the on-site inspection training programs were joined by bridge engineers of JICA Expert in Ethiopia Office and local consultants who made a request to observe the bridge inspection activity.

#### (2) Lectures

Four lecture sessions were given in total. Documents used in these lectures can be found in Appendix 10.

1) Key points of visual inspections and overview of inspection instruments
On October 5, 2010, a lecture was given at the Conference Room No. 3 on the third floor of the DRR head office, to explain how to conduct field surveys/visual inspections, how to use inspection devices, and how to evaluate information obtained with inspection devices. The lecture was attended by 17 DRR officers.

Before reading the Inspection and Evaluation Manual (draft), we explained to DRR staff members the key points of visual inspection techniques. We also explained the mechanism of, and how to use, a pole camera, an auxiliary tool in conducting visual inspections.

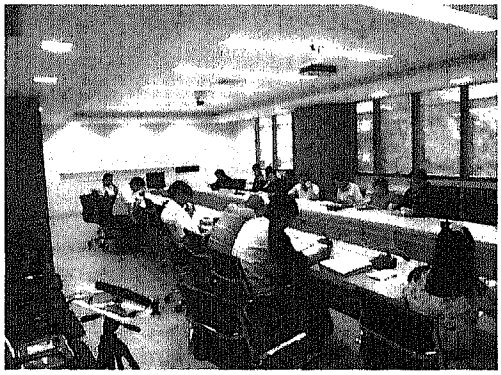

*Fig. 7.1.1 Lecture*

*Fig. 7.1.2 Explaining how to use devices*

We also explained how to use non-destructive inspection instruments through hands-on experience. Specifically, we gave explanations about (i) the Schmidt hammer, electromagnetic wave radar, and concrete test hammer that are used for concrete structures, and (ii) the thickness gauge and salinometer that are used for steel structures.

We also introduced some other tools that are used in inspection work, such as an infrared thermometer and laser range finder.

2) Explaining how to use single-lens reflex digital cameras

On October 18, 2010, a lecture was held at the Conference Room No. 4 on the third floor of the DRR head office, to explain how to use single-lens reflex digital cameras and process images obtained on-site. Specific applications in Japan were also presented. The lecture was attended by seven DRR staff members.

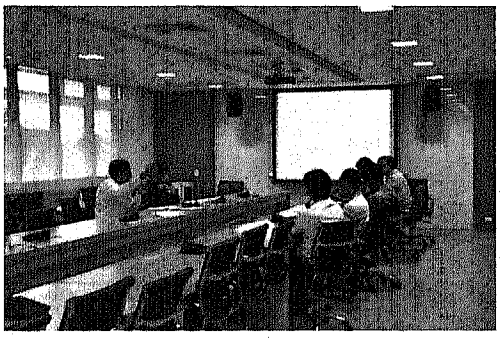

*Fig. 7.1.3 PowerPoint lecture*

*Fig. 7.1.4 Lecture*

We explained the importance of taking photos for the ease of data processing. We also explained the advantages of using the single-lens reflex digital cameras for some bridge inspections. Also, their data recording functions are useful. The explanation was based on specific applications in Japan.

3) Explaining how to process images obtained from inspections with single-lens reflex digital cameras

On October 22, 2010, a lecture was given at the Conference Room No. 3 on the third floor of the DRR head office, to explain how to process images obtained with single-lens reflex digital cameras. The lecture was attended by 12 DRR staff members.

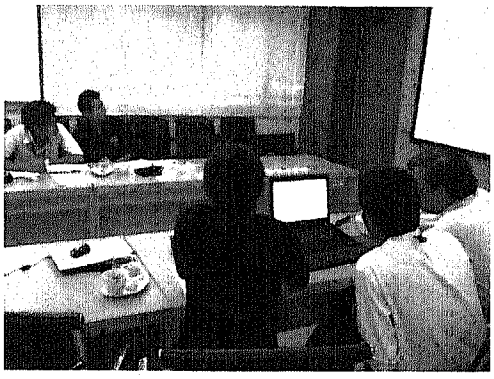

*Fig. 7.1.5 PowerPoint lecture*

*Fig. 7.1.6 Lecture*

We explained the image processing procedure by utilizing photographs taken by DRR staff members during on-site inspections. Before giving the lecture, we asked the DRR to select a engineer who would use the PC for demonstration purposes. After explaining the outlines of the procedure to all participants, we illustrated specific steps and asked the selected engineer to use the PC for getting aimed image.

4) Presenting results of bridge inspections

On November 12, 2010, we presented results of visual inspections for 12 bridges over the Chao Phraya River at the Conference Room No. 3 on the third floor of the DRR head office. In this presentation, we exchanged opinions with participants about the major causes of damages and deterioration, evaluation of the status quo, and the future progress of deterioration. The presentation was attended by seven DRR staff members.

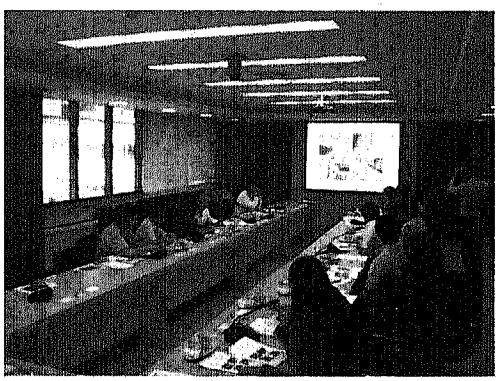

*Fig. 7.1.7 PowerPoint lecture*

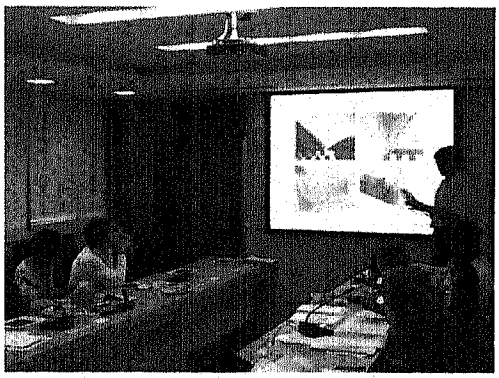

*Fig. 7.1.8 Exchanging opinions*

Overall, the 12 bridges over the Chao Phraya River are well maintained and managed, and the current routine maintenance activities should be continued in the future. Meanwhile, we discussed the necessity of monitoring some damages, because DRR would identify the causes of the damages.

### 7.1.2 Sharing LCC calculation techniques

#### (1) Explaining how to calculate LCC

On July 30 and September 8, 2010, we explained how to calculate LCC for 12 bridges over the Chao Phraya River.

*Fig. 7.1.9 Explaining how to calculate LCC on July 30, 2010*

*Fig. 7.1.10 Explaining how to calculate LCC on September 8, 2010*

#### (2) Discussing items to be checked regarding the BMMS, etc.

**1) Conference on September 30**

We conducted an interview survey about the status of the BMMS in operation, etc.

**2) Conference on October 4**

We conducted an interview survey about the status of the BMMS in operation, the maintenance and management plans (processes after inspections) and the requests/needs regarding the Maintenance and Management Manual and the Inspection Manual, and the roles of each department in charge of bridge inspection and maintenance at DRR.

**3) Conference on October 5**

We confirmed the items in which DRR gave priority in the BMMS.

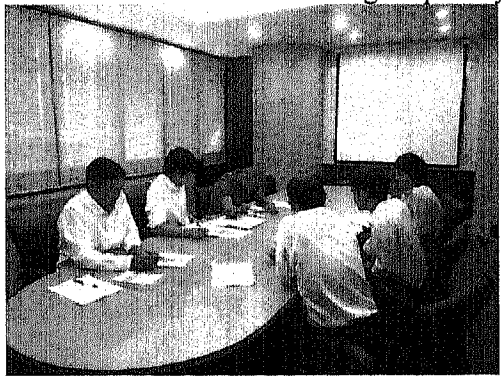

*Fig. 7.1.11 Conference on October 4, 2010*

## 7.2 Lectures, etc.

### 7.2.1 Status of bridge maintenance and management in Japan, and case study of asset management

After conducting interview surveys about the local bridge maintenance and management system in four district offices, we delivered bridge maintenance and management practices in Japan (see Table 5.3.1, Chapter 5). In mid-September, we delivered a similar presentation (including a field survey report regarding bridges in respective districts; see *5.3.2 (1) Field survey results*, *5.4 Proposals for regional bridge maintenance and management framework*) at the DRR head office.

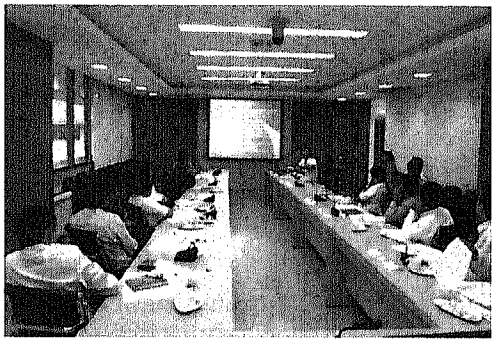

*Fig. 7.2.1: Presentation at DRR (1)*

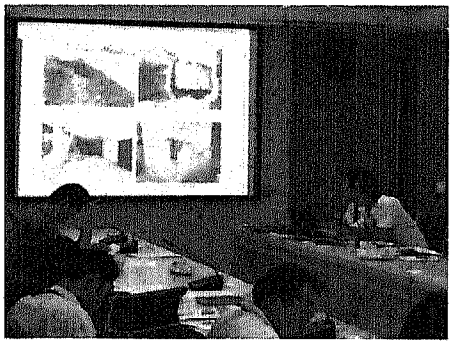

*Fig. 7.2.2: Ppresentation at DRR (2)*

*Bridge Maintenance and Management in Japan* (a Power Point document prepared for the presentation) can be found in Appendix 12. The contents were as follows,

(1) Bridge maintenance and management practices at present and in future in Japan

(2) Case study of asset management in Prefecture A in Japan (commitment to extend life of bridges)

(3) Actual effectiveness of asset management (increased efficiency in long-term maintenance and management, reduced maintenance and management costs, and enhanced standardization).

### 7.2.2 Technology transfer through international symposium

#### (1) Introduction

An international symposium (organized by the DRR) was held at the DRR head office during the Phase 2 Investigation (from November 25 through 28). This scientific symposium regarding roads and bridges was attended by 60 DRR officers, and broadcast live to all the regional offices (75 provinces) across Thailand.

We decided to take advantage of this opportunity to actively promote technology transfer.

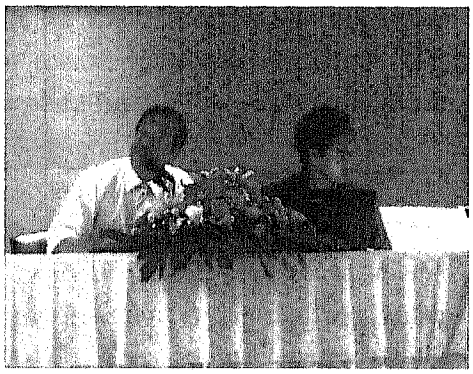

*Fig. 7.2.3: Presentation at the international symposium (1)*

*Fig. 7.2.4: Presentation at the international symposium (2)*

### (2) Details of our presentation

1) Bridge Management System

We presented bridge maintenance and management practices in Japan.

- Many of bridges in Japan were built during the rapid economic growth after the war. In 25 years later, over 50% of those bridges will be 50 years or older after construction. Japan faces the challenge of ensuring bridge maintenance and management economically, as well as keeping safety of these bridges.
- We presented (i) documents available from the National Institute for Land and Infrastructure Management, (ii) case study in which steel truss bridges were damaged, and (iii) findings derived from structural calculations, to clarify the check points/elements of bridges.
- Regarding maintenance and management practices, we presented (i) the process from data input to output and (ii) a PDCA-based system.

2) Inspection of 12 bridges over the Chao Praya River

We presented the overview of our inspection results and instruments that we used to inspect those 12 bridges over the Chao Phraya River.

- Visual inspection is not only the first step of bridge inspection but also bridge maintenance activities. It should be noted, however, that inspectors' scope of observation is limited without assistance of inspection tools. So, we presented tools to aid inspectors expand their scope of observation: a pole camera for inspecting areas beyond inspectors' height, and a 'bridge checker' for inspecting the lower side of concrete slabs without requiring inspectors to go under bridges.

  We noted that, based on the results of this bridge inspection, the 12 bridges are properly managed, but that in-depth inspection and monitoring will be required because some damages were observed.

### 7.2.3 Presentation to the Regional Bridge maintenance division, Bureau of Road Maintenance

Before starting our bridge investigation, we prepared the Inspection and Evaluation Manual (draft) for 12 bridges over the Chao Phraya River. As requested by the DRR, the manual is designed to be applicable to inspections of small- and medium-sized bridges in local areas, as long as part of the manual is modified.

At DRR's request, we explained the outline of this manual to the manager and members (engineers and technicians) of the regional bridge division, while referring to inspection results of local bridges located in the suburbs of Bangkok, which were done by our team.

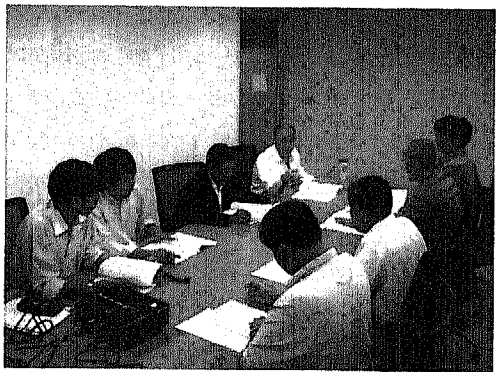

*Fig. 7.2.5 Presentation to the Regional Bridge Section, the Maintenance and Management Department, DRR*

Stated below are Q&A's and other comments.

- The manager of the regional bridge division (shown back in the photograph) explained to the divisional members that this manual will be used to conduct inspections on local bridges and collect data, and that arrangements will be made to give the instructions to regional offices from the Director General.
- Divisional members commented that this manual may be easy to apply in local areas.
- It was pointed out that unevenness of the road surface beyond the standard indicated in this manual can be found at many locations in local areas.

In local areas, the water erosion is more serious than that indicated in this manual.

### 7.2.4 The final presentation at DRR

The final presentation was held at DRR headquarters on March 3, 2011. The purpose of this was not only to report our work but also to transfer the bridge inspection, evaluation of the results, long-team maintenance techniques. The report 1 to 4, and Appendix-7 was used for this presentation. Q and A session was also held. The number of DRR officers attended this was 23.

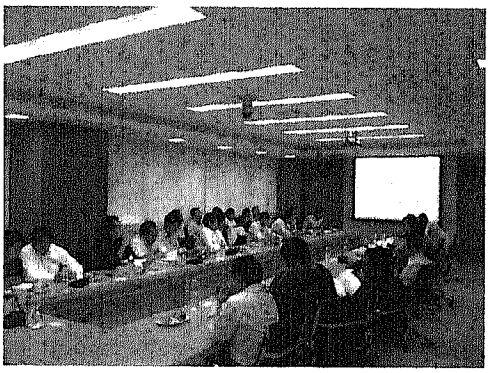

*Fig. 7.2.6 Presentation at DRR (1)*

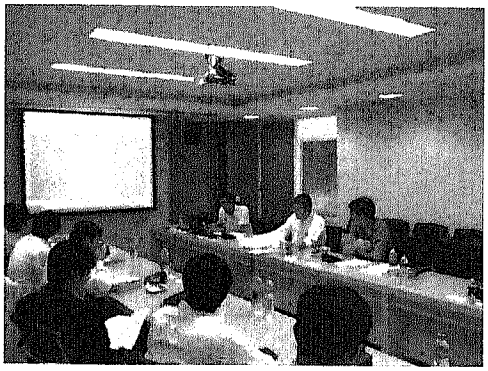

*Fig. 7.2.7 Presentation at DRR (2)*

# Chapter 8 Conclusions

This assignment was difficult. One reason was that there were several basic changes of the implementation. From the beginning, about 3 months was delayed to start the visit to Thailand because of the political turmoil. The contract term became 3 months shorter because the end of the contract was not changed much. This made our work more busier than the original. Another change was that of the inspection vehicle. The use of the vehicle was found to be risky in the sense of safety after the basic site check and alternative method was introduced. The third big change was the survey target bridges. Taking into account the DRRs strong request, not only Chao Phlaya 12 bridges but some rural bridges were studied sharing certain energy.

The other reason was that this mission contained substantial difficulty by nature. To formulate the long term preventive maintenance plan is the work to integrate many uncertain factors. To predict the timing and condition of the bridge collapse is extremely difficult. Their deterioration speed depends highly on the natural and social conditions. The counter measure will be taken under the strong restrictions of budget and the maintenance level will be decided with the administrative judgments. These conditions change as time passes. Further, it is necessary to accumulate design drawings and data to make planning, but as of now, we could not find such data in DRR. Thinking of these circumstances, we placed a priority in the making of forms with adopting some assumptions. It is possible to consider that futile costs can be cut and efficient budget performance will be obtained by continuing the work to refine the maintenance plan.

Survey results are summarized as below.

### 1. The healthiness of the bridges.

The 12 bridges seem to have been maintained comparatively well. Among them, some deformed or damaged members were seen in the truss bridges, but judged to be not emergent damages. Some not pleasing cracks were seen in the IRR bridges. But it looked not so serious and enough if it be treated after the detail inspection and study planned in the next year. Compared to these 12 bridges, many serious defects were seen in the bridges in the rural areas. As design method also contains some problems, we recommended DRR to take rapid measures to this issue.

### 2. Formulations of the manuals

About the inspection and evaluation manual, it is compiled as simple and clear as possible so that it can be used practically. It was formulated after the discussions with DRR engineers and taking into accounts their offers with agreement. It is very important to make the manual widely known among the site technicians and workers and to make reforms in the course of the actual appreciations. And for that it will be necessary for DRR to pay a certain effort from now.

About the long term maintenance plan of each bridge, it was difficult to formulate that with least available data. For its necessity, many can agree but if try to step into concrete discussion,

it was difficult to attract their interest. As it is impossible to make a perfect plan with least data, we made a form to start with employing many assumptions. We want to ask DRR to customize it as a practical one improving it by activating PDCA cycles. First of all, it is important to start. The meaning of the action is not small because by this, the accumulation of data becomes easy and the understanding of the maintenance direction becomes clear and deep.

### 3. Maintenance structure

It was felt that the linking is not sufficient among the bureaus, sections and offices and for that, human resources and knowledge resources are not fully utilized. And there is a shortage of budget and officers. Specially, the shortage is noticeable in the rural areas. Present structure of DRR is mostly for the road maintenance and it is said that the number of the engineers who can understand the bridge structures is very few. If it is difficult to hire engineers, a rapid measure like the training of the technicians and workers should be taken to strengthen the maintenance structures. We tried some advices and pilot trainings but they were too small compared to the gigantic DRR structure and not sufficient.

### 4. Management system

There are several systems existing in DRR but none is utilized widely.
Here, we made recommendations from the point of simplicity and practicality. Most important points are the data collection and the integrated management of them. In the emergent situation, it is impossible to make a retrofit plan without design document and data. It is important to shift the style of paper and private possession to that of IT storage with open access to related officers.

### 5. Technical transfer

Utilizing OJT, we preceded the work doing discussions with DRR engineers as much as possible. We opened explanatory meetings and lectures frequently. Being asked by DRR, we made presentations in the international conference introducing our work. But it seems not sufficient. DRR's systematic education and training is necessary from now.

Front half of this survey was difficult because the communications with relevant engineers were not functioning well and materials were difficult to gather. But as time went by, the circumstances became clear and associations with engineers in different organizations became active. At the last month of the 3rd site survey, we could have collected materials to judge the conditions. It was pleasing to know that there are many officers who helped our survey for the purpose to improve the maintenance conditions of the DRR bridges. We appreciate their cooperation.

On the next page of this chapter, the comment by the leader of our counterparts is appeared.

**Comments from DRR. (by Director of International Cooperation Division)**

1. Manual made by JICA study team shall be a useful tool to improve the maintenance system for bridges in Thailand.

2. The effort of JICA study team to provide OJT, lectures and presentations to the selected engineers is highly appreciated.

It will be a great help to improve the bridge maintenance structure of DRR.

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(Dr. Chakree Bamrungwong)

Director of International Cooperation Division


JICA