Chapter 6 Development of a Regional Bridge Maintenance Planning and Support System

6.1 Collection and Analysis of Existing Bridge Management Information

In order to develop bridge maintenance plans, it is essential to collect and accumulate inventory data and inspection data on bridges. However, adequate data has not been acquired in conventional bridge maintenance work. Problems and countermeasures concerning existing bridge management information are described below.

6.1.1 Collection of Management Information on Existing Bridges

In order to resolve the above problem, existing management information on bridges was collected, and this was analyzed and sorted to determine whether it was necessary or not. The collected management information comprised the following. On the following page is indicated a bridge management ledger that is used frequently in DRR.

- Conventionally used bridge ledgers in Thailand
- Items in the bridge maintenance databases used in Japan
- Information necessary for developing bridge maintenance plans

6.1.2 Problems with Existing Bridge Management Information

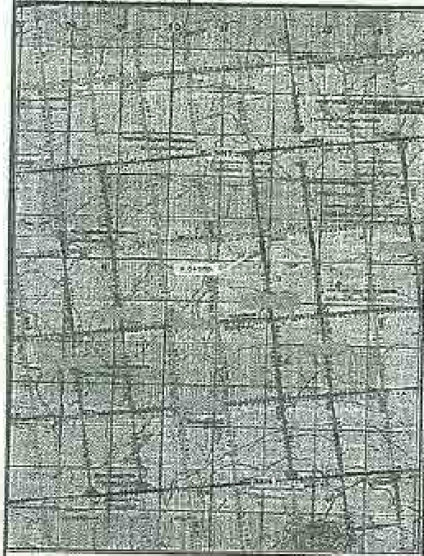
The problems with existing bridge-related data in DRR are as follows:

- Information necessary for developing maintenance plans is lacking.
- Because of the overall high number of data items that need to be entered and the fact that the entered contents are complicated for workers, the data completion rate is low.

DRR bridge Profile

ประวัติสะพานในโครงข่ายทางหลวงชนบท

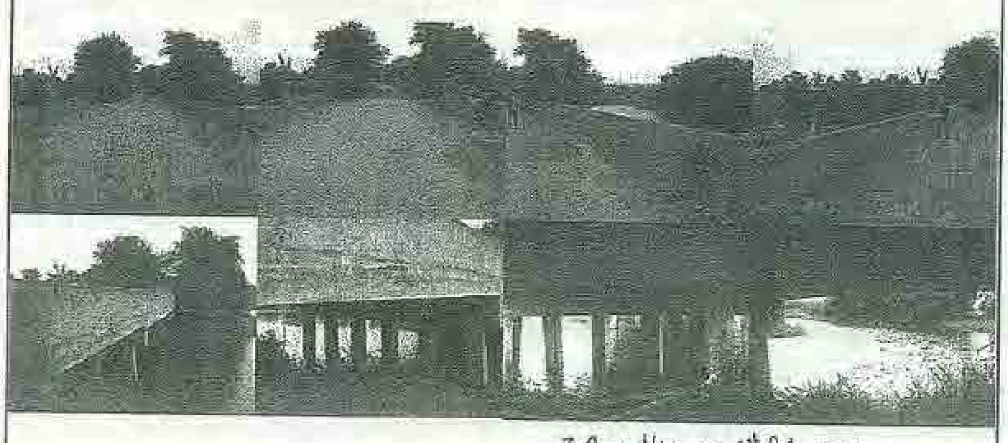
จังหวัด Province	ลพบุรี Lopburi	ข้อมูลด้านวิศวกรรม Engineering Information			
รหัสสะพาน Bridge Code	ลบ.4019 LB. 4019	ความยาว length	26.00 ม.ม.	26 (8 + 10 + 8)	
ชื่อสะพาน Bridge name		ความกว้าง width	9.00 ม.ม.		
ชื่อลำน้ำ River name	ห้วยยาง Huay Yang	ทางเท้า Path	- ม.ม.	UP	DN
ชื่อหมู่บ้าน Village name	ห้วยแก้ว Huay Kean	ทางหลวงชนบท DRR		L CS 6/8	R CS 6/8
ตำบล	พัฒนานิคม Pattananikom	ท.	ม.	L 2.300	R 7.935
อำเภอ	พัฒนานิคม Pattananikom	ปริมาณจราจร traffic condition	PCU		
ปีก่อสร้าง Built year		Slope Protection		L	R
		Approach slab	ม. m	L	R
		Guard Rail	ม.ม.	L	R
		ไฟฟ้าแสงสว่าง Light pole	ต้น poles		-



ประวัติการซ่อมบำรุง Maintenance History

งบประมาณ Budget Year ปีงบประมาณ	budget (Baht) (บาท)	หน่วย Unit Conduct ดำเนินการ	Activities/Work งานกิจกรรม
2548	Annual	asphalt surface maintenance	บำรุงปกติผิวทางลาดยาง
2549			บำรุงปกติผิวทางลาดยาง
2550			บำรุงปกติผิวทางลาดยาง

รูปภาพ



Information on 9th Oct 2007

ข้อมูล ณ วันที่ 9 ตุลาคม 2550

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Figure 6.1-1 Conventionally Used Bridge Ledger in Thailand (1/2)

Bridge Inspection form — Bridge code ลบ. 4019 S.2+300 — Page

แบบฟอร์มการสำรวจสะพาน	รหัสสะพาน ลบ.4019 #2+300	แผ่นที่ 1/8

วันที่ทำการสำรวจ Inspection date 9 ตุลาคม 2550 (9th Oct 2007) — เวลาสำรวจ Inspection time เริ่ม start 09.20 น.

ผู้สำรวจ Inspector นายธวัชชัย แก้วมณีชัย Mr. Thawatchai Kaewmaneechai — เสร็จ finish 10.10 น.

สภาพอากาศและอุณหภูมิ Weather and Temperature แจ่มใส ปกติ — วิธีการสำรวจ Inspection method

Man Hours 4 คน 4人

	ข้อมูลทั่วไปของสะพาน Bridge general information			ข้อมูลโครงสร้างสะพาน Bridge structure information		
1	จังหวัด Province	ลพบุรี Lopburi	10	โครงสร้างช่วงหลัก Main structure	3 (8+10+8)	
2	รหัสสายทาง route code	ลบ.4019 Lop. 4019		วัสดุ RC+PC Material	ประเภท type	SLAB
3	หลักกิโลเมตร Kilometer stone	2+300	11	โครงสร้างช่วง Approach Approach area structure		
4	ชื่อสะพาน Bridge name	-		วัสดุ Material -	ประเภท type -	
5	ชื่อลำน้ำ Canal name	ห้วยยาง Huay Yang	12	จำนวนช่วงสะพานหลัก Number of main bridge parts	3 (8+10+8)	
6	หมู่บ้าน Village name	ห้วยแก้ว Huay Keaw	13	จำนวนช่วงสะพาน Number of bridge parts	3	
7	ตำบล 区	พัฒนานิคม Pattananikom	14	โครงสร้างพื้นสะพาน Bridge pavement structure	RC + PC	SLAB
8	อำเภอ 市	พัฒนานิคม Pattananikom	15	ผิวจราจร 路面	คอนกรีต concrete	
9	ตำแหน่ง GPS GPS position					

	ข้อมูลการใช้งานสะพาน Bridge usage information				ข้อมูลทางเรขาคณิต		
16	ปีที่ก่อสร้าง Built year			25	ความยาวช่วงสะพานสูงสุด Maximum bridge parts length	m. (ม.)	10.00
17	ปีที่ทำการซ่อมแซมหลังสุด Last maintenance year			26	ความยาวสะพานทั้งหมด Bridge overall length	m (ม.)	26.00
18	ประเภทการใช้งาน Usage type		Number of lanes	27	ความกว้างทางเท้า footpath width	m (ม.)	-
	บนสะพาน Above the bridge	ถนน Road	จำนวนเลน 2		ซ้าย left -	ขวา right	-
	ใต้สะพาน Under the bridge	ลำน้ำ canal	จำนวนเลน -	28	ความกว้างผิวจราจร 路面 width	m (ม.)	6.00
19	ปริมาณการจราจร Number of passing cars (คัน/วัน) (cars/day)			29	ความกว้างโครงสร้างสะพาน Bridge structure width	m (ม.)	9.00
20	ปริมาณยานยนต์หนัก Numbers of trucks (คัน/วัน) (cars/day)			30	ความกว้างช่วง Approach Approach area width	m (ม.)	-
21	ปีที่สำรวจปริมาณจราจร Year of inspection (passing cars)				ซ้าย left -	ขวา right	-
22	ระยะทางเบี่ยง ทางอ้อม (กม.) Road diversion/indirect distance (km)			31	การแบ่งทิศจราจร traffic direction		ไม่มี 無し
23	สะพานในแนวยุทธศาสตร์ Strategic bridge			32	แนวเอียงของสะพาน Bridge	degree (องศา)	-
24	ทิศทางจราจร traffic direction	2 ทิศทาง 2 ways		33	ระยะน้อยที่สุดเหนือสะพาน Minimum range above the bridge	m (ม.)	-
				34	ระยะน้อยที่สุดใต้สะพาน Minimum range under the bridge	m (ม.)	2.50

	ข้อมูลทางน้ำ Canal information	
35	ลักษณะทางน้ำ Waterway type	ลำน้ำ canal
36	การป้องกันตอม่อ Pier protection	-
37	ความสูงคมนาคมใต้สะพาน (m) (ม.) Height of transportation under the bridge	
38	ความกว้างคมนาคมใต้สะพาน (m) (ม.) Width of transportation under the bridge.	-

หมายเหตุ Note.

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Figure 6.1-2　Conventionally Used Bridge Ledger in Thailand (2/2)

6.1.3 Review of Existing System

The existing inspection assessment manual and maintenance planning manual have to an extent been developed with a view to reducing the required skill level and workload of workers in consideration of the actual condition of regional bridge inspections. However, when it comes to application, it is necessary to further strengthen the maintenance setup while also taking enhancement of work efficiency and improvement in the skill level of inspection workers into account. One technique for improving efficiency is the enhancement of data processing efficiency based on use of the bridge maintenance and management system (BMMS).

BMMS is software for conferring the order of priority based on various basic data such as bridge inspection results, environmental conditions around bridges and so on and supporting the implementation of scheduled repair measures within a limited budget.

The BMMS that is owned by the DRR Maintenance Department is software that was developed based on the results of research on maintenance systems conducted by Chulalongkorn University. The software development phase has been completed and the software is equipped with functions such as repair priority adjudication and GIS bridge position information display, etc. The current BMMS has been released for operation by regional offices, and inputting and updating of inspection results can be conducted from the web.

However, according to hearing surveys of the developers and DRR personnel, the system contains the following problems and is not yet ready to output useful data:

- Inputting items are too complicated for workers, and the detailed contents create a heavy workload.
- Damage forecasts in cases where repairs are not conducted in the years when damage is discovered are included in the system. However, the formula for estimating these has not been fully verified.
- The BMMS contains basic information concerning bridge names and lengths for 5,728 bridges (4,936 bridges on DRR roads and 792 independent bridges not linked to roads). However, the system contains hardly any detailed information regarding shoulder widths and so on. There have so far been no damage reports and it has not been confirmed whether the BMMS functions of priority adjudication and rough budget calculation are working.

Moreover, technical issues are as indicated blow.

(1) Management levels are unclear

Concerning the integrity of bridges, the management levels that need to be maintained are unclear. In other words, because maintenance targets corresponding to the characteristics of bridges are unclear, it is difficult to efficiently maintain such a huge number of bridges.

(2) Deterioration forecasting techniques are not established

In the BMMS manual, a deterioration forecasting method that is based on a theoretical formula using concrete test results (salt content, neutrality test) is introduced, however, this is treated as a technical element that presumes implementation of equalization but is not incorporated into the BMMS itself. Moreover, when using the theoretical formula to forecast deterioration, it is necessary to implement tests at all bridges in order to grasp trends in the level of damage. However, in the current situation where engineers and budget are lacking, it is not realistic to implement tests on all the bridges being managed.

(3) The technique for applying the order of priority is complex

Thinking on the order of priority in the BMMS is broadly divided into indicators of load bearing ability, safety, usability and environmental performance, etc. and assessment is carried out based on total values of assessment items that have been compartmentalized under each indicator. These indicators require an extremely large amount of basic data comprising not only bridge inventory and inspection results but also surrounding environment and conditions, etc. For this reason, due to the complexity of work, it is not a practical option in the current situation where inspection data cannot even be sorted.

(4) The concept of equalization is not incorporated

Because the concept of equalization corresponding to budget constraints is not incorporated, it is difficult to implement countermeasures at appropriate times in consideration of the characteristics of bridges. Moreover, in cases where measures cannot be implemented due to budget constraints, i.e. cases where measures are postponed, because it isn't possible to grasp subsequent changes over time in integrity, it is difficult to quantitatively explain the risks of postponement.

(5) Outputs cannot explain the validity of maintenance costs

In budget negotiations with the Finance Bureau geared to securing the budget for maintenance, it is necessary to design materials (outputs) so that it is easy to explain the necessity of maintenance costs and the validity of amounts. However, in the current BMMS, since repair costs in each fiscal year are simply added up, risks when maintenance costs are insufficient and variations in integrity in each investment pattern are not outputted. As a result, it is difficult to explain the validity of the costs incurred in maintenance.

(6) Inspection results are not automatically incorporated into the system

Because engineers in regional offices lack knowledge and experience concerning maintenance plans, making it difficult for them to prepare complicated inspection report sheets, they use simplified report sheets. However, because these simplified sheets cannot be incorporated into the system in their current state, full-time staff members have to perform the inputting work. In order to improve the system efficiency and prevent human errors, it is necessary for inspection report sheets to be automatically incorporated into the system.

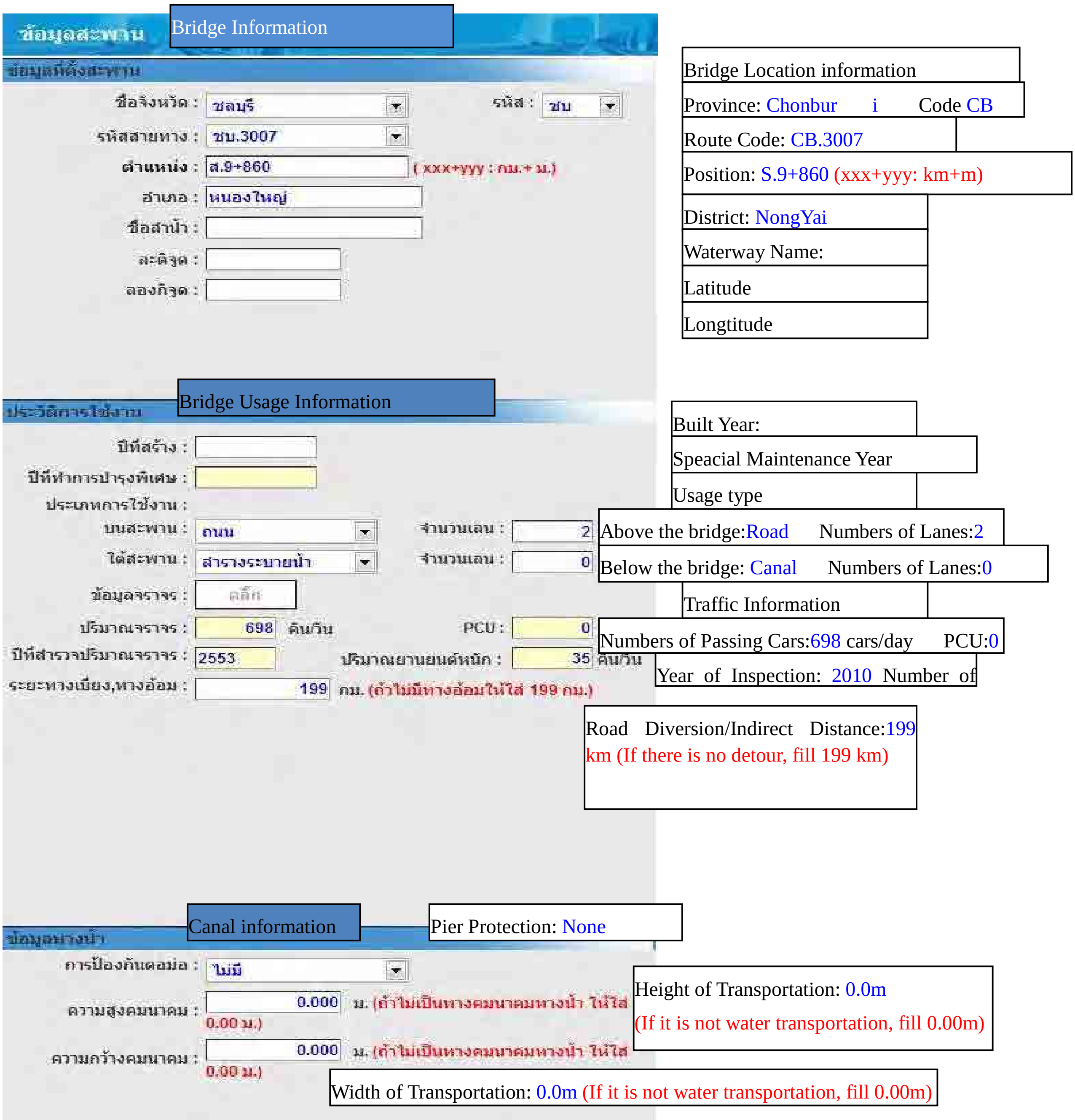


Figure 6.1-3 Example of an Inputting Screen in the BMMS in Operation in DRR (1/2)

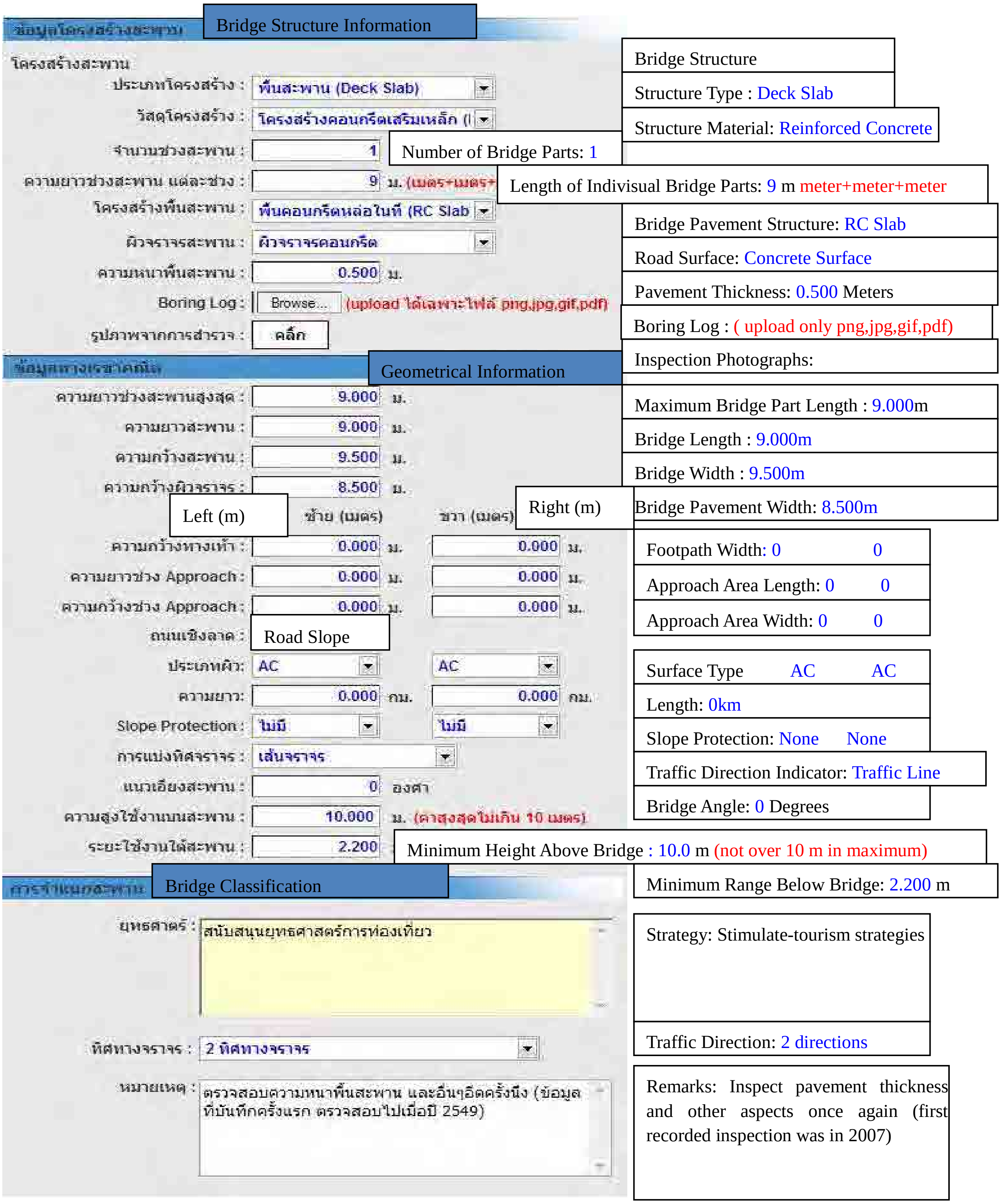


Figure 6.1-4 Example of an Inputting Screen in the BMMS in Operation in DRR (2/2)

6.1.4 Basic Policy for Bridge Management Information

The basic policy for selecting items of bridge management information is as follows:

- Adopt the information required for developing bridge maintenance plans as management information.
- In order to consider the level of importance in bridge management in Thailand, conduct discussions with DRR for all items to determine whether each item is necessary or not.
- In order to reduce the burden of data preparation work for workers, keep the number of data items to a minimum.
- Since almost all the bridges targeted for management are made of concrete, give priority to the data items related to concrete bridges and omit data items for other special bridges. It was discussed and agreed with the DRR Maintenance Bureau that steel bridges would not be included.

The management information that was collected in the manner described in 6.1.1 (Collection of Management Information on Existing Bridges) was analyzed and sorted according to the above policy and the necessary information items were decided. The targets for sorting were categorized as follows.

Table 6.1-1 Management Information Categories

No	Category	Explanation
1	Bridge basics	Basic information for the overall bridge
2	Superstructure	Information on the bridge superstructure
3	Substructure	Information on the bridge substructure
4	Span composition	Information on bridge spans
5	Inspection history	Bridge inspection history information. Accumulate outline information from each inspection.
6	Periodic inspection results	Periodic inspection results information. Accumulate results according to the Inspection Survey and Assessment Manual prepared in this project.
7	Repair history	History information on bridge repair works. Accumulate outline information from each repair works.

Appendix 5.1 gives details on the results of sorting under each category.

6.2 Basic Policy in Maintenance Planning

6.2.1 Planning Flow and Examination Items

Long term maintenance planning has the objective of smoothly facilitating policy transition from conventional breakdown maintenance/repair work and rebuilding to preventive repairs and scheduled rebuilding, and thereby extending the useful life of bridges and cutting the costs incurred in repair and rebuilding work.

Figure 6.2-1 shows the examination items and examination flow for the bridge long term maintenance planning to be introduced to DRR.

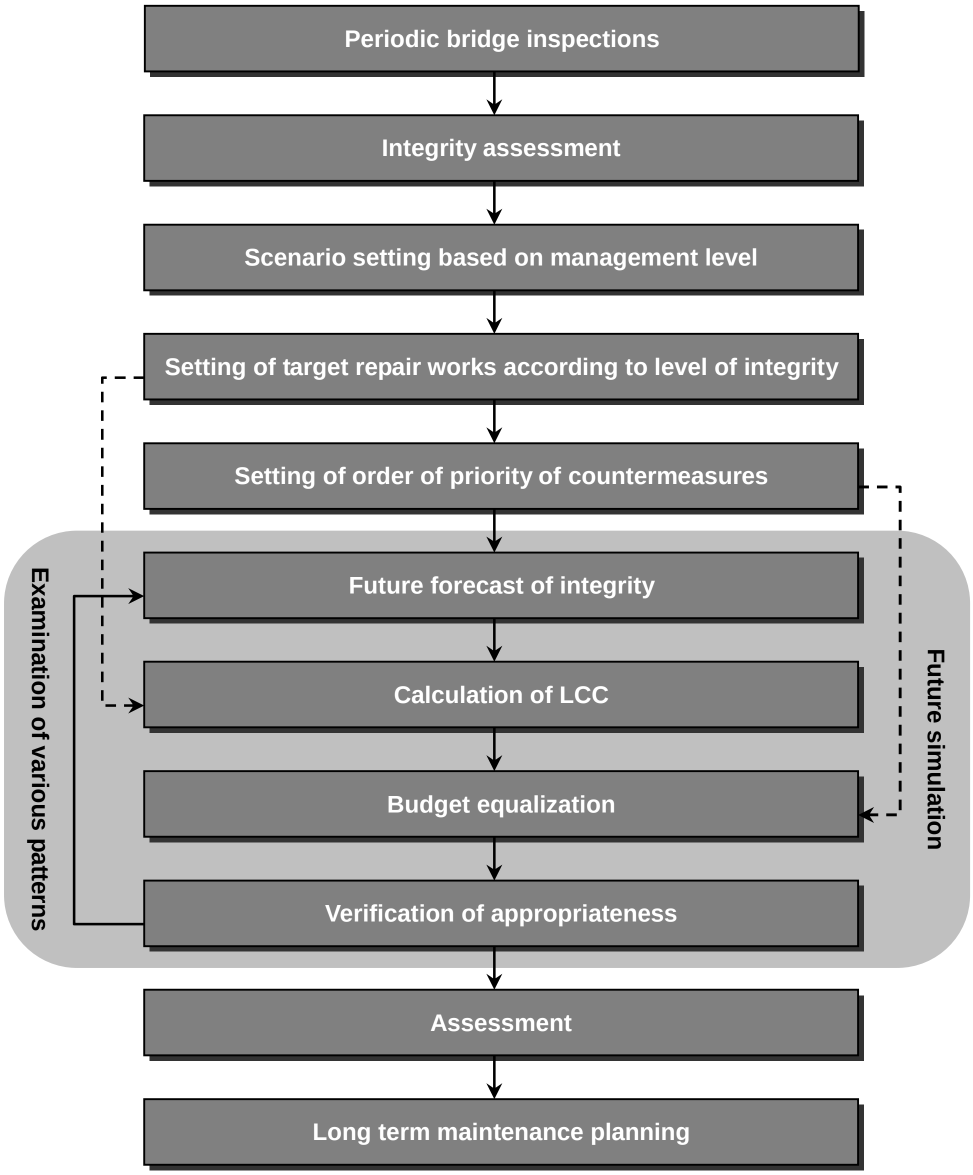


Figure 6.2-1 Flow and Examination Items of Regional Bridge Long term Maintenance Planning

[Commentary on each item]

- Bridge periodic inspections … Bridge periodic inspections conducted according to the Inspection Work and Assessment Manual
- Integrity assessment … Quantitative assessment of bridge integrity (durability and load bearing ability) assuming a maximum score of 100. Assessment is implemented in units of bridge members and spans.
- Scenario setting based on management level … The management level is set based on the importance assessment score. The management level setting becomes the maintenance target for each bridge.
- Setting of target repair works according to level of integrity … Target repair works are set according to the level of integrity of each member. This is used as the basis for calculating LCC.
- Setting of order of priority of countermeasures … This technique for determining the order of priority puts safety first and presumes policy transition to preventive repairs. It can be used for equalizing budget.
- Future forecast of integrity … Bridge deterioration into the future is forecast based on the deterioration forecasting technique.
- Budget equalization … Based on the order of priority and level of damage progression and so on in units of bridges and members, the bridges that can be worked on are selected according to the upper level single-year budget.
- Verification of appropriateness … The investment budget in various patterns and management target for regional bridges overall are set and future simulation is implemented. Future budget trends, distribution of the level of integrity and management level achievement rate, etc. are comprehensively assessed and a feasible plan is developed according to the actual conditions in DRR.
- Assessment … The level of safety improvement, life extension and cost reduction effect and so on are assessed.
- Long term maintenance planning … Inspection schedule, repair schedule and upgrade schedule for each bridge

Concerning the planning technique, a broad explanation was conducted for the managers and members of the DRR Planning and Maintenance Bureau. Discussions will be held within the DRR from now on details such as selection of indicators of bridge importance and setting of the management level and so on.

6.2.2 Integrity Assessment

(1) Definition of the Level of Damage and Integrity

In order to develop long term maintenance plans, it is important to quantitatively gauge the state of bridges. Here, as the method for quantitatively gauging the bridge condition, the bridge (member) integrity will be calculated.

Here, the level of damage and integrity are defined as follows.

- Level of damage: This indicator expresses the level of criticality of damage associated with each member number. The level of damage is expressed according to the results of damage assessment obtained in inspection.
- Integrity: This indicator expresses the level at which bridge or member functions are sustained. Put another way, it is an indicator for gauging the overall condition of members or bridges upon considering the variation or scope of the level of damage confirmed according to each member number.

Summing up, through assessing the integrity of members or bridges utilizing the level of damage obtained by inspection, the condition of bridges shall be gauged.

(2) Thinking on Assessment of Integrity

Since DRR has many bridges under its jurisdiction but is faced with financial constraints, it is vitally important for it to develop feasible budget plans. Bearing this in mind, integrity based on inspection findings will be assessed by the following technique.

Broadly speaking, there are two approaches to conducting integrity assessment as indicated below:

- Assess the overall situation upon focusing on the worst damage: Safe-side assessment
- Generally assess the variation and scope of damage: Mean assessment

Table 6.2-1 shows the main features of each approach.

Table 6.2-1 General Approaches to Integrity Assessment

Thinking	Safe Side Assessment (Focus on the worst damage)	Mean Assessment (Consider variation and scope of damage)
Merits	- In order to focus on the worst damage, integrity is assessed on the safe side so this is effective for risk avoidance.	- Because members or overall bridges are assessed, the variation and scope of damage can be reflected in the level of integrity. - Based on the above, because accuracy in LCC calculation is enhanced, this is suitable for budget control. - Comparative assessment of localized damage and overall damage is possible.
Demerits	- Because it is difficult to reflect variation and scope of damage in the level of integrity, accuracy of LCC calculation declines. - It’s difficult to perform comparative assessment of localized damage and overall damage. - There’s risk that budget will be planned too much on the safe side and that maintenance plans will have low feasibility.	- Because localized serious damage stops being conspicuous, separate supplementary measures are needed from the perspective of avoiding risk.

When developing long term maintenance plans in DRR, the approach that entails generally assessing the variation and scope of damage, which is suited to budget control and enables comparative assessment of bridges, will be adopted.

However, since there is a possibility that serious localized damage may be hidden when using this technique, it shall be combined with risk aversion measures.

6.2.3 Introduction of the Management Level

The bridges that are managed by DRR have varied location and use conditions, for example, bridge size, traffic volume, emergency transport roads and intersection conditions. Therefore, it would be highly inefficient and irrational to maintain these bridges at the same level and based on the same thinking.

As a method for efficiently and effectively maintaining all the bridges under DRR’s management, the management level approach will be introduced. Through introducing the management level, bridges shall be managed at a level that corresponds to the level of importance and purpose of use of each bridge, i.e. the maintenance scenario for each bridge shall be prepared.

The management level is a so-called maintenance target whereby the integrity of a bridge is maintained at a certain level and plans for achieving the said target are developed. Moreover, the act of setting a management level for each bridge is the act of setting the basic maintenance concept of DRR (deciding which bridge conditions to give priority to), and it is also important in terms of fulfilling accountability.

Moreover, setting the maintenance scenario according to the management level can also be viewed as setting the timing of bridge repair measures and this is linked to the establishment of the general order of priority for repairs. For example, in the case where a similar degree of damage (integrity score of around 50) is occurring in numerous bridges at the present time, bridges with a high management level will be regarded as having reached or exceeded the repair implementation stage and to be in need of immediate repairs, whereas bridges with a low management level will be regarded as not having reached the repair implementation stage and safe to be left untouched for the time being. Through introducing the management level approach to the current situation where it's easy to imagine there are numerous damaged bridges, it will be possible to rationally spread out the initial investment amount that is concentrated in the initial planning stage.

6.2.4 Determination of the Order of Priority of Countermeasures

In order to develop long term maintenance plans, it is necessary to calculate the feasible single-year budget for DRR (i.e. equalize the budget) while maintaining bridge integrity into the future. Therefore, the order of priority of maintenance work will be determined in order to examine budget equalization.

6.2.5 Forecasting of Future Integrity

Rather than conducting conventional stopgap maintenance, in order to switch to preventive maintenance that entails forecasting future deterioration and implementing measures from the medium to long term viewpoint, it is necessary to grasp the future condition of bridge deterioration (what kinds of deterioration will arise and when?). In other words, forecasting how bridges will deteriorate in the future is an important factor in developing long term maintenance plans.

However, there is currently no established technology for predicting future bridge deterioration and since this is still an area of research, it must be said that it is currently difficult to quantitatively and accurately forecast future conditions of deterioration. As is shown in Table 6.2-2, commonly used methods for deterioration forecasting at present are broadly divided into theoretical methods and data analysis methods. Therefore, the method that is most appropriate for the project will be adopted upon considering the characteristics of each.

Table 6.2-2 Comparison and Selection of Deterioration Forecasting Methods

Technique	Theoretical Technique	Technique based on Data Analysis
Outline	Technique for theoretically forecasting deterioration based on know-how and experience gained up till now.	Technique for forecasting deterioration through collecting and analyzing existing inspection data.
Typical example	- Concrete deterioration (salt damage, neutralization) - RC floor plate stress - Coating deterioration on steel members Etc.	- Markov movement probability
Features	- Deterioration under limited conditions can be forecast in specific members and materials.	- Because actual measured values are used, accuracy is high concerning deterioration when implementing inspections. - This is often adopted when basic inspection results and inspection data are lacking.
Problems in application	- Members, materials, deterioration forecast and deterioration conditions, etc. are restricted. - Survey findings other than inspection results (indoor tests and non-destructive tests using samples), materials tests and structural calculation information are needed. - Depending on execution and environmental conditions, etc., there is risk that forecasts will differ greatly from actual conditions.	- In cases where there are not enough inspection results, the deterioration forecasting accuracy is low and the basis becomes weaker. - In order to build a highly accurate deterioration forecasting formula, at least some multiple inspection results are needed and costs are incurred in enhancing the inspection data.
Cases of adoption	- Part of the Ministry of Land, Infrastructure and Transport - Ehime Prefecture	- PONTIS - Part of the Ministry of Land, Infrastructure and Transport - Kochi Prefecture - Hyogo Prefecture - Wakayama Prefecture - Hokkaido Development Bureau
Adoption or Non-adoption	X	Adopted - Inspection data can be used as basic data. - Accuracy can be improved through accumulating inspection data.

6.2.6 Direction of Examination of Long term Maintenance Planning

When implementing future simulations geared to developing life extension repair plans, it is necessary to clarify the maintenance targets in order to verify the validity of plans.

The maintenance target refers to how far the management level should be raised for each bridge. The act of setting the management level for each bridge is synonymous with setting scenarios corresponding to the maintenance target for each bridge, i.e. setting the lower level of integrity that needs to be maintained. Accordingly, because the integrity level to be maintained becomes higher as the management level is set at a higher degree, this is ideal for securing safety and security. However, since this policy increases the number of bridges that require repair work, it carries the risk of causing great financial difficulty.

Accordingly, the long term maintenance plan will be examined with a view to rationalizing maintenance by setting each bridge's management level according to the level of importance of each bridge while securing the safety and security of DRR's bridges overall and limiting budget at a feasible level.

6.2.7 Basic plan and its update for application to local bridges

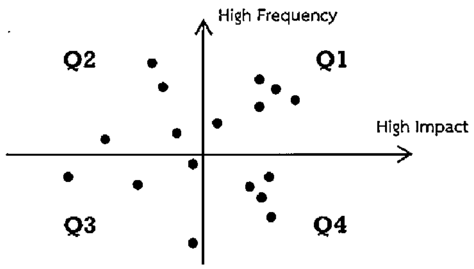
Long-term maintenance management plan for local bridges should be developed involving the current domestic status of Thailand in association with bridge structure feature, damage cases, and environmental conditions around local regions.

The basic rules for developing long-term bridge maintenance management plan are described as follows.

(1) Define bridge priority evaluation index

Long-term maintenance management plan for local bridges would be developed based on the control level defined by considering the various current status involving social condition, service criteria, and environmental conditions that are shown around local regions.

Control level means to indicate the degree of need for bridge. DRR has defined and set the control level of each road indicating traffic volume, population, total income of residents, and the capability of key social facilities – government office, school, hospital, station, and airport. The control level of bridge could be defined and set up considering the road control level and opinions from DRR in terms of five baseline parameters – traffic crossing status, total traffic volume, heavy vehicle traffic, and bridge length.



การแสดงค่า Importance Degree ที่จำแนกตาม Risk Analysis

จากแผนภูมิข้างต้น สามารถแสดงความหมายและแนวทางการแก้ไขปัญหาที่เกิดบนแต่ละจตุภาค (Quadrant) ตามหลัก Risk Management ได้ ดังนี้

จตุภาค	ความหมาย	แนวทางแก้ไขปัญหา
Q1	โอกาสที่เกิดสูง มีความรุนแรงสูง	ป้องกันเพื่อไม่ให้เกิดความเสียหาย หรือทำให้ลดความรุนแรงของความเสียหายให้มากที่สุด
Q2	โอกาสที่เกิดสูง มีความรุนแรงต่ำ	เพิกเฉยต่อความเสียหายที่เกิดขึ้น
Q3	โอกาสที่เกิดต่ำ มีความรุนแรงต่ำ	ยอมรับความเสียหายและทำการเยียวยาเมื่อเกิดความเสียหาย
Q4	โอกาสที่เกิดต่ำ มีความรุนแรงสูง	ถ่ายโอนความรับผิดชอบแก่ผู้ที่มีความเชี่ยวชาญในการรับผิดชอบความเสียหาย เช่น การประกันภัย

ผลที่ได้จากการวิเคราะห์สามารถนำไปใช้จัดลำดับความสำคัญของถนนของกรมทางหลวงชนบทและสามารถนำไปต่อยอดเพื่อปรับปรุงการบริหารทรัพย์สินของกรมทางหลวงชนบทได้อย่างมีประสิทธิภาพสูงสุด

Figure 6.2-2 Setup of route priority factor

(2) Use integrity evaluation method providing risk management

Periodic inspection on local bridges is being carried out by technicians of regional offices.

They are trying to improve the inspection skill by taking a note and photos to gain more accurate data for damage assessment. In case of evaluating the degree of serious damage, possible to affect developing long-term maintenance management plan, it is badly required to be performed by engineers with a high level of expertise. DRR officials are well aware of the current situation and pointed it out.

To avoid this kind of risk, the procedure is developed that the damage, identified to belong to five damage classifications and evaluated by technicians, would be reevaluated by engineers with technical expertise.

Among five damage classifications, three for reevaluation are listed in Table 6.2.3

Table 6.2-3 Three damage classifications

Classification		Definition of Classification	Evaluation
[Classification1]	Emergency repair is necessary	Emergency repair is necessary to recover damage in the short time to provide service as normal.	「E」
[Classification2]	maintenance and repair for damage with high priority	maintenance and repair for damage with high priority	「R」
[Classification3]	Other damages, excluded in Classification 1 and 2.	Other damages, Not in Classification 1 and 2.	「5」

Here, out of the classified damage levels, concerning Classification 1 which refers to damage that requires urgent attention, and Classification2 which refers to damage with a high priority for maintenance and repair, evaluation methods in the long-term maintenance plan are indicated below.

Classification 1: damage that requires urgent attention (E)

Since traffic is already hindered due to bridge collapse and so on, urgent attention is needed. Accordingly, in the long-term maintenance plan, this is not targeted for evaluation of soundness, and the following handling is conducted in the simulation:

Members that are evaluated as “E” following re-evaluation of the inspection results are omitted from simulation.

Assuming that the members evaluated as “E” undergo complete maintenance and repair countermeasures under urgent response in three years from the day of inspection implementation, they will be reverted to simulation from the fourth year onwards. Soundness at the time of reversion will be 100 points.

Classification 2: damage with high priority for maintenance and repair (R)

Within damage classification 5, this refers to damage that is deemed to have particularly high urgency and to carry a risk of critically impacting bridge safety by expert engineers.

Accordingly, the soundness of members experiencing damage having a high maintenance and repair priority (R) is calculated as follows.

■ Damage with a high maintenance and repair priority (R)
Soundness = 10 (total soundness = 90)

Moreover, if damage having a high maintenance and repair priority (R) occurs in even one member number, the soundness of members is evaluated as 10.

(3) Cost estimate for repair by taking into account the current status of Thailand

Cost of repairing the damaged bridge or its part is estimated considering the result of interview or questionnaire study about the past work record in Thailand.

Table 6.2-4 Maintenance and repair of slab deck (slab deck bridge, plank girder bridge, and box girder bridge)

Control level	Measures	Repair item	Before-repair soundness	After-repair soundness	Unit price per square meter
A	Preventive action	Protection painting, Scaffolding	80	95	3,000 THB/m^2
B	Repair 1 (soft)	Protection painting, Anti-crack injection, Section recovery, Scaffolding	60	95	4,000 THB/m^2
C	Repair 2 (medium)	Protection painting, Anti-crack injection, Section recovery, Scaffolding	40	95	4,000 THB/m^2
D	Repair 3 (hard)	Protection painting, Anti-crack injection, Section recovery, CFRP sheet attachment, Scaffolding	20	100	14,000 THB/m^2
Other	Replacement	Bridge replacement	0	100	118,800 THB/m^2

Table 6.2-5 Cost estimate of repair work of slab deck (slab deck bridge, Plank Girder Bridge, Box Girder Bridge)

Component	Repair	Method	unit price (THB)	unit price (Yen)	Calculation	Remark
Slab deck bridge, Plank girder bridge, Box girder bridge	Preventive action	waterproofing layer	825 THB/m^2	2,500 yen/m^2		①
		Asphalt pavement	660 THB/m^2	2,000 yen/m^2		②
		Protective coating	2,310 THB/m^2	7,000 yen/m^2		③
		Scaffolding	1,980 THB/m^2	6,000 yen/m^2		Scaffold area/Bridge area=1.2
		Total	**6,000** THB/m^2	**18,000** yen/m^2		1,000THB round
	Repair1 (minor)	Repair	3,795 THB/m^2	11,500 yen/m^2		①+②+③
		Anti-crack injection	2,640 THB/m^2	8,000 yen/m^2	= 8,000yen/m×1m/m^2	cracking density 1m/m^2 assumed
		Section recovery	1,650 THB/m^2	5,000 yen/m^2	= 50,000yen/m^2×0.1	Section recovery area 10% assumed
		Scaffolding	1,980 THB/m^2	6,000 yen/m^2		
		Total	**11,000** THB/m^2	**31,000** yen/m^2		1,000THB round
	Repair2 (medium)	Repair	3,795 THB/m^2	11,500 yen/m^2		①+②+③
		Anti-crack injection	3,960 THB/m^2	12,000 yen/m^2	= 8,000yen/m×1.5m/m^2	cracking density 1.5m/m^2 assumed
		Section recovery	3,300 THB/m^2	10,000 yen/m^2	= 50,000yen/m^2×0.2	Section recovery area 20% assumed
		Scaffolding	1,980 THB/m^2	6,000 yen/m^2		
		Total	**14,000** THB/m^2	**40,000** yen/m^2		1,000THB round
	Repair3 (serious)	Repair	3,795 THB/m^2	11,500 yen/m^2		①+②+③
		Anti-crack injection	5,280 THB/m^2	16,000 yen/m^2	= 8,000yen/m×2m/m^2	cracking density 2m/m^2 assumed
		Section recovery	4,950 THB/m^2	15,000 yen/m^2	= 50,000yen/m^2×0.3	Section recovery area 30% assumed
		CFRP attachment	23,100 THB/m^2	70,000 yen/m^2		Actual unit price
		Scaffolding	1,980 THB/m^2	6,000 yen/m^2		
		Total	**40,000** THB/m^2	**119,000** yen/m^2		1,000THBround

6.3 Construction of the Bridge Maintenance and Management System (BMMS)

6.3.1 BMMS Master Plan

(1) Outline of BMMS

The BMMS (Bridge Maintenance Management System) is a system for supporting the development of maintenance plans and is composed of the systems shown in Table 6.3-1.

Table 6.3-1 BMMS Component Systems

No	System	Explanation
1	Bridge database	- This is the database that acts as the base for the BMMS. - All data inputting and outputting based on the following systems is carried out from this database.
2	Bridge management Web system	- This is the system for inputting and outputting bridge inventory data, inspection data and repair works data. - It can also perform inputting and outputting of bridge ledger sheets. - The entire system operates on a Web browser.
3	Tablet system	- This system supports the inputting of inspection results in work according to the Inspection Survey and Assessment Manual prepared in this project. - It operates on tablet applications, thereby allowing work to be performed outdoors.
4	Long term bridge maintenance planning simulation system	- This system supports the formulation of life extension maintenance plans for groups of bridges. - In plan formulation, data that has been collected in the bridge database by the bridge management Web system and tablet system is utilized. - This is a standalone system that operates on PC.

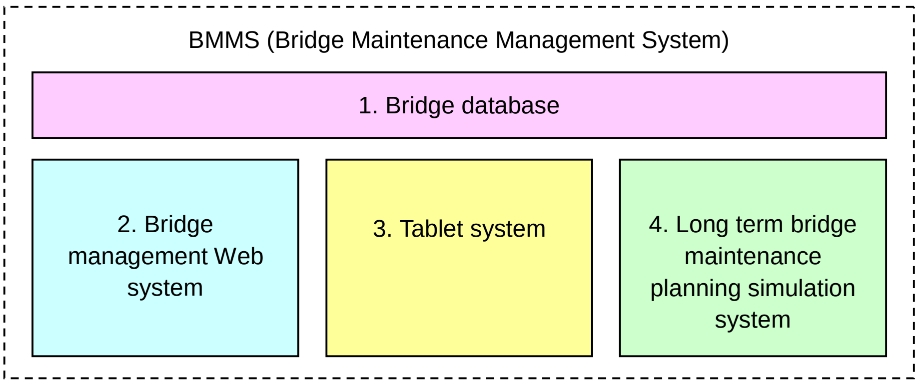


Figure 6.3-1 BMMS Component Drawing

Figure 6.3-2 shows the image of these systems in use.

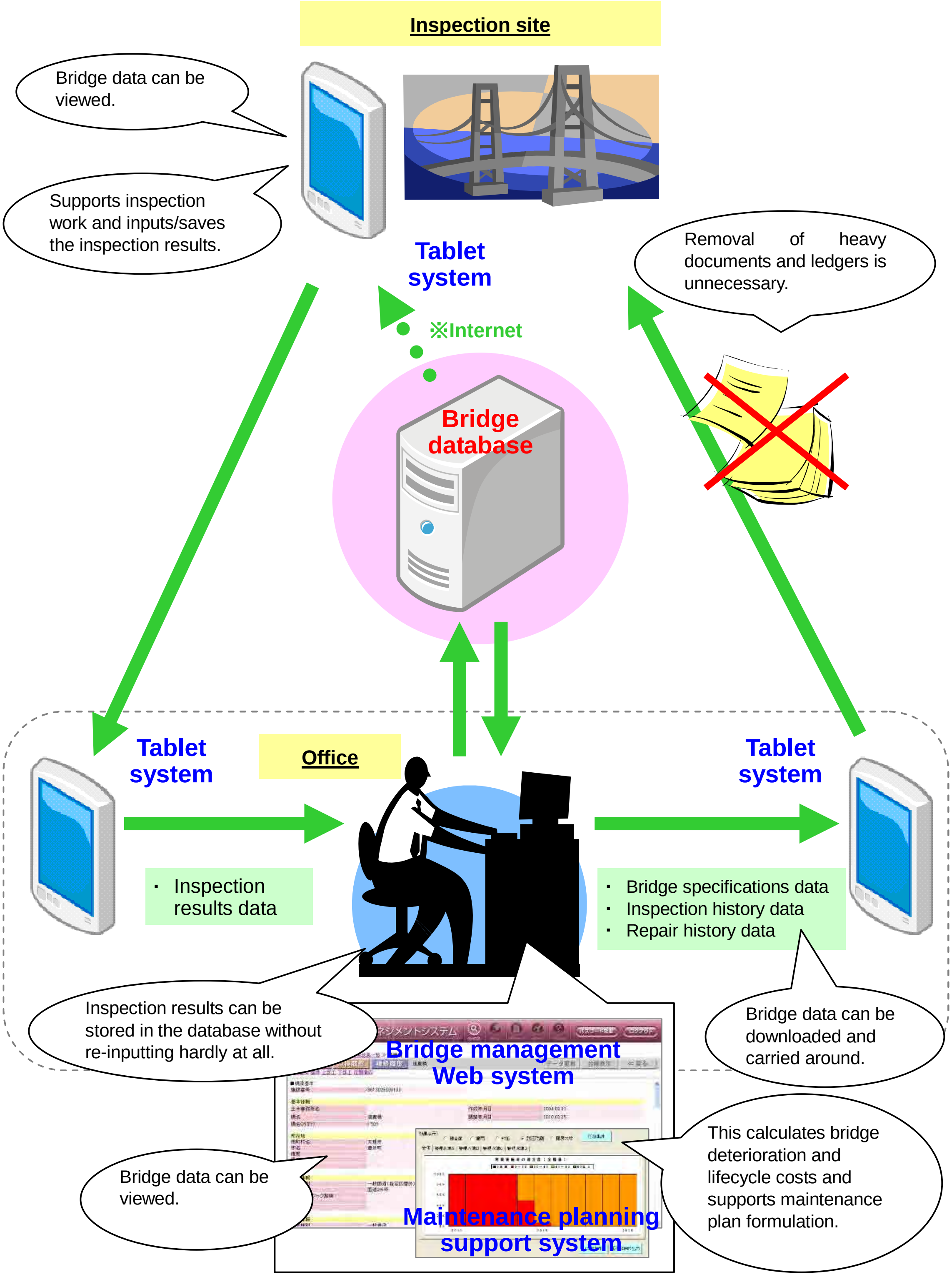


Figure 6.3-2 Image of BMMS Systems in Use

(2) BMMS Development Plan

In development of the BMMS, work on developing each system will be started after building the master bridge database. Since each system operates independently, development can be advanced simultaneously.

The development flow is illustrated in Figure 6.3-3.

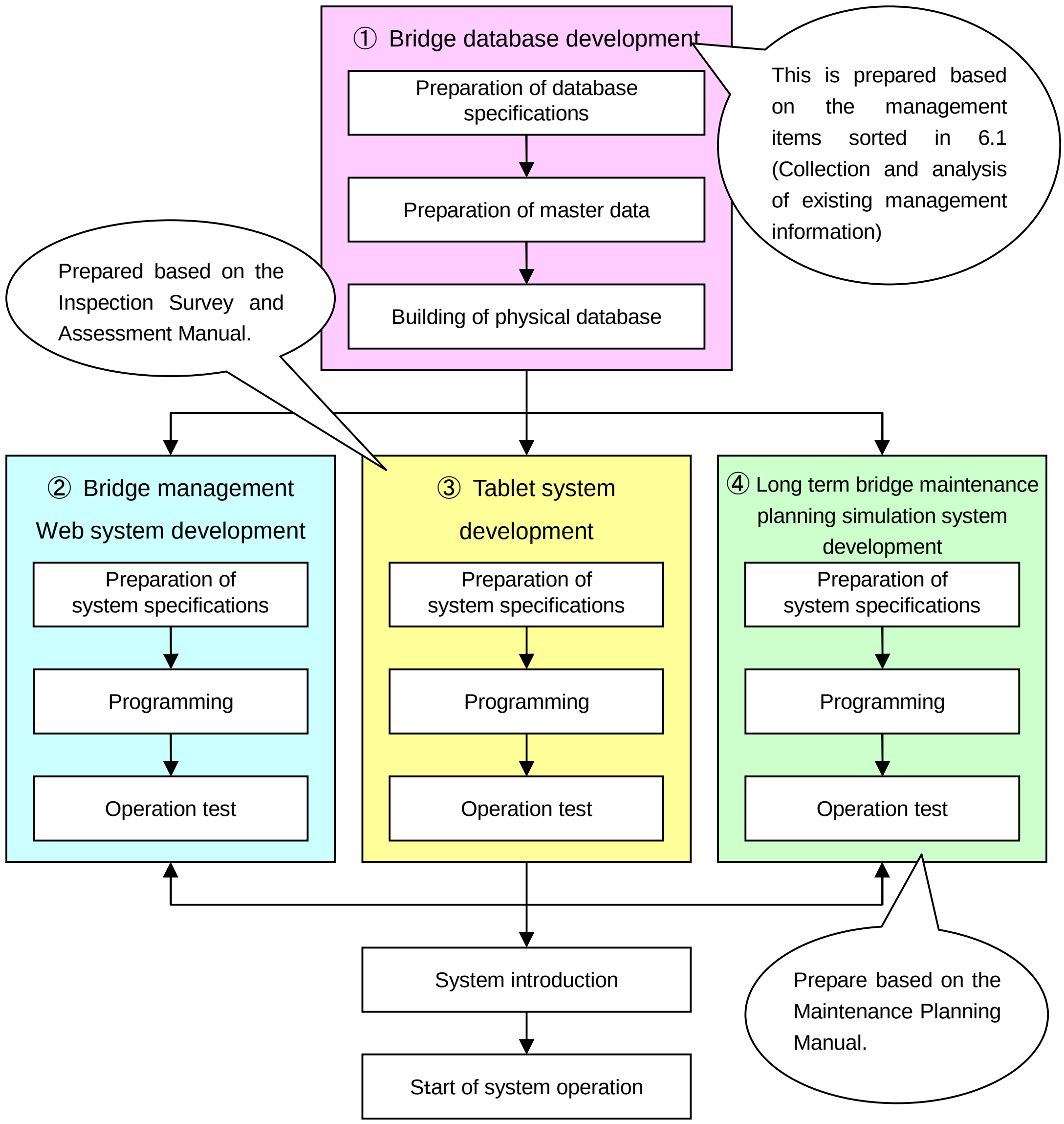


Figure 6.3-3 BMMS Development Flow

6.3.2 Development of a Bridge Database

(1) Compilation of Database Specifications

The bridge database specifications were compiled based on the information categories that were arranged and decided in Section.

Table 6.3-2 shows the list of tables, while Figure 6.3-4 is the ER Diagram that indicates the relationships between tables. Moreover, the table structure design items are as indicated in Table 6.3-3, while Appendix 5.2 gives the detailed structure of each table.

Table 6.3-2 List of Tables

No.	Logical name	Physical name (Table name)
1	General data of bridge	T_BRIDGE_BASE
2	Superstructure data	T_BRIDGE_SUPER
3	Substructure data	T_BRIDGE_SUB
4	Span data	T_BRIDGE_SPAN
5	State of crossing	T_BRIDGE_CROSS
6	Additional equipment	T_BRIDGE_ADD
7	Inspection history	T_BRIDGE_INSPECT_HISTORY
8	Result of Inspection	T_BRIDGE_INSPECT_RESULT
9	Inspection history for flood	T_BRIDGE_INSPECT_HISTORY_FLOOD
10	Repair history	T_BRIDGE_REPAIR_HISTORY
11	User Information	T_USER_MANAGEMENT
12	Master data	*It is different every kind.

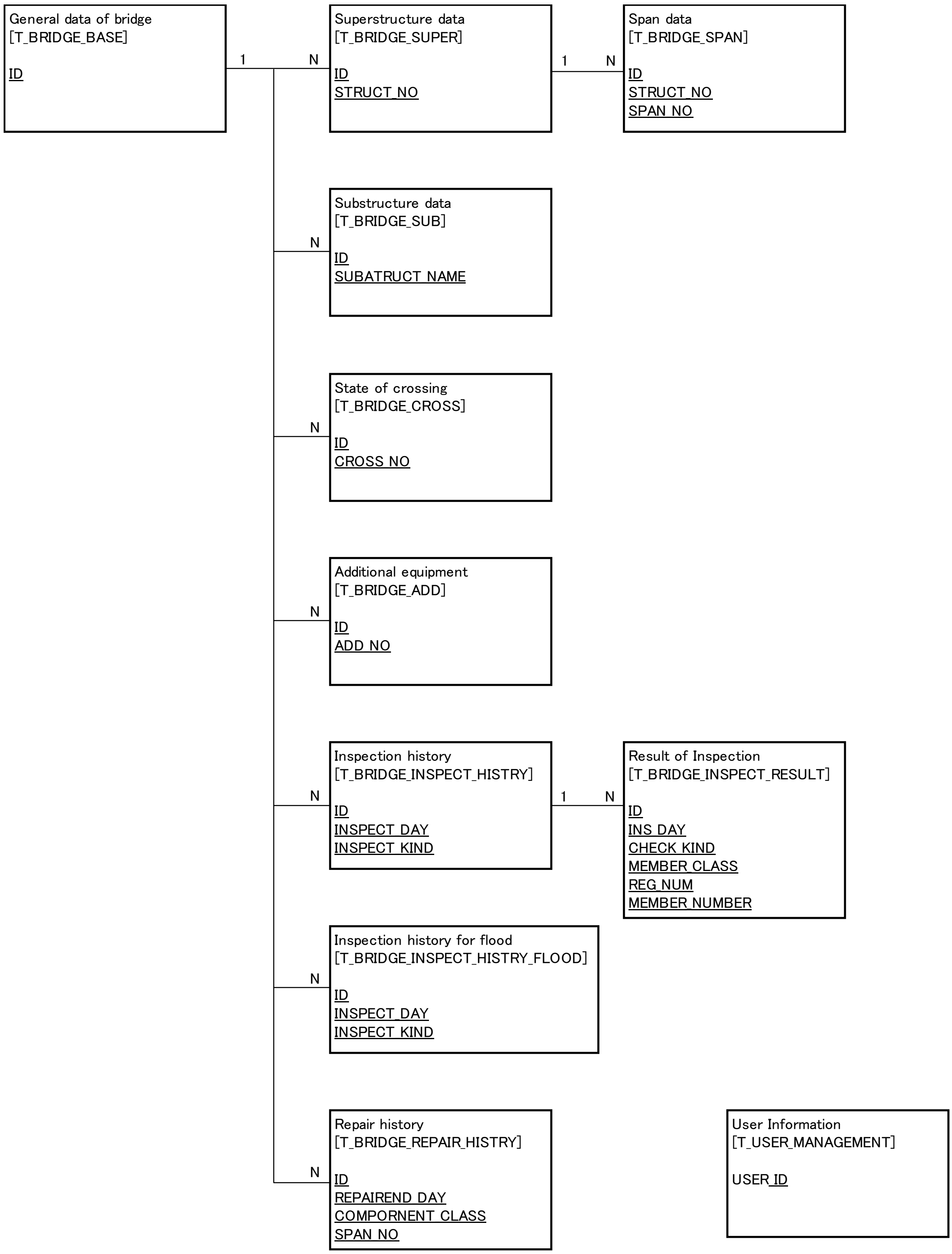


Figure 6.3-4 ER Diagram

Table 6.3-3 Design Specifications of Table Structure

No.	Item	Description
1	Table Name	Physical name of table in Table 6.3-2
2	Record length	Maximum length per record
3	Item name (Japanese)	Logical name of item (Japanese)
4	Item name (English)	Logical name of item (English)
5	Field name	Physical name of item
6	Data type	Data type of field
7	Data length	Maximum data length of field
8	Default value	Default value of field in inserting record
9	Not Null	Not admit Null in Field
10	Primary key	Field as primary key in table
11	Master table	Name of Master table for field that input value is a code * “(2)Preparation of Master Data”
12	For LCC analysis	Field to use for Long term bridge maintenance planning simulation system
13	Note	Note for data

(2) Preparation of Master Data

The master code table for managing the codes and decodes in the database was prepared according to the specifications in (1).

Table 6.3-4 shows the prepared master code table, while Appendix 5.2 shows the master codes/decodes stored in each table.

Concerning the specific contents of codes/decodes, discussions were held with the DRR (Bureau of Road Maintenance) and consent was obtained upon conducting examination in light of the contents of the inspection survey and assessment manual and actual conditions in Thailand.

Table 6.3-4 List of Tables (Master Data)

No.	Logical name	Physical name (Table Name)
1	District office	M_DISTRICT
2	Province	M_PROVINCE
3	Amphoe	M_AMPHOE
4	Kind of bridge	M_BRIDGE_KIND
5	Material of guard fence	M_FENCE_MATERIL
6	Type of center barrier	M_CENTER_TYPE
7	Kind of route	M_ROUTE_KIND
8	Route name	M_ROUTE_CODE
9	Route in strategic plan	M_STRATEGE_ROUTE
10	Route for emergency transportation	M_URGENT_TRANSPORT
11	Kind of traffic surface	M_PAVE_KIND
12	Slope protection	M_SLOPE_PROTECT
13	Material of main girder	M_MAIN_MEATERIAL
14	Type of girder	M_BEAM_DIVISION
15	Type of bridge structure	M_STRUCT_FORM
16	Material of expansion device	M_EXTEND_MATERIAL
17	Type of substructure	M_SUBATRUCT_TYPE
18	Type of foundation	M_FOUNDATION_TYPE
19	Type of bearing	M_BEARING_TYPE
20	Direction of bearing	M_BEARING_DIRECT
21	Division of crossing	M_CROSS_DIVISION
22	Type of waterway	M_WATERWAY_TYPE
23	Pier prevention	M_PIER_PREVENT
24	Type of added equipment	M_EQUIP_KIND
25	Kind of inspection	M_INSPECT_KIND
26	Member classification	M_MEMBER_CLASS
27	Rank of damage	M_DAMAGE RANK
28	Existence	M_WHETHER_COLUMN
29	Correspondence	M_PERTINENCE
30	Authority	M_AUTHORITY_DIVISION

(3) Construction of Physical Database

The database was constructed according to the specifications prepared in (1) and (2) above.

Table 6.3-5 shows the database server specifications at the construction location.

Table 6.3-5 Database Server Specifications

Category		Details
Hardware	Bender	IBM
	CPU	2 x Intel Xeon Six Core X5680 3.33GHz/ 1333MHz, 12MB L3Cache
	RAM	24GB (6x4GB) PC3-10600 1066MHz LP 240-pin Registered ECC DIMMs
	HDD	2xIBM 146GB 15K 6Gbps SAS SFF Slim Hot-Swap (2.5”)
Software	VM	VM Ware V sphere Enterprise Plus with 1 Year Subscription
	OS	UBUNTU Server 11.10 (64bit)
	DBMS	Postgres SQL Server 9.1
Installation site	—	DRR IT Center

6.3.3 Development of the Bridge Management Web System

(1) Preparation of System Specifications

1) Arrangement of Functional Requirements

The DRR employees arranged the functional requirements of the Bridge Management Web System, which conducts the inputting and outputting of bridge inventory data, inspection data and repair data, and they compiled these into the system specifications document.

When arranging the functional requirements, use case analysis was carried out in order to clarify the relationships with system behavior (use cases) and external environment (actors: other systems, users, etc.). As the results, Table 6.3-6 shows the list of use cases, while Figure 6.3-5 shows the use case drawing.

The system specifications document was prepared based on these functional requirements. Appendix 5.3 shows the details of the system specifications document.

Table 6.3-6 List of Use Cases (Bridge Management Web System)

Use Case		Function	Relationship with Actors			
			System manager	DRR employees	Tablet system	Life extension repair plan simulation system
Recognition	Log-in	Enter the user ID and password.	■	■	－	－
Data viewing	Data search	Specify conditions and search from the data items concerning inventory, inspection history and repair history.	－	■	－	－
	Viewing of inventory data	Display optional inventry data in tabular format.	－	■	－	－
	Viewing of inspection history data	Display optional inspection history data in tabular format.	－	■	－	－
	Viewing of inspection history data (flood countermeasures)	Display optional inspection history data (flood countermeasures) in tabular format.	－	■	－	－
	Viewing of repair history data	Display optional repair history data in tabular format.	－	■	－	－
Data updating	Updating of inventory data	Newly input / Change / Delete optional inventory data.	－	■	－	－
	Updating of inspection history data	Newly input / Change / Delete optional inspection history data.	－	■	－	－
	Updating of inspection history data (flood countermeasures)	Newly input / Change / Delete optional inspection history data (flood countermeasures).	－	■	－	－
	Updating of repair history data	Newly input / Change / Delete optional repair history data.	－	■	－	－
Ledger inputting and outputting	Bridge ledger export	Output the optional bridge management ledger sheet (Excel).	－	■	■	－
	Bridge ledger import	Read the optional bridge management ledger sheet (Excel).	－	■	■	－
	Inspection sheet export	Output the optional inspection survey sheet (Excel).	－	■	－	－

Use Case		Function	Relationship with Actors			
			System manager	DRR employees	Tablet system	Life extension repair plan simulation system
	Inspection sheet import	Read the optional inspection survey sheet (Excel).	—	■	■	—
	Inspection sheet export (flood countermeasures)	Output the optional inspection survey sheet (flood countermeasures) (Excel).	—	■	—	—
	Inspection sheet import (flood countermeasures)	Read the optional inspection survey sheet (flood countermeasures) (Excel).	—	■	■	—
Information	Viewing of communications	Display communications pertaining to system operation.	—	■	—	—
	Update of communications	Newly input / Change / Delete communications pertaining to system operation.	■	—	—	—
	Viewing of data update information	Specifically display that data updating has been performed.	—	■	—	—
	Update of data update information	Automatically input information when data updating is conducted.	—	—	—	—
Manual	Manual download	Download the various manuals.	—	■	—	—
	Manual upload	Upload the various manuals.	■	—	—	—
LCC support	Table data download	Download (CSV) the data necessary to conduct the life extension repair plan.	—	■	—	■
Managemen t	Master data management	Display / Newly input / Change / Delete the various master data.	■	—	—	—
	User authority management	Display / Newly input / Change / Delete each user information and authority.	■	—	—	—

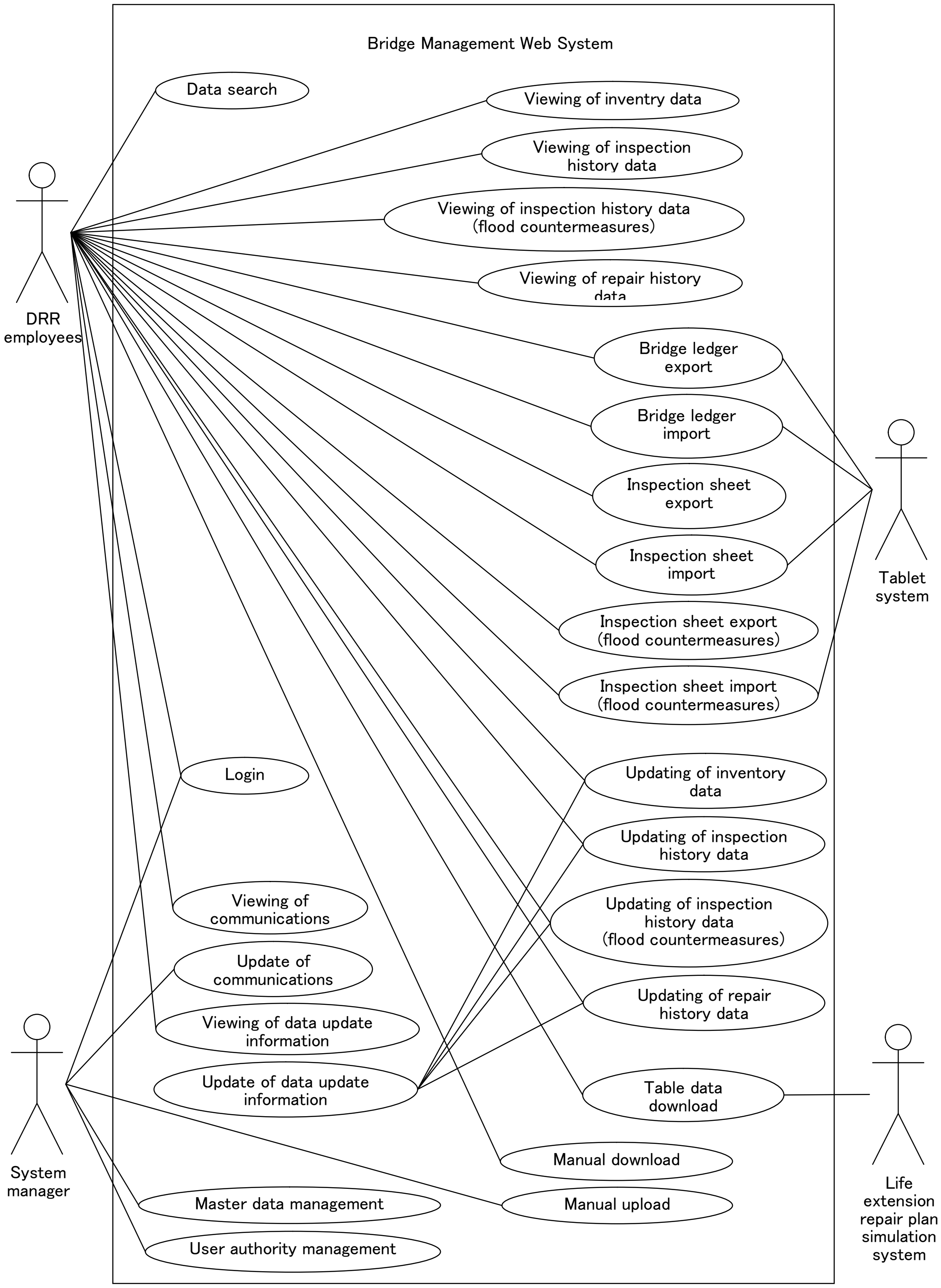


Figure 6.3-5 Use Case Drawing (Bridge Management Web System)

2) Arrangement of User Permission

A user ID and password are required in order to operate the bridge management Web system. It has been decided to allocate user IDs according to departments, except for the Director-General, Deputy Director-Generals and Chief Engineer. User IDs will be allocated the following destinations:

- Director-General
- Deputy Director-General (3)
- Chief Engineer
- Bureau of Road Construction
- Bureau of Bridge Construction
- Bureau of Road Maintenance
- Bureau of Planning
- Bureau of Training
- Bureau of Testing , Research and Development
- Bureau of Local Road Development
- Bureau of Location and Design
- Bureau of Traffic Safety
- Information and Technology Center
- Bureau of Rural Road (District Office 1-18)

Also, it has been decided to stipulate permission and limit the scope of operation according to each user department. For example, the Bureau of Road Maintenance can view and update data, while the Bureau of Road Planning, etc. can only view data. Also, operation of repair history data has been restricted only to the departments concerned because it includes budget information.

Table 6.3-7 shows the details of user permission. These have been discussed and agreed with the DRR Bureau of Road Maintenance.

Table 6.3-7 System user permission

Database System : User Permission

User	Controls										
	Data Search								Download data for long term maintenance planning	Administrator Menu	Manual
	Inventroy data		Inspection history		Inspection history for flood		Maintenance history				
	View	Update	View	Update	View	Update	View	Update	Download	All	Download
System Administrator (Super user)	○	○	○	○	○	○	○	○	○	○	○
IT Center (Super user)	○	○	○	○	○	○	○	○	○	○	○
Director-General	○	×	○	×	○	×	×	×	×	×	○
Deputy Director-General (1)	○	×	○	×	○	×	×	×	×	×	○
Deputy Director-General (2)	○	×	○	×	○	×	×	×	×	×	○
Deputy Director-General (3)	○	×	○	×	○	×	×	×	×	×	○
Chief Engineer	○	×	○	×	○	×	×	×	×	×	○
Bureau of Road Construction	○	×	○	×	○	×	×	×	×	×	○
Bureau of Bridge Construction	○	×	○	×	○	×	×	×	×	×	○
Bureau of Road Maintenance	○	○	○	○	○	○	○	○	○	×	○
Bureau of Planning	○	×	○	×	○	×	○	×	×	×	○
Bureau of Training	○	×	○	×	○	×	×	×	×	×	○
Bureau of Testing , Research and Development	○	×	○	×	○	×	×	×	×	×	○
Bureau of Local Road Development	○	×	○	×	○	×	×	×	×	×	○
Bureau of Location and Design	○	×	○	×	○	×	×	×	×	×	○
Bureau of Traffic Safety	○	×	○	×	○	×	×	×	×	×	○
District Office (1)	○	△	○	△	○	△	△	△	△	×	○
District Office (2)	○	△	○	△	○	△	△	△	△	×	○
District Office (3)	○	△	○	△	○	△	△	△	△	×	○
District Office (4)	○	△	○	△	○	△	△	△	△	×	○
District Office (5)	○	△	○	△	○	△	△	△	△	×	○
District Office (6)	○	△	○	△	○	△	△	△	△	×	○
District Office (7)	○	△	○	△	○	△	△	△	△	×	○
District Office (8)	○	△	○	△	○	△	△	△	△	×	○
District Office (9)	○	△	○	△	○	△	△	△	△	×	○
District Office (10)	○	△	○	△	○	△	△	△	△	×	○
District Office (11)	○	△	○	△	○	△	△	△	△	×	○
District Office (12)	○	△	○	△	○	△	△	△	△	×	○
District Office (13)	○	△	○	△	○	△	△	△	△	×	○
District Office (14)	○	△	○	△	○	△	△	△	△	×	○
District Office (15)	○	△	○	△	○	△	△	△	△	×	○
District Office (16)	○	△	○	△	○	△	△	△	△	×	○
District Office (17)	○	△	○	△	○	△	△	△	△	×	○
District Office (18)	○	△	○	△	○	△	△	△	△	×	○

※△ : Control about bridges managed by the district office is permitted.

(2) System Development

The system was developed according to the prepared system specifications. Figures 6-11~6-16 show screen examples from the actually developed system.

URL：http://bim.drr.go.th/bmms/

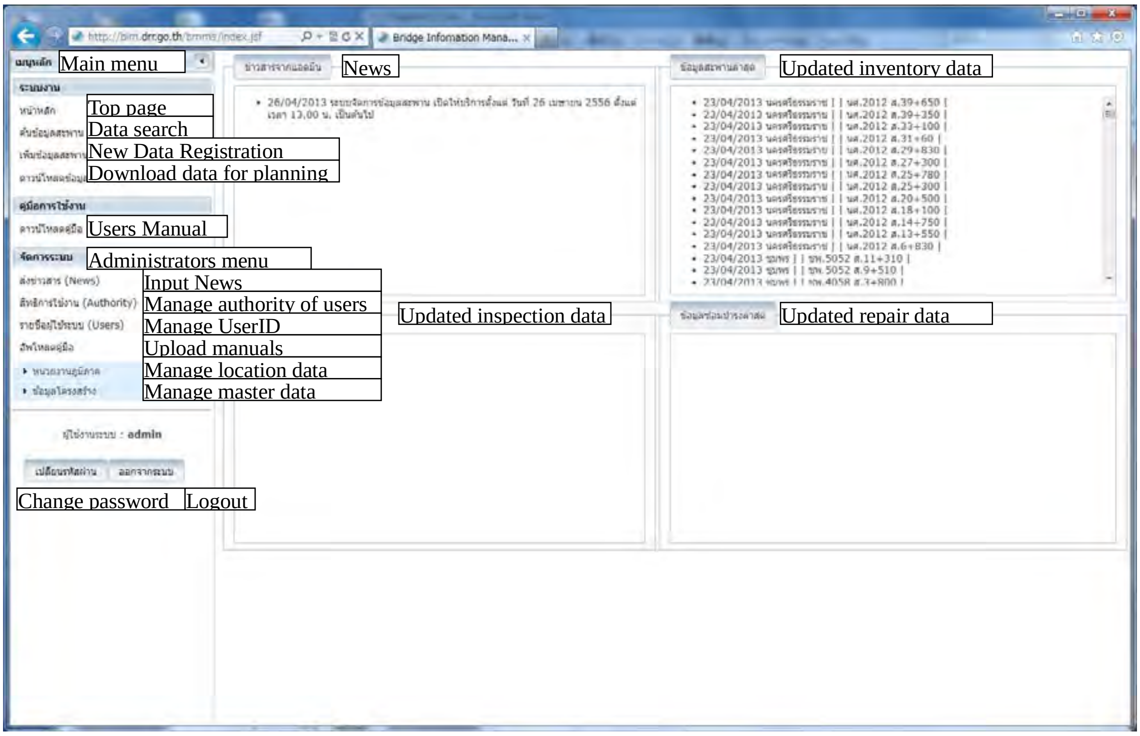


Figure 6-6 Menu and Information Screen

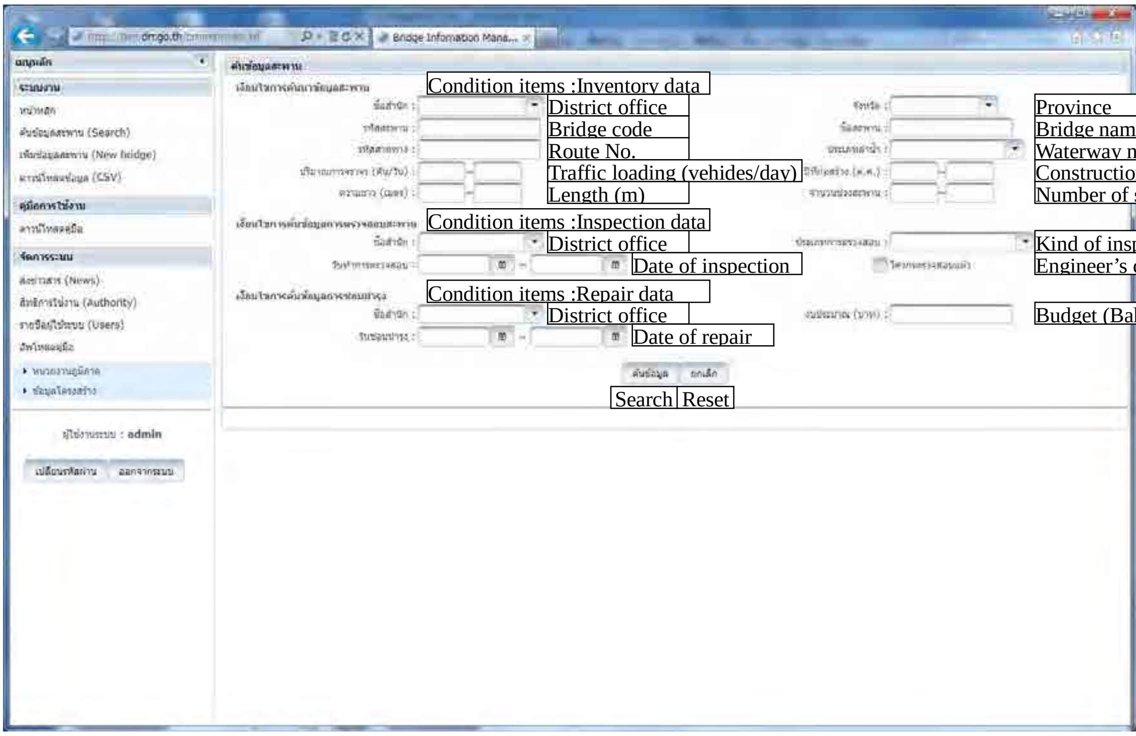


Figure 6-7 Search Conditions Inputting Screen

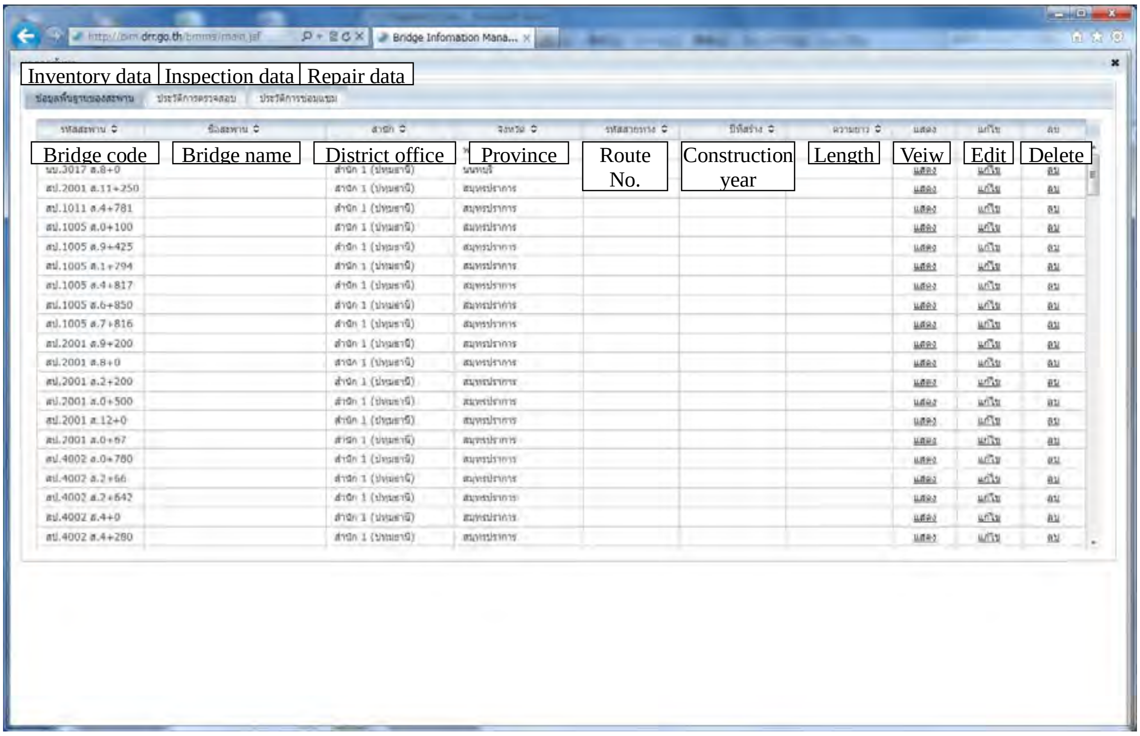


Figure 6-8 Search Results List Screen

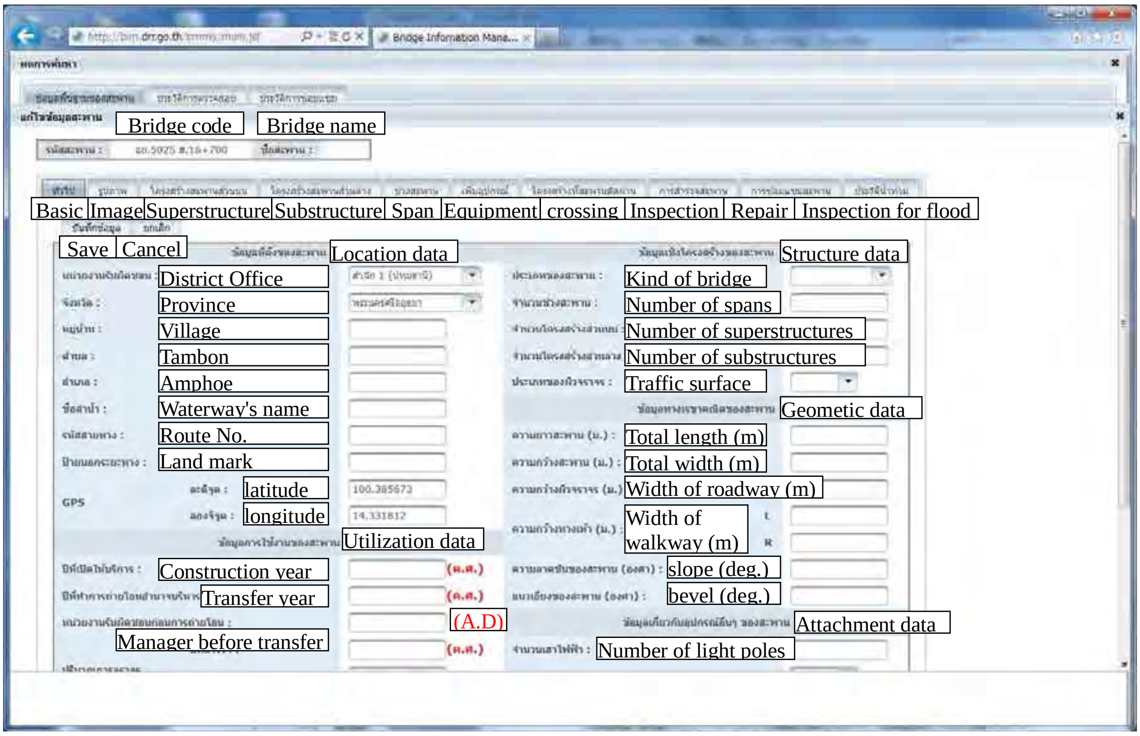


Figure 6-9 Data Editing Screen (Specifications)

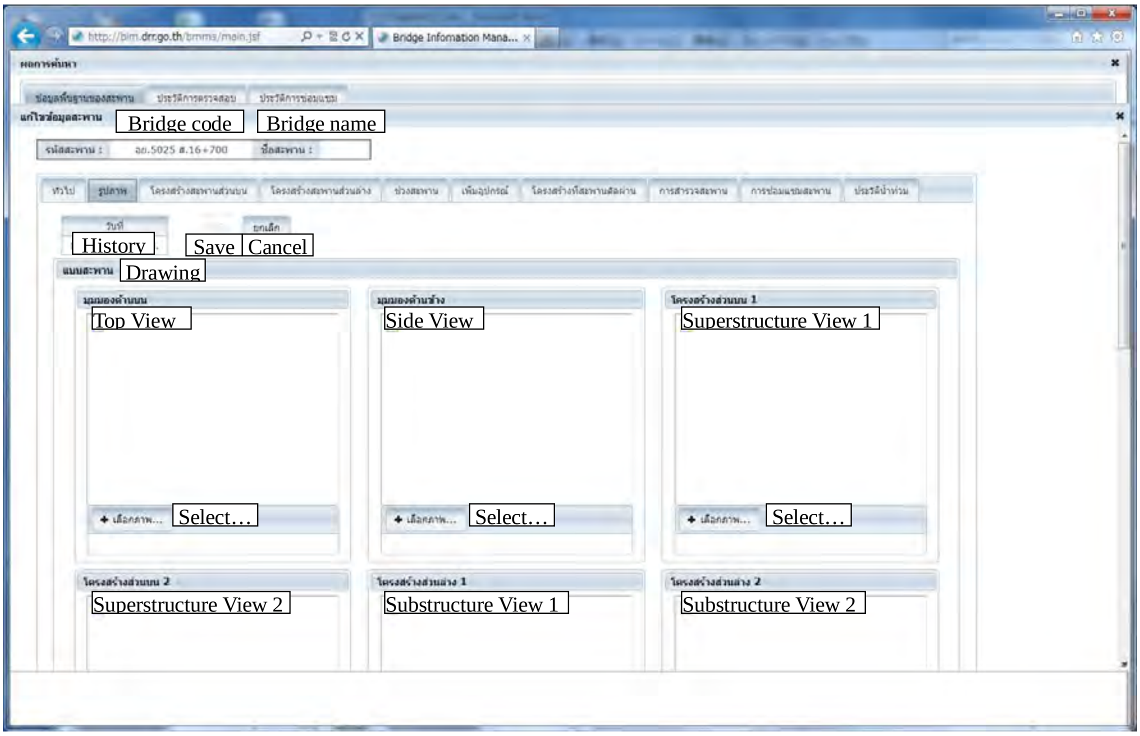


Figure 6-10 Data Editing Screen (Figures and Photographs)

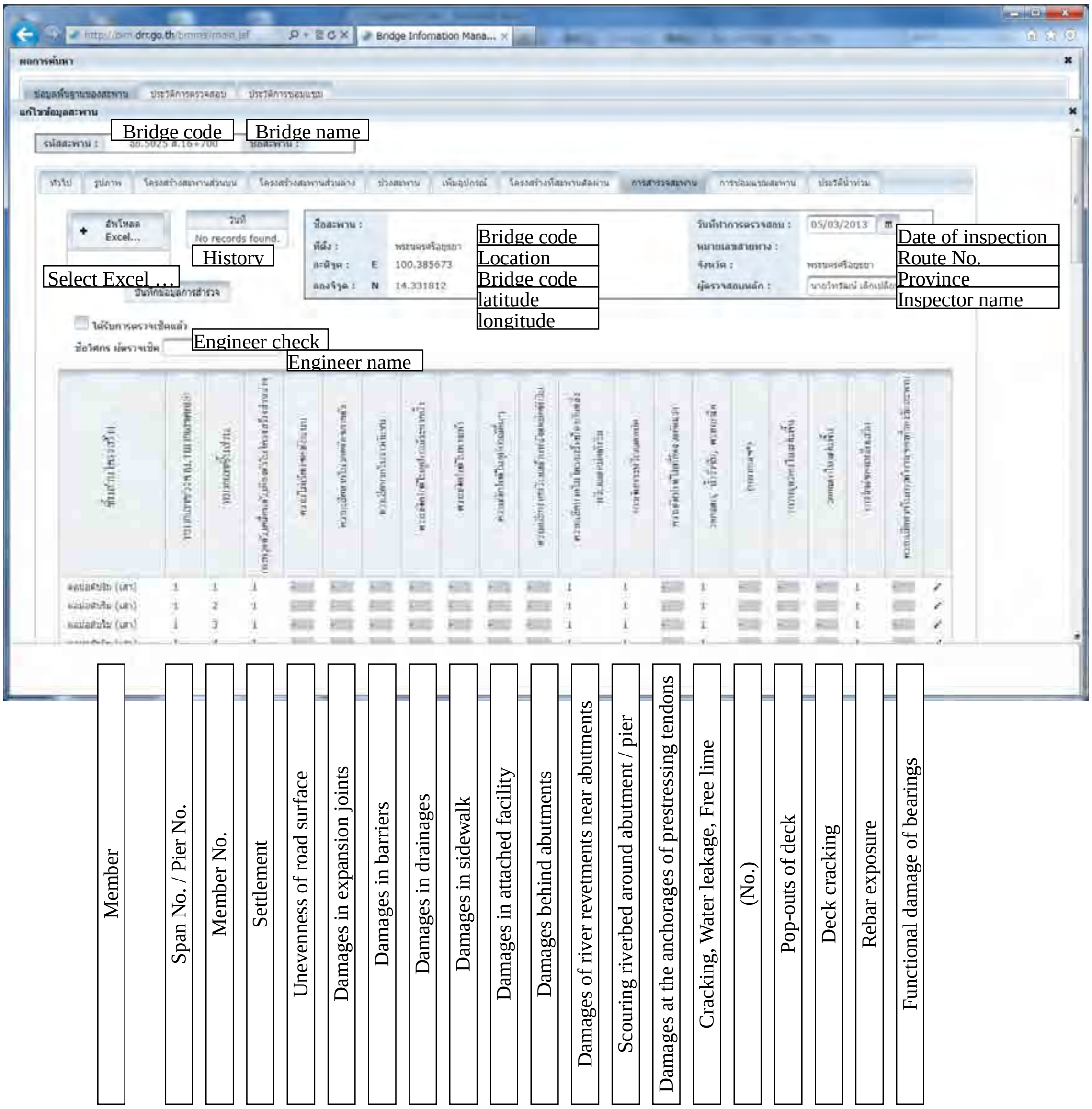


Figure 6-11　Data Editing Screen (Inspection Results)

(3) Manual Preparation

The following operation manuals were prepared. Details on each are given in Appendix-5.7 and Appendix-5.8.

・Bridge management web system operation manual (for managers)

・Bridge management web system operation manual (for general use)

6.3.4 Tablet System Development

(1) Preparation of System Specifications

Functional requirements of the tablet system, which supports the inputting of inspection results in field work according to the inspection survey and assessment manual, have been compiled into the system specification document.

When arranging the functional requirements, use case analysis was carried out in order to clarify the relationships with system behavior (use cases) and external environment (actors: other systems, users, etc.). As the results, Table 6.3-8 shows the list of use cases, while Figure 6.3-12 shows the use case drawing.

The system specifications document was prepared based on these functional requirements. Appendix 5.4 shows the details of the system specifications document.

Table 6.3-8 List of Use Cases (Tablet System)

Use Case		Function	Relationship with Actors			
			DRR employees	Inspector	Bridge management web system	Life extension repair plan simulation system
List of bridges	Bridge ledger import	Read the bridge management ledger sheets (Excel) exported from the bridge management web system.	■	■	■	—
	Bridge list display	Display the read list of bridges (targets for inspection).	—	■	—	—
	Map display of bridge positions	Display the positions of the read bridges on a map.	—	■	—	—
Basic information confirmation	Basic information viewing	Display the read basic information of bridges.	—	■	—	—
	Basic information editing	Input corrections to basic information of bridges and information on inspectors.	—	■	—	—
	Acquisition of GPS coordinates	Acquire latitude and longitude from the tablet GPS function, and record the information as bridge coordinates.	—	■	—	—
	Shooting of bridge status photographs	Shoot and record photographs of the current status of bridges using the digital camera on the tablet.	—	■	—	—
Inspection results recording	Preparation and display of the damage record list	Prepare a damage record list from the bridge basic information. It is possible to move from this list to the inputting screen for each inspection item.	—	■	—	—
	Drawing and display of bridge schematic diagrams	Automatically draw and display schematic diagrams (overall drawings and partial drawings) from the bridge basic information. It is possible to move from these schematic diagrams to the inputting screen for each inspection item.	—	■	—	—

Use Case		Function	Relationship with Actors			
			DRR employees	Inspector	Bridge management web system	Life extension repair plan simulation system
	Inputting of damage rank	Display the explanations, reference photos and drawings (stated in the inspection survey and assessment manual) and input the rank concerning damage of each inspection item.	–	■	–	–
	Inputting of damaged locations	Draw the damaged locations on the schematic diagram of the target region.	–	■	–	–
	Shooting of damage photographs	Shoot and record photographs of the damaged locations using the digital camera on the tablet.	–	■	–	–
	Transfer of damage photographs	Transfer photographs of damage taken with other digital cameras to the tablet by wireless. After that, select them as damage photographs.	–	■	–	–
	Inputting of survey results related to flood countermeasures	Input the results of ordinary time survey of flood countermeasures.	–	■	–	–
Inspection results outputting	Bridge ledger export	Output the bridge management ledger sheet (Excel) reflecting the corrected basic information.	■	■	■	–
	Inspection sheet export	Output the inspection survey sheet (Excel) reflecting the inputted inspection results.	■	■	■	–
	Inspection sheet export (flood countermeasures)	Output the inspection survey sheet (flood countermeasures) (Excel) reflecting the inputted inspection results.	■	■	■	–

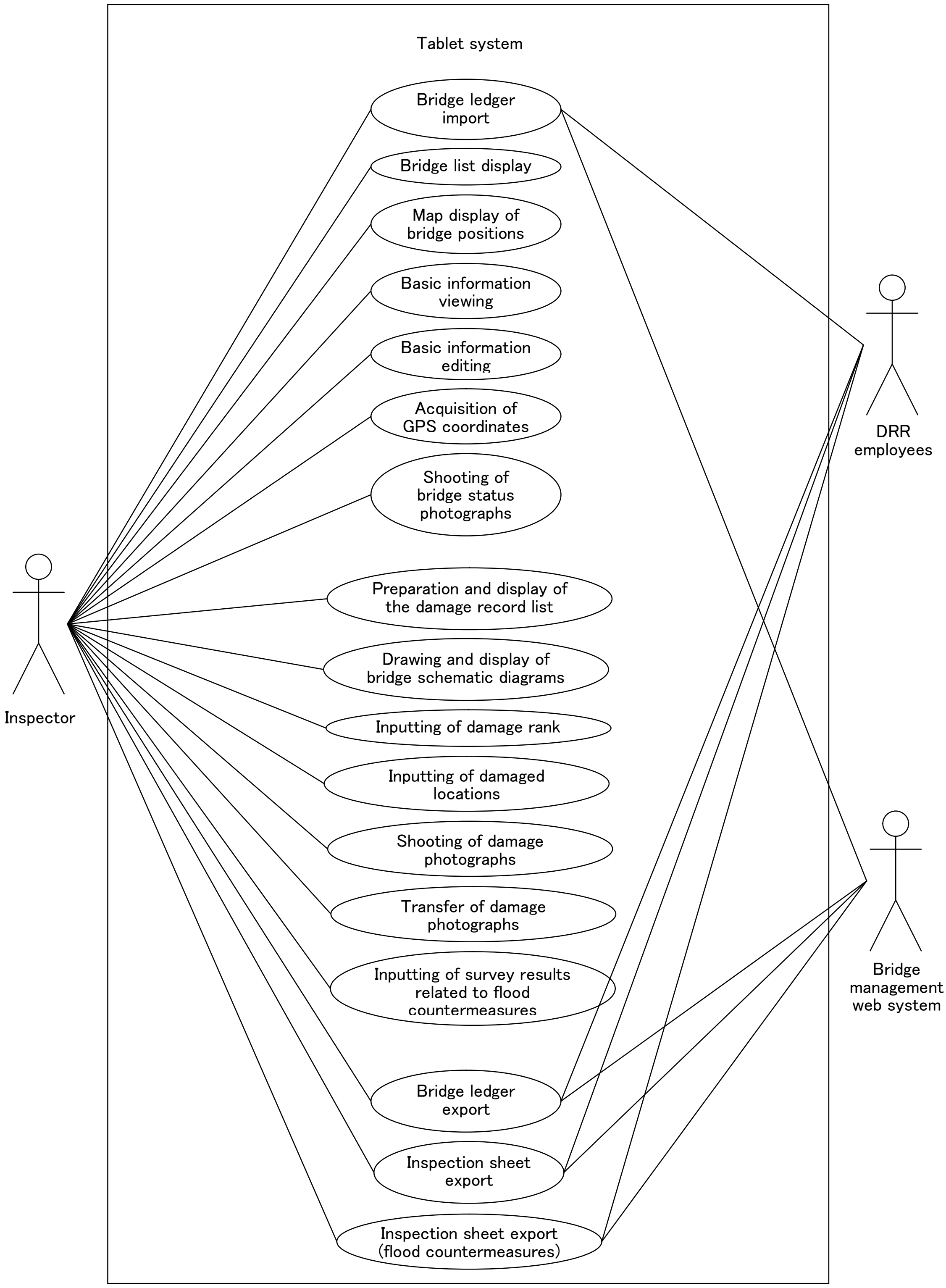


Figure 6.3-12 Use Case Drawing (Tablet System)

(2) Prototype Development and Arrangement of Improvement Items

The prototype system was developed according to the prepared system specifications, and this prototype was used to carry out lectures and practical training on bridge surveying and inspection for employees of the DRR headquarters and district offices. Based on the opinions concerning inspection work that were expressed at this time, detailed corrections were made and items for system improvement were prepared. The improvement items and contents are indicated below.

1) Items reflected in system design in the initial stage of development

In designing the tablet inputting system, the following wishes were expressed by DRR headquarters.

Items reflected in the system

- Numerous pile vents are damaged. We want to input data on damage to substructures.
- We want a function for automatically preparing a photograph ledger of the inspection results. It would be a good idea if photos taken by tablet could be inserted.
- In addition to tablet photographs, can photographs taken by external cameras be imported?
- We want to be able to display maps offline.
- It would be good if inspection pictures (with different number of spans and piles, etc.) can be automatically displayed based on the bridge information.
- We want to automatically paste figures showing damaged locations on the inspection ledger.

Items for which development is an issue for future development:

- Insertion of 3D pictures so that pictures can be rotated.
- We want to input all ledger information on bridges. →It will be possible to input basic information. Detailed information such as traffic volume and drawing information will be inputted from the web system.
- Two or more levels of damage can be inserted to one member.
- It will be possible to insert the detailed location and scope of damage. →The system has been improved so that rough dimensions can be inserted.

2) Inspection results inputting skip

As a result of holding discussions with the staff of DRR headquarters, it was initially designed so that inspection work could not be completed until all members and inspection items were inputted.

At the time of the lectures and training on bridge survey and inspection, employees of the district offices expressed the following opinions:

＜Opinions of the district offices＞

・It is too time consuming and inefficient to input all members and inspection items.

・There are also bridges where the majority of members have no damage.

・We want the inspection results to show whether visual confirmation was performed for all members including those where damage was not observed.

In view of these opinions, the contents for improvement were arranged as follows:

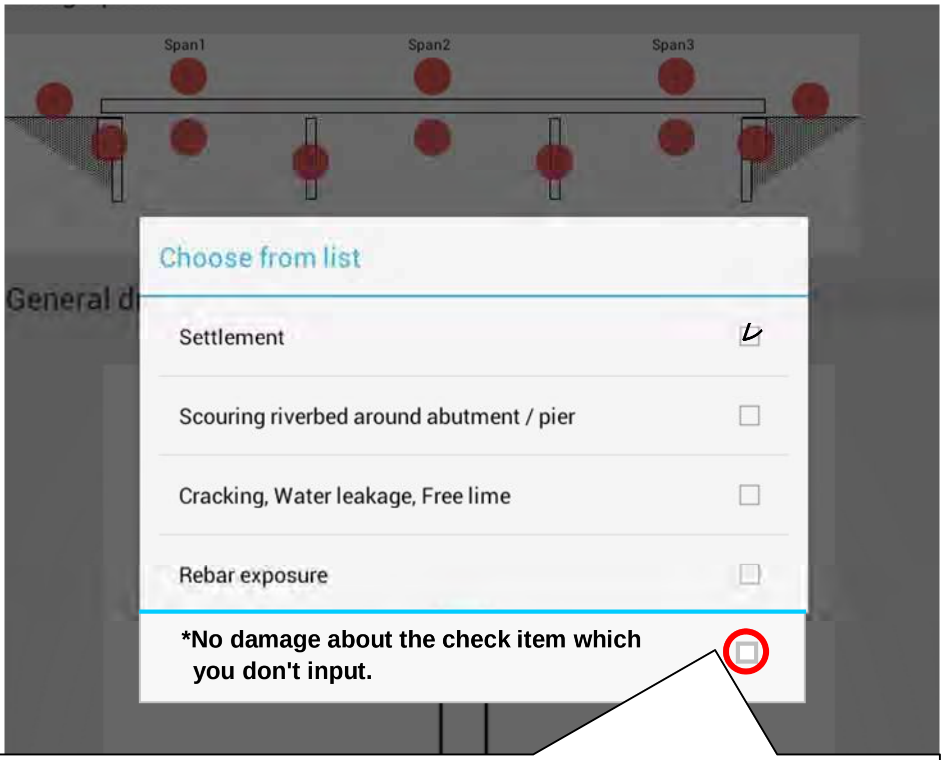
＜Improvement contents＞

・Concerning members where no damage is found, automatically input damage rank 1 (no damage) for all inspection items in a single action.

・Regard all automatically inputted items as already inspected and display this fact on simple bridge drawings.

・Even if there are members or inspection items for which the inspection results have not yet been inputted, make it possible to output the inspection sheet on Excel and to close the system.

The next page shows the improvement image. Moreover, concerning the method of operation, judgment will be made by the DRR employees in charge depending on the level of the surveyor implementting the inspection.



By inserting a check mark …

① This means that inspection items that are not inputted (items other than Settlement in this example) are regarded as having “No damage.” However, do not check inspection items that haven’t been inputted yet.

②All items in this region are regarded as already inputted, and the ◎ marks on the bridge schematic diagram are colored blue.

③ When outputting the Excel file, “1” is outputted in the cells of all items not yet inputted for this member in the inspection Data Table sheet.

Figure 6-13　Improvement 1: Inspection Results Inputting Skip

3) Recording of damage size

In light of preparation of the long-term bridge maintenance plan, employees of DRR headquarters have raised the following opinions.

＜Opinions of DRR headquarters＞

・When preparing long-term maintenance plans, in order to accurately calculate budget, in addition to the types and ranks of damage, it is necessary to understand the size of damage.

・It is hoped to build data on damage size so that it can be used in preparing future maintenance plans.

In light of these opinions, the contents of improvement have been arranged as follows.

＜Improvement contents＞

・It will be possible to input the size of damage with respect to the following five inspection items:

① Damage at anchorage of PC tender : Number of damaged locations
② Cracking, water leakage, free lime: Extent of damage (vertical x horizontal)
③ Deck pop-outs : Extent of damage (vertical x horizontal)
④ Deck cracking : Extent of damage (vertical x horizontal)
⑤ Rebar exposure :Extent of damage (vertical x horizontal)

・In cases where nothing is inputted about damage size even though the inputted damage rank is 2 or higher (damaged), a warning will be issued to input that information.

・The inputted damage size will be outputted in the inspection sheet Excel file (as an additional sheet).

The following page shows an image of improvement.

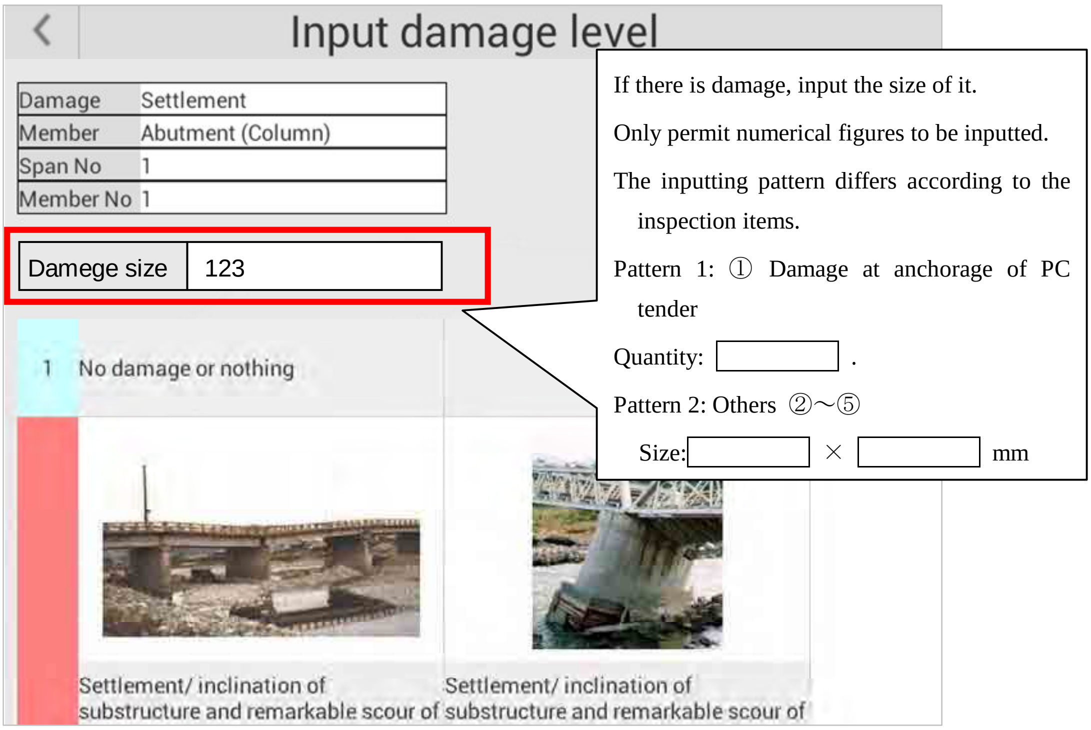


Figure 6-14 Improvement 2: Recording of Damage Size (1/2)

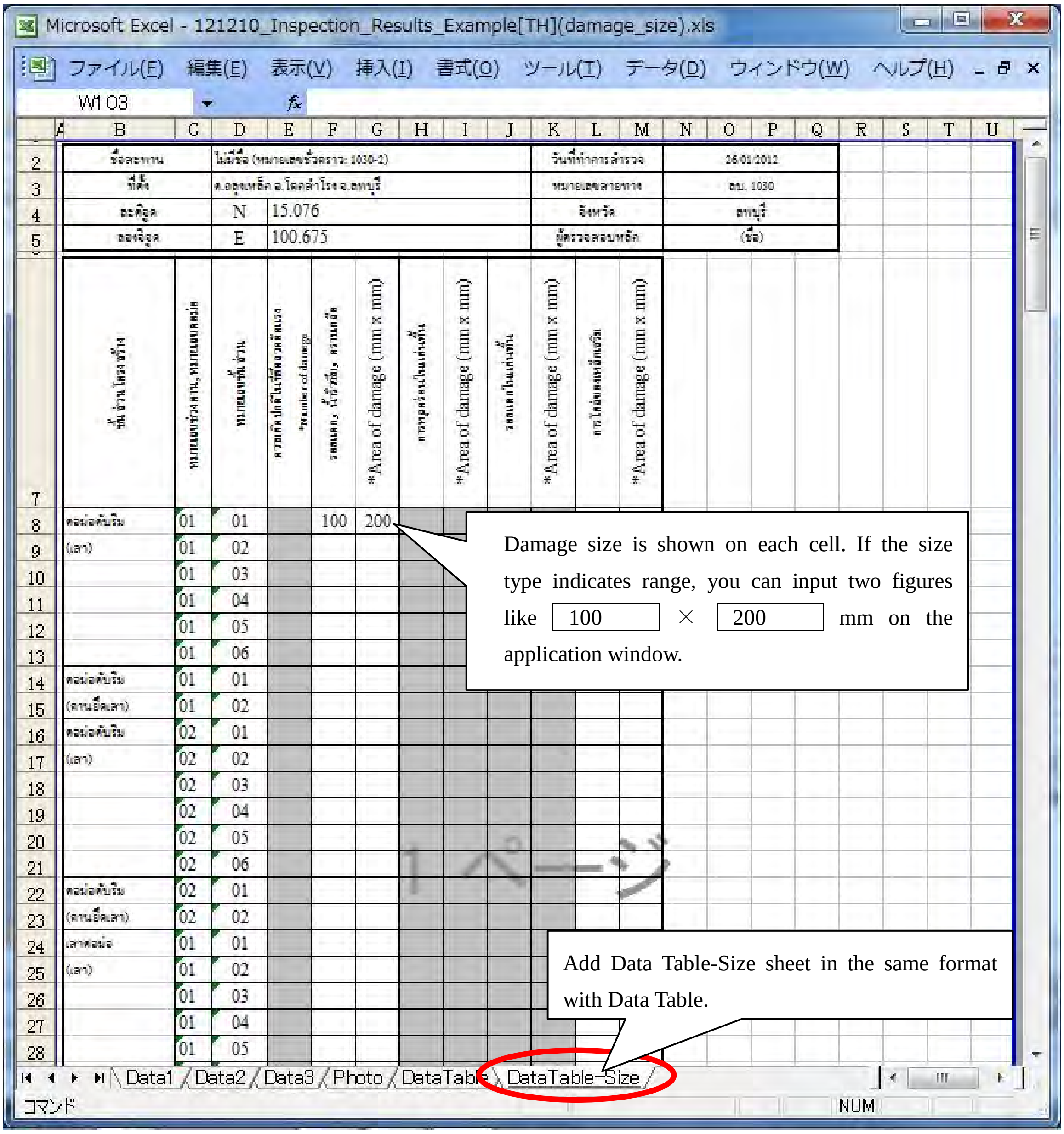


Figure 6-15 Improvement 2: Recording of Damage Size (2/2)

(3) System Development

The system was developed according to the prepared system specifications and improved items. Moreover, it was confirmed that the system works with tablet terminals that satisfy the following equipment specifications.

Table 6-9 Tablet Terminal Specifications

Maker and model	Samsung Galaxy Note 10.1 (GT-N8000)
Platform	Android 4.0
Display size	10.1 inch
Resolution	1280 x 800
Functions	Digital camera, WiFi, GPS

Figures 6-21~6-33 show screen examples from the actually developed system.

Figure 6-16 Startup Screen

Figure 6-17 Bridge Data Read Screen

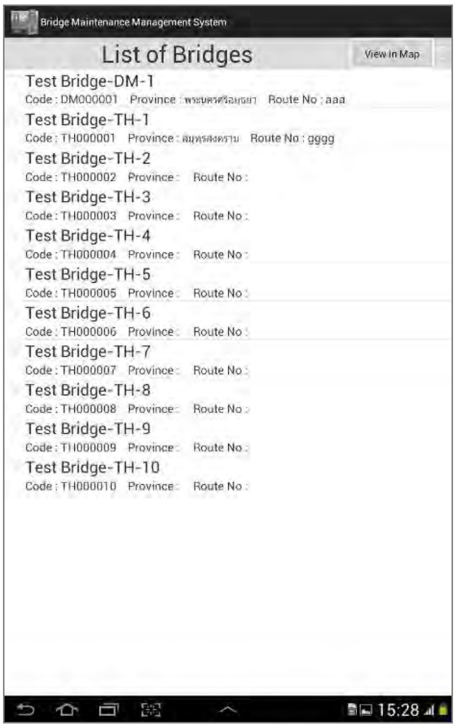


Figure 6-18 List of Bridges Screen

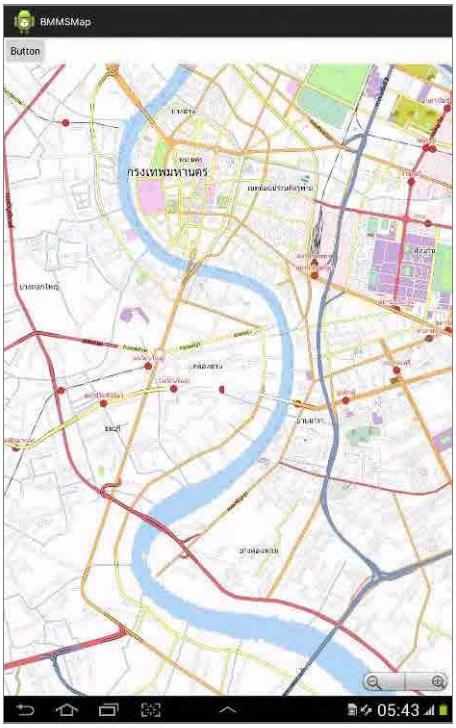


Figure 6-19 Map Screen

Figure 6-20 Basic Information Viewing Screen

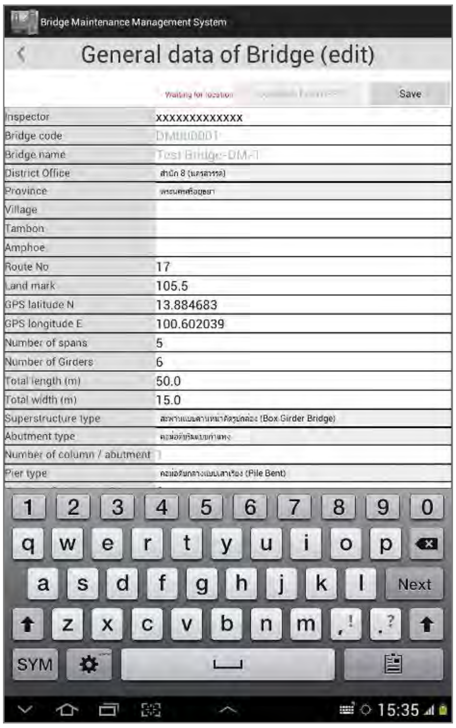


Figure 6-21 Basic Information Editing Screen

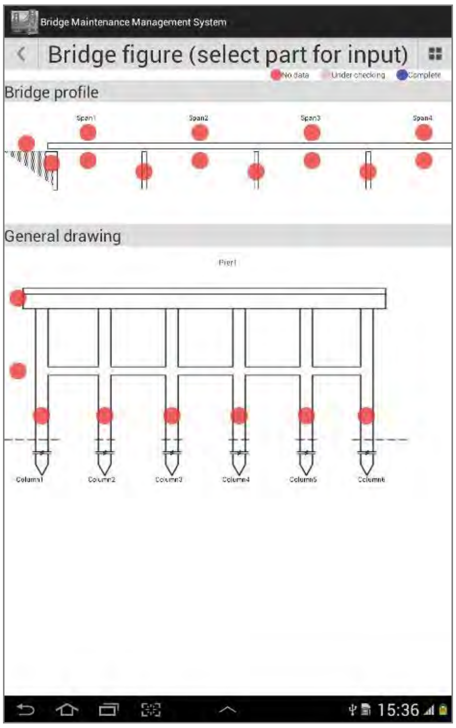


Figure 6-22 Inspection Location Designation Screen

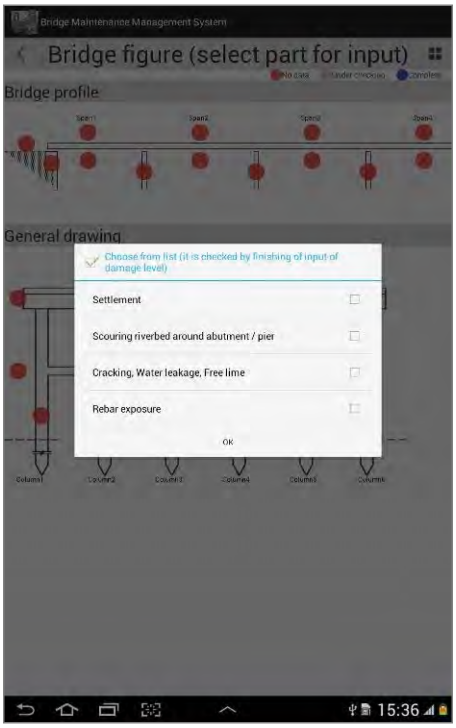


Figure 6-23 Inspection Items Designation Screen

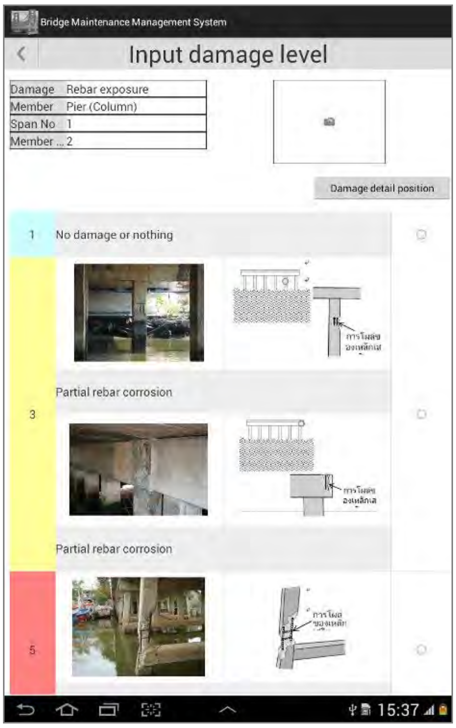


Figure 6-24 Damage Rank Input Screen

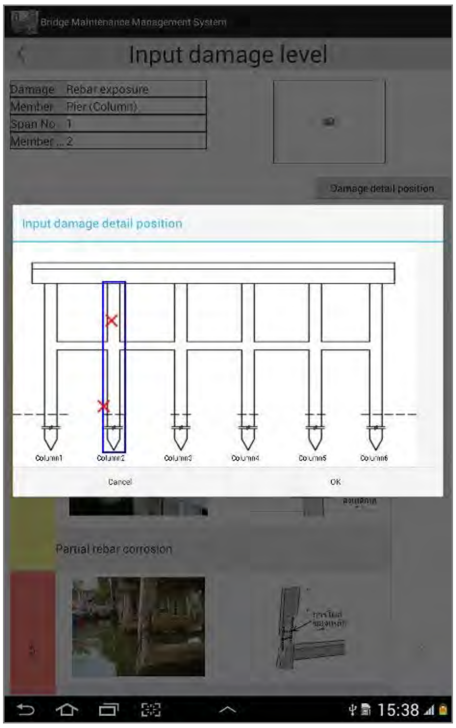
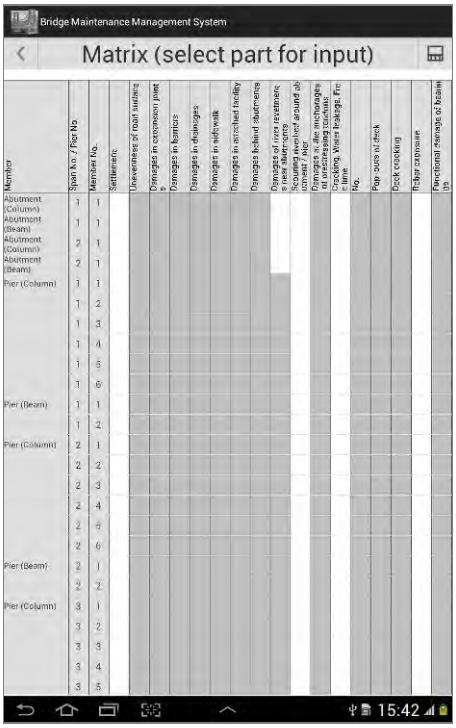


Figure 6-25 Damage Position Input Screen

Figure 6-26 Photo Shooting and Selection Screen



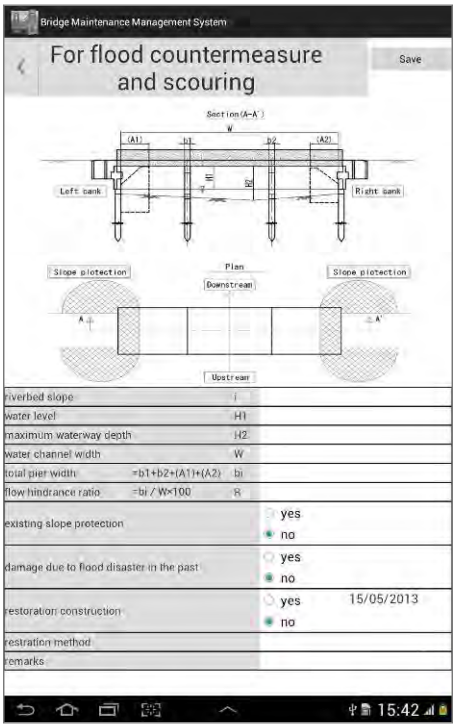


Figure 6-27 Inspection Results Screen

Figure 6-28 Flood Countermeasure Survey Results Input Screen

(4) Manual Preparation

The following operation manual was prepared. Details are given in Appendix-5.9.

6.3.5 Life Extension Repair Plan Simulation System Development

(1) Preparation of System Specifications

Functional requirements of the life extension repair plan simulation system, which supports the compilation of long-term maintenance plans for bridges, have been compiled into the system specification document.

When arranging the functional requirements, use case analysis was carried out in order to clarify the relationships with system behavior (use cases) and external environment (actors: other systems, users, etc.). As the results, Table 6.3-10 shows the list of use cases, while Figure 6.3-29 shows the use case drawing.

The system specifications document was prepared based on these functional requirements. Details of the system specifications document will be shown next time.

Table 6.3-10 List of Use Cases (Life Extension Repair Plan Simulation System)

Use Case		Function	Relationship with Actors			
			DRR employees (headquarters)	DRR employees (local office)	Bridge management Web system	Tablet system
Data inputting	Importing data file	Read the data files exported by the bridge management Web system, and display the data list on the screen.	■	■	■	—
	Selection of registered data	Read the data files exported by the bridge management Web system, and optionally select the bridges to be registered and the inspection implementation period.	■	■	■	—
	Data registration	Store the data specified in the registered data selection function into the system database.	■	■	—	—
Basic condition setting	Setting of conditions for deciding the management level	Based on the bridge length, traffic volume and conditions of crossings, etc., set the conditions for deciding the management level for each bridge.	■	■	—	—
	Setting of conditions for deciding the importance degree	Assuming the bridge length, traffic volume and conditions of crossings, etc. to be assessment items, set the conditions for deciding the importance assessment point for each bridge. Also, set the importance degree score allocation and weighting coefficient for each assessment item.	■	■	—	—
	Degradation prediction formula calculation	Calculate the degradation prediction formula based on the detailed inspection results (damage judgment of members) and Markov's transition probability line.	■	■	—	—
	Setting of optimum repair time	Optionally adjust the degradation prediction formula that was calculated using the degradation prediction formula calculation function.	■	■	—	—

Use Case		Function	Relationship with Actors			
			DRR employees (headquarters)	DRR employees (local office)	Bridge management Web system	Tablet system
	Setting of repair method according to healthy degree	Designate the optimum period (healthy degree) for implementing repairs at each management standard.	■	■	─	─
	Setting of repair unit price	Decide repair methods according to each degree of integrity of target members at the repair implementation point.	■	■	─	─
LCC calculation simulation	Setting of budget conditions	Set the repair unit price according to each repair method.	■	■	─	─
	Setting of target bridges	Set the budget amount according to each future fiscal year.	■	■	─	─
	Calculation of healthy degree evaluation	Set the simulation target period.	■	■	─	─
	Degradation prediction	Set conditions according to each managing office, bridge length and management standard, and set the bridges targeted for simulation.	■	■	─	─
	Decision of order of priority	Calculate the degree of integrity of each member based on the results of detailed inspection (member damage judgment).	■	■	─	─
	Budget equalization	Based on the degradation prediction formula obtained with the degradation prediction formula calculation function, simulate the future degradation progression.	■	■	─	─
	Graph display	Based on the divergence of integrity from the optimum repair period (integrity maintenance level according to each management standard) and conditions concerning importance assessment point, etc., decide the order of priority of countermeasures according to bridge span and member region.	■	■	─	─

Use Case		Function	Relationship with Actors			
			DRR employees (headquarters)	DRR employees (local office)	Bridge management Web system	Tablet system
	List display	Decide repairable members within the scope of each year's budget constraints set in advance.	■	■	—	—
	File output	If the projected budget is exceeded, repair from the next year onwards and decide the repair timing upon taking changes in the order of priority according to progression of degradation into account.	■	■	—	—

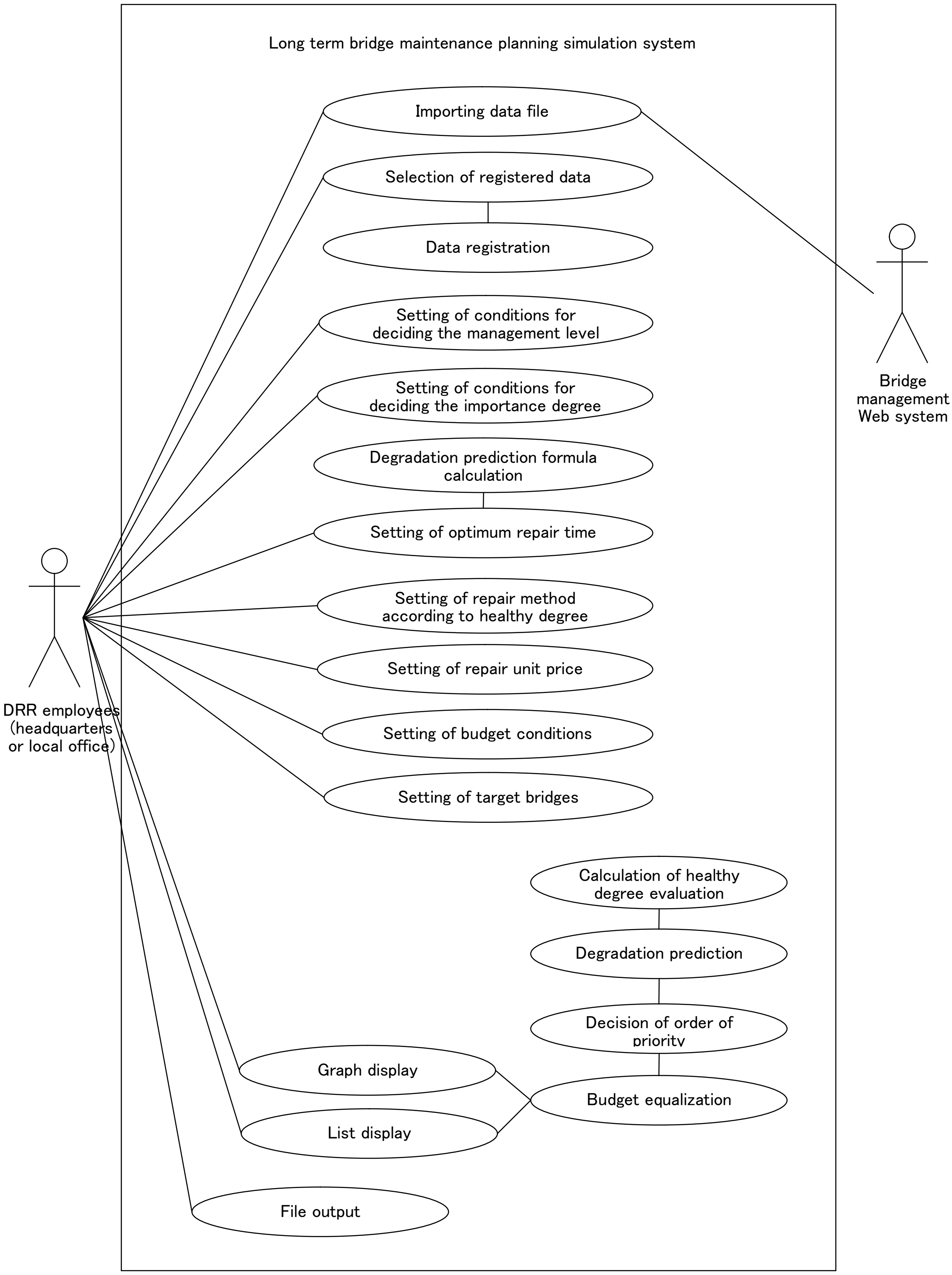


Figure 6.3-29 Use Case Diagram

(Long term bridge maintenance planning simulation system)

(2) System Development

The system was developed according to the prepared system specifications and improved items. Moreover, it was confirmed that the system works with tablet terminals that satisfy the following equipment specifications.

Table 6-11 PC Equipment Specifications

OS	Microsoft Windows 7 (32bit)
Resolution	1024 x 768 or higher
Software	Microsoft Excel 2010 Microsoft Access 2010 * Run time only Microsoft .net Framework 3.5

Figures 6-35~6-45 show screen examples from the actually developed system.

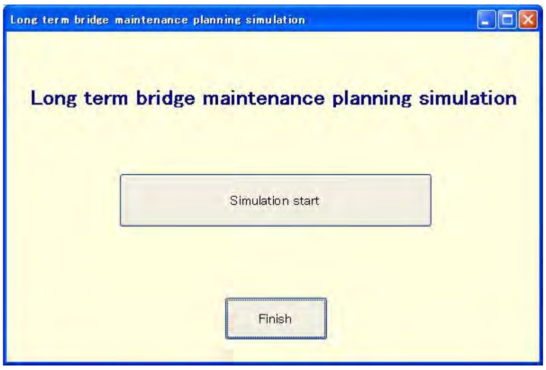


Figure 6-30 Startup Screen

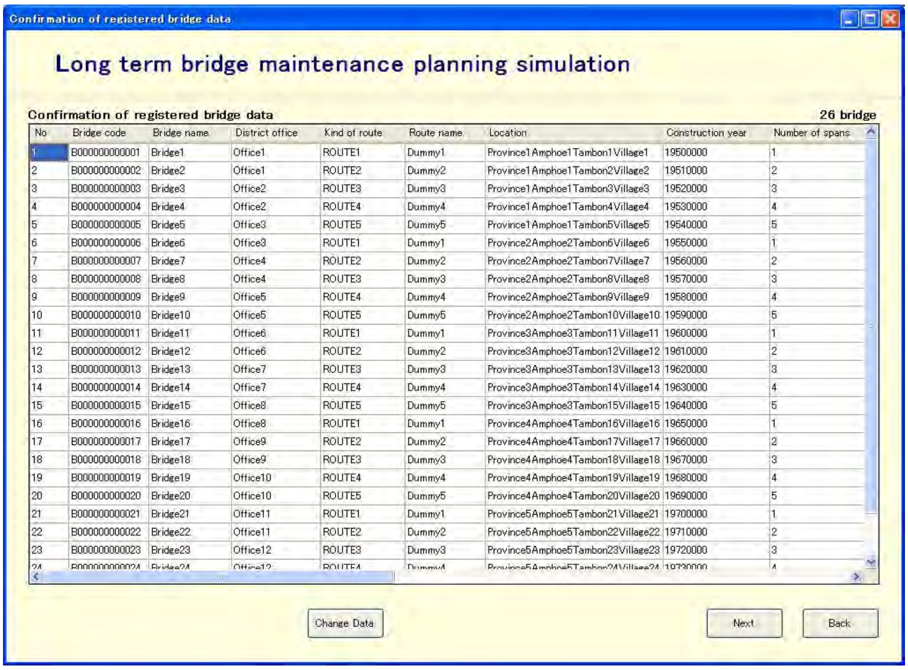


Figure 6-31 Data Registration Confirmation Screen

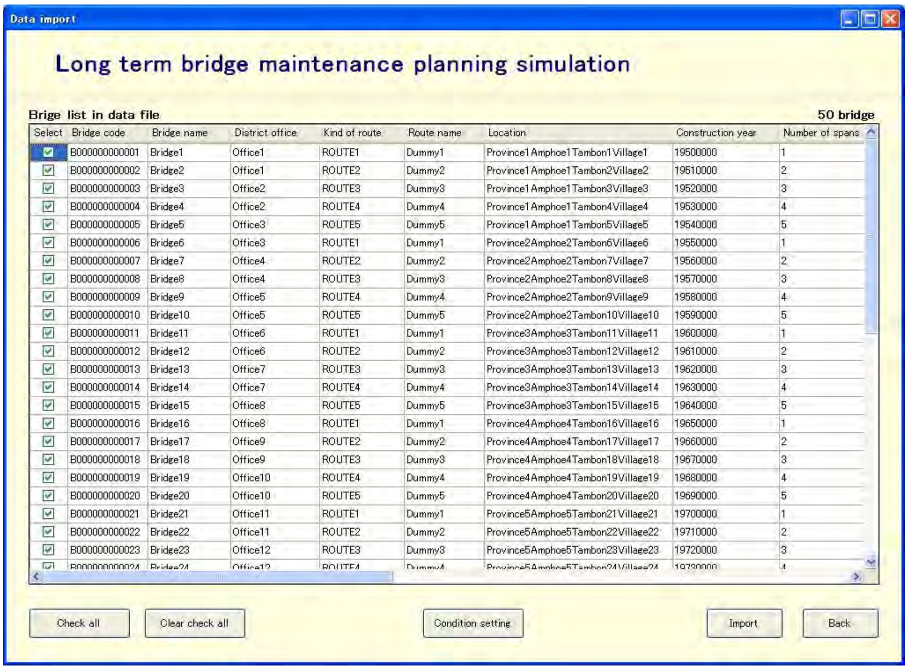


Figure 6-32 Data Import Screen

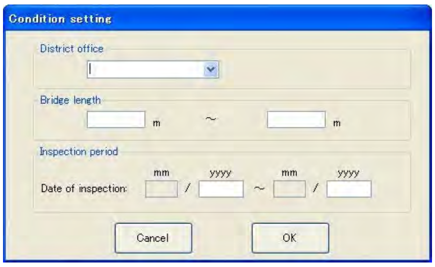


Figure 6-33 Data Import Conditions Setting Screen

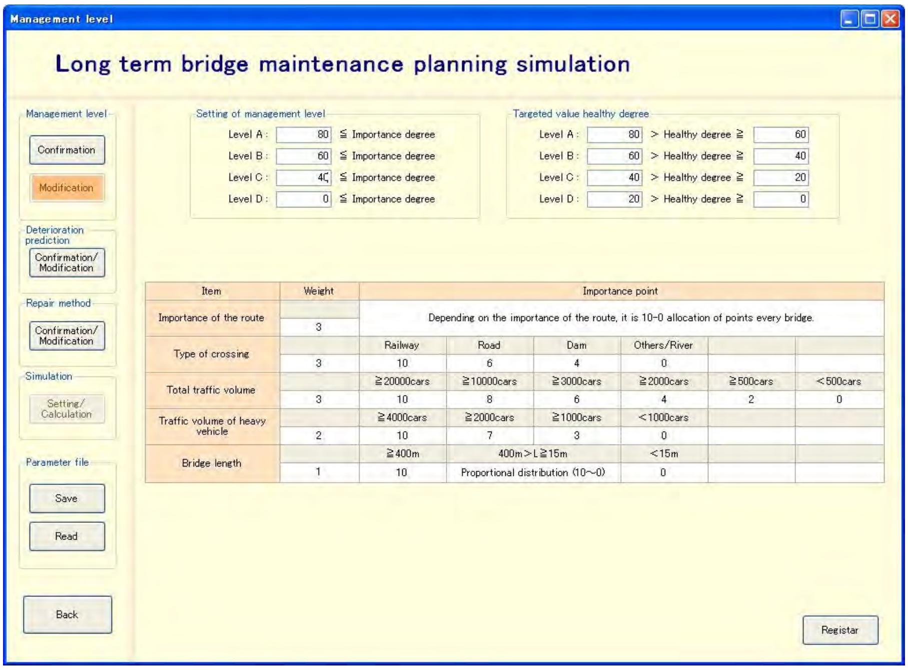


Figure 6-34 Calculation Parameters Setting Screen (Conditions for Setting Management Level)

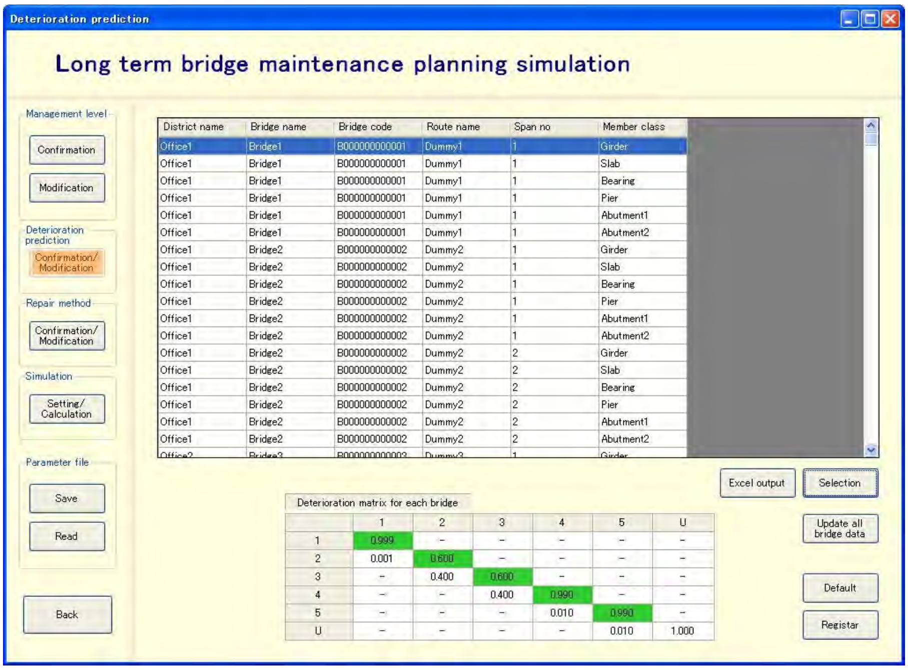


Figure 6-35　Calculation Parameters Setting Screen (Deterioration Prediction Formula)

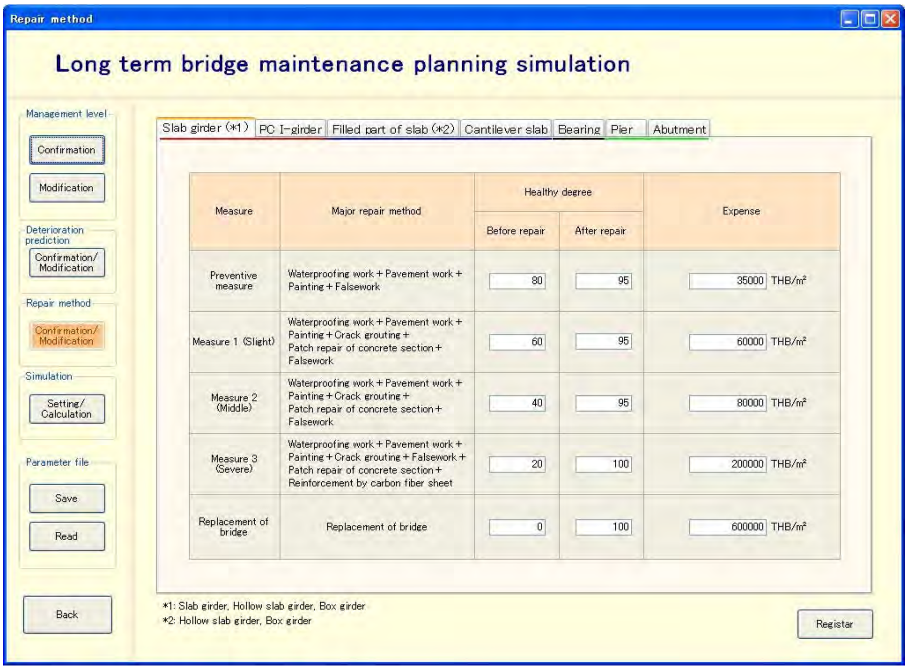


Figure 6-36　Calculation Parameters Setting Screen (Repair Measures)

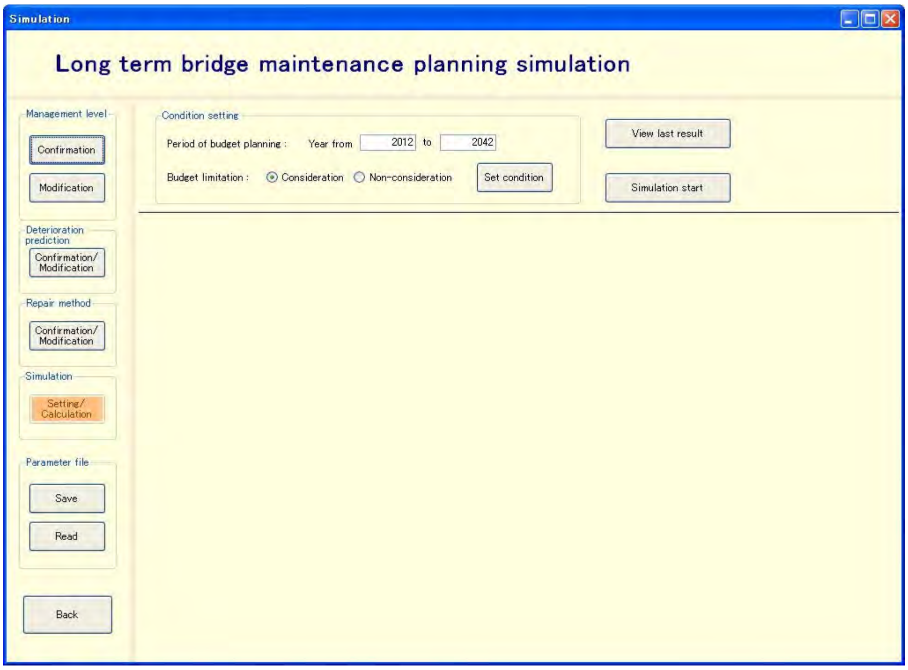


Figure 6-37 Calculation Conditions Setting Screen

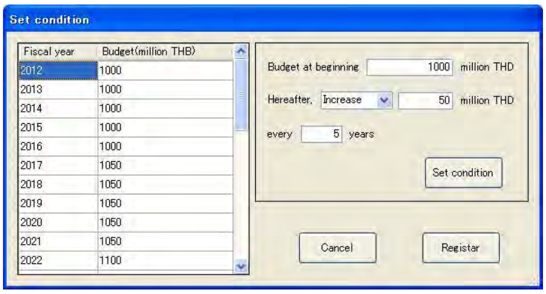


Figure 6-38 Budget Setting Screen

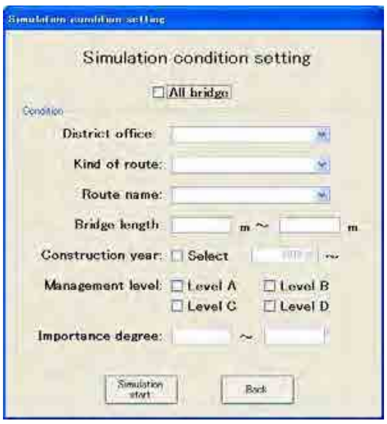


Figure 6-39 Target Bridge Conditions Setting Screen

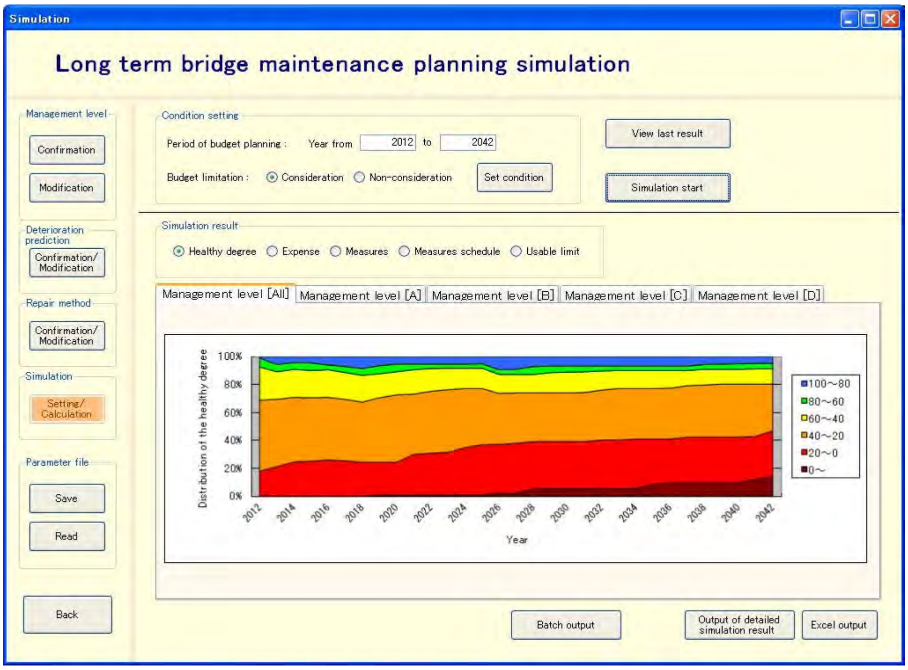


Figure 6-40 Calculation Results Display Screen

(3) Manual Preparation

The following operation manuals were prepared. Details on each are given in Appendix-5.10 and Appendix-5.11.

・Bridge Long-term Maintenance Planning Simulation System Installation Manual

・Bridge Long-term Maintenance Planning Simulation System Operation Manual

Chapter 7 Flood Disaster Emergency Inspection and Issues

7.1 Flood Damage Situation Overview

The scale of flood (area, period), which has occurred in the north and central regions of Thailand since late July 2011, was larger than that in the previous years. Figure 7.1.1 shows a comparison of inundated area due to the flood in 2011 and 2009.

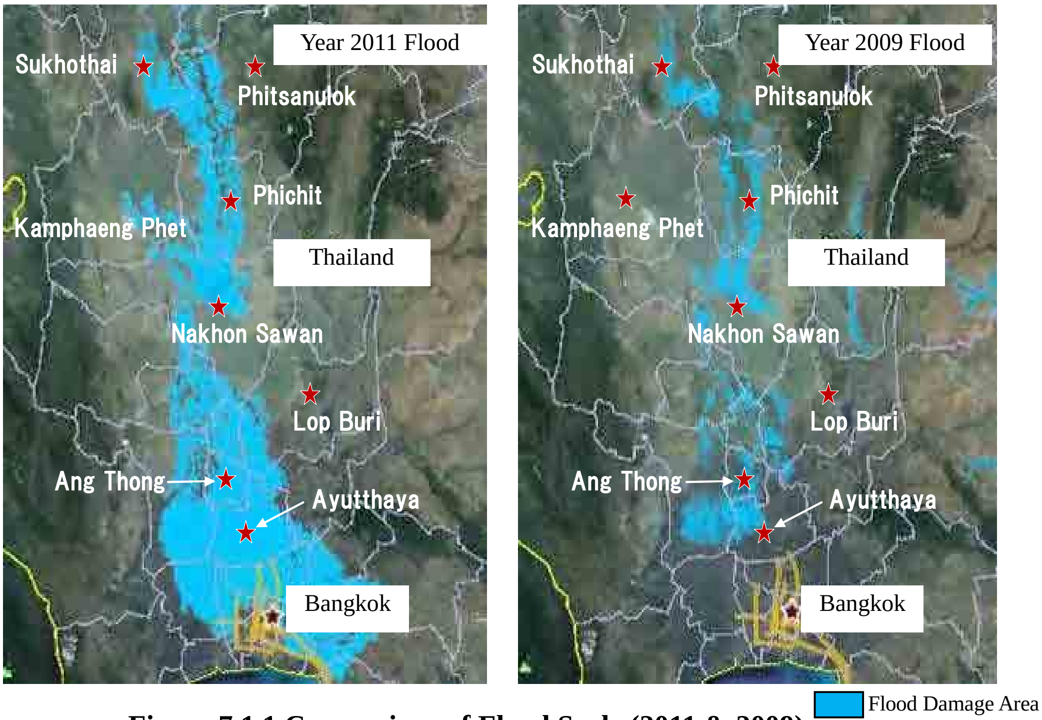


Figure 7.1.1 Comparison of Flood Scale (2011 & 2009)

(Source: http://flood.gistda.or.th/)

7.1.1 Road Damage Overview

Road network system in Thailand can be divided into (1) national road and provincial road of 51,000 km (2) rural road of 48,000 km (3) community road of 84,000 km. The road network has been recently constructed and relatively new when compared with the railway network, hence, most of road network remain in good condition even after the flood. The national roads under the control by Department of Highways (hereinafter DOH), Ministry of Transport of Thailand remain in a relatively good condition even after the flood. In DOH, the annual budget required for routine maintenance work is sufficiently secured, however, there is still lack of budget needed for periodic maintenance work (available only 80%). In the future, a rapid decrease of service life of road network may be expected due to increasing vehicle load, insufficient maintenance work, and any damages induced by flood. Regarding DRR, even though the information is less compared to DOH, it is seemed that the maintenance budget is insufficient, thus causing a difficulty in periodic maintenance work.

The typical damages observed in roads are listed as follows:

・Cracking and peeling of pavement due to opening to traffic during flood for a long period

・Damage to pavement on downstream side by a combination of overflow of water on pavement and traffic load

・Erosion of embankment due to the overflow of water (severely damaged on the downstream side)

・Damage to slope protection adjacent to drainage facilities (particularly overflow pipes)

・Damage to traffic safety facilities (signal, pavement marking line, guard rail)

In addition, the restoration methods are responsible of each management organization.

7.1.2 Disaster Situation in Japanese Industrial Estates

Apart from the roads, agricultural and industrial estates were also damaged by the great flood in 2011. According to the Japan External Trade Organization (JETRO), the flood damage occurred in the industrial estates near Bangkok and Ayutthaya, the central area of Thailand, in which many Japanese companies have been operating. About 450 Japanese companies in 7 industrial estates were flooded, and most of them had to stop the operation. The industrial estates, which were affected by the flood, are shown in Figure 7.1.2. If the companies outside the industrial estates are also included, 10,000 companies in total were damaged and the economic losses were estimated to reach 1.12 trillion Baht (about 2.8 trillion Yen).

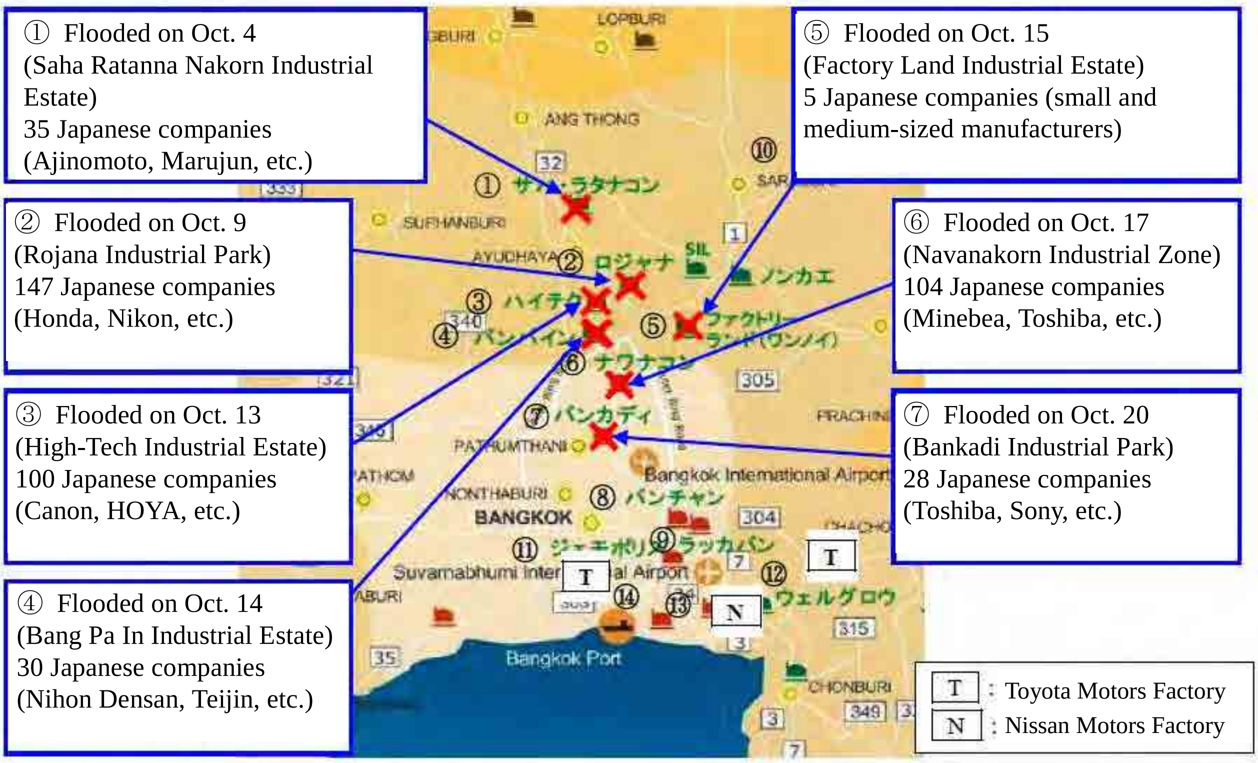


Figure 7.1.2 Map of Japanese Industrial Estates near Bangkok and Ayutthaya

(Source: NKSJ-RM report)

7.1.3 First Survey of Flood Damage (Immediately After the Disaster: December 2011)

(1) Interview at DRR's Headquarters

The followings are the results of interview with DRR, which was held during December 19-21, 2011 at the headquarters.

・ There are two basic types of floods. One is the flood that occurs in the area with slope gradient such as mountainous terrain (Flash flood), and the other is the flood that occurs in the flat area with prolonged stagnant water (Inundation). Most of the floods in 2011 are the latter one.

・ The flood with prolonged stagnant water, similar to the flood in 2011, causes great damages to the roads, but relatively small damages to the bridges. However, it is also important to consider the flash flood (the one that occurs in the area with slope gradient), which can cause damages to the bridges.

・ In Nakhorn Sawan province, which is close to the headstream of Chao Phraya River, the water level was 2-3 m, and severe damages were observed in the approach roads adjacent to the bridges. However, damages on the bridges have not been reported so far. (Severe damages were observed in the roads. The causes of damages were believed to be scouring and erosion.)

・ DRR aimed for high durable roads, which are regardless of the flood types. Therefore, it is necessary to consider the risk due to flood in the bridge master plan.

・ To quickly implement the restoration measures after the flood, it is essential to develop the manual for repairing measures and the bridge inspection manual in case of floods.

In December 2011, DRR developed a plan for the emergency measures for roads that were damaged by the flood in 2011. In this plan, the technical support regarding restoration measures for the roads and bridges after the flood was requested. The targeted routes include the road extension of 40km long, which have been flooded in the past 7 consecutive years. The specific requirements are as follows:

・ Site investigation and evaluation of damage condition after the disaster
・ Inspection manual for bridge and approach road after the flood
・ Manual for restoration measures (repairing) after the flood
・ Bridge master plan and feasibility study considering the flood risk
・ Flood forecast to evaluate effect on existing roads using hydraulic model
・ Training in Japan
・ Provision of topographical survey results
・ Dispatch an engineer to the Bureau of Road Maintenance to support the management of emergency measures

Table 7.1.1 Summary of Inundation during the Past 7 Years

Number of flooded provinces (Nos.)	63
Flooded area (km2)	68,320
7 straight years flooded area (km2)	1,196
Total country area (km2)	597,348
Number of flooded routes (Nos.)	914
Total length of flooded DRR roads (km)	6,923
Total length of 7 straight years flooded DRR roads (km)	40
Total length of DRR roads (km)	49,000

(2) Disaster site investigation (December 2011)

The accurate information of roads and bridges that have been flooded for 7 consecutive years was not available from DRR. To gather such information, therefore, the site investigation in the areas that were affected by the flood for 7 consecutive years (west Ayutthaya) was carried out.

The results of site investigation were that slope collapses were found in some parts of embankment, and some potholes were observed on the pavement surface in the routes under management by DRR. On the other hand, there were no damages in the bridge structure, and only the collapse of approach road surface was observed. In this investigation, bridges and approach roads were found to be generally in good condition, and significant damages could not be observed.

(3) Problems in restoration measures

Due to the flood, which has occurred since late July 2011, the damages of roads, bridges, and approach roads were confirmed, however, the location of damaged bridges as well as the damage levels were not available, even in the late December 2011.

According to DRR, the flood has continued until the beginning of December 2011, however, it is necessary to transfer information rapidly in order to draw a plan for restoration measures after the flood. In any case, information regarding the damage condition of bridges and approach roads were insufficient, hence, it is essential to implement an emergency inspection and to evaluate the damages based on the inspection results.

Slope slide

Joint opening

Collapse of approach road (plane view)

Collapse of approach road (side view)

Erosion of soil under approach road

Cavity due to soil erosion

Figure 7.1.3 Damage Condition (as of December 21, 2011)

(4) Necessity of 2nd investigation to solve problems

From the results of 1^{st} investigation, it was confirmed that further emergency investigation (2^{nd} investigation) is required. In the 2^{nd} investigation, visual inspection and data collection related to the damaged bridges and approach roads in inundated area have to be implemented in order to grasp the actual damage condition of such structures.

1) Visual inspection of damaged bridges

The visual inspection of bridges and approach roads damaged by flood will be carried out. The scope of inspection needs to cover the 40 km roads under the management by DRR, which have been damaged by the floods for 7 consecutive years. Scope of targeted bridges must be selected after discussion with DRR In addition, if emergency repairing work is done to bridges or approach roads at site, the information related to repairing condition must also be collected.

2) Data collection of damaged bridges

The data collection from the DRR’s regional organizations who manage the targeted bridges will be implemented by means of collecting documents related to the bridge inspection record and interviewing about the bridge inspection condition.

3) Evaluation of damaged condition

From the visual inspection results and the collected documents from the management organization, the damages observed in the rural bridges will be classified based on bridge type and location of damage, and the damage tendency of the targeted bridges will be analyzed subsequently.

4) Proposal for maintenance of rural bridges during emergency case (Flood)

By investigating the actual condition of inspection work of bridges and approach roads during emergency case (flood) via methods described in 1) to 3), the maintenance method during emergency case (flood) and the investigation method using appropriate technology will be proposed to the management organization (DRR).

7.2 Second Survey of Flood Damage

7.2.1 Interview Survey of the Offices of Provincial Rural Road

In the second survey, the engineers and technicians in the offices of Provincial Rural Road (hereinafter “the provincial office”) which have controlled the target routes were interviewed on their inspection methods and maintenance ways during our visit to the target bridges. Likewise, the related documents such as their inspection manuals, reports on the flood damage, maintenance reports were confirmed in each target office. The summary of the interviews is described below and the results of the interviews are shown in Table 7.1.1.

(Summary of the interviews)

- Inspection method

・ The director of each target provincial office is responsible for the inspections.

・ The applied inspection manual, the frequency of the routine inspections, the recordkeeping method, the means of correspondence are not unified yet.

・ In this flood, most of the target provincial offices carried out the inspections in three stages, just when the flood started, during flooding, after finishing flooding.

・ The periods of the inspections in this flood carried out by each provincial office are various because the extent of damages in each province differed. In general, the brief surveys and the detailed surveys took one to four days and two to four weeks, respectively.

・ Every target office has a shortage of inspectors. Besides, total road length and the number of bridges in charge per inspector are various with respect to each provincial office.

・ The existing inspection manuals in DRR have few articles in which the bridge maintenances and inspections are specified.

・ The inspectors tend to assess damages of road & bridge on the basis of their experience since there is no adequate inspection manuals stipulated by DRR.

・ The inspections mainly focuses on the damages of pavements. Therefore, there are few records relating to substructures, revetments, slopes of approach road, riverbed, etc.

- Means of correspondence

・ The information of inspection results is circulated to the related persons below.

(Inspector → Provincial office → Bureau of Rural Road → Each Bureau in DRR Headquarter)

・ The applied correspondence methods are various with respect to each provincial office.

(e.g. letter (Report), E-mail, phone, etc.)

- Related organization

・ In some bridge sites, the embankments and the bridges over a canal are managed by the Royal Irrigation Department (hereinafter “RID”) and only the pavements are managed by DRR.

・ It is often the case that RID is responsible for opening and closing gate attached to a bridge.

・ In some target bridge sites, DRR erected a temporary bridge over a canal as a emergency repair after a discussion between RID and DRR. Since then, the repaired bridges have been apparently controlled by DRR.

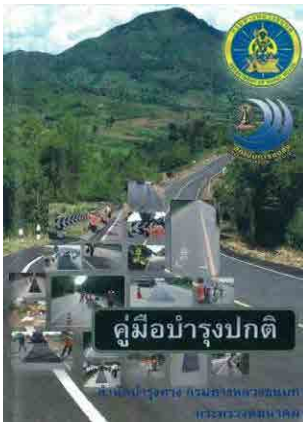
Table 7.2.1 Results of interview survey of the offices of Provincial Rural Road

Target region		Central				North			
Bureau of Rural Road		No.1 Pathum Thani		No.2 Saraburi		No.8 Nakhon Sawan			No.9 Uttaradit
Office of Provincial Rural Road		Ayutthaya	Ang Thong	Sing Buri	Lop Buri	Nakhon Sawan	Kamphaeng Phet	Phichit	Sukhothai
Applied Inspection Manual		Routine Maintenance Manual	Routine Maintenance Manual	Manual for Construction and Maintenance of Road	Manual for Construction and Maintenance of Road	Routine Maintenance Manual	Manual for Construction and Maintenance of Road	Routine Maintenance Manual	Routine Maintenance Manual
Number of Inspectors		2	4	6	4	5	5	5	3
Number of Routes (Total Road Length)		51 (563km)	32 (383km)	29 (249km)	99 (1,032km)	23 (375km)	24 (400km)	42 (599km)	40 (446km)
Number of Bridges		80	76	44	71	17	89	70	64
Routine Inspection	Inspection Method	Visual inspection The inspectors are DRR's engineers or technicians	Visual inspection The inspectors are DRR's engineers or technicians	Visual inspection on pavement & bridge face only, 5 – 10 minutes per a bridge, The inspectors are DRR's engineers or technicians	Visual inspection on pavement & bridge face only, 5 – 10 minutes per a bridge, The inspectors are DRR's engineers or technicians	Visual inspection, The inspectors are DRR's engineers or technicians	Visual inspection, The inspectors are DRR's engineers or technicians	Visual inspection, The inspectors are DRR's engineers or technicians	Visual inspection The inspectors are DRR's engineers or technicians
	Frequency of Inspection (Annual)	A few times	1 time	Once every 3 months for the first two years. Once a year after that.	A few times per a year In case of having a complaint from the local residents	2 times	3 times	2–4 times	1–3 times
Emergency Inspection	Inspection Method	Visual inspection	Visual inspection	Visual inspection	Visual inspection	Visual inspection	Visual inspection	Visual inspection	Visual inspection
	Frequency of Inspection (Annual)	Just after starting flooding, During flooding, After finishing flooding, (Total : About two months)	Just after starting flooding, (Only one day)	Just after starting flooding, During flooding, After finishing flooding, (Total : About ten days)	For 4 days after starting flooding. For 2 weeks after finishing flooding for the study & planning.	For 2 days after starting flooding. For 1 month after finishing flooding for the detailed study.	For 1 day after starting flooding. For 1 month after finishing flooding for the detailed study.	For 15 days after starting flooding. For 1 month after finishing flooding for the detailed study.	For 1 day after starting flooding. For 20 days after finishing flooding for the detailed study.
Inspection Record & Documentation Obtained from DRR		Route & bridge list, Bridge management record, Report on flood damage, Periodic maintenance report	Bridge management record, Report on flood damage, Periodic maintenance report	No documents obtained	Road inspection report, Route & bridge list	Report on flood damage, Route & bridge list	Periodic maintenance report, Bridge inspection record, Report on flood damage, Report on emergent maintenance & repair	Estimate report on periodic maintenance, Route & bridge list, Report on flood damage, Photos of flood damages & repairing	Route & bridge list, Periodic maintenance report, Report on flood damage
Correspondence Procedure		Inspector → Office of Provincial Rural Road → Bureau of Rural Road → Each Bureau in DRR Headquarter							
Means of Correspondence		Letter (Report), Phone	Letter (Report), E-mail	Phone, E-mail	Phone, E-mail	Letter (Report)	Letter (Report), Phone	Letter (Report)	Phone, Website

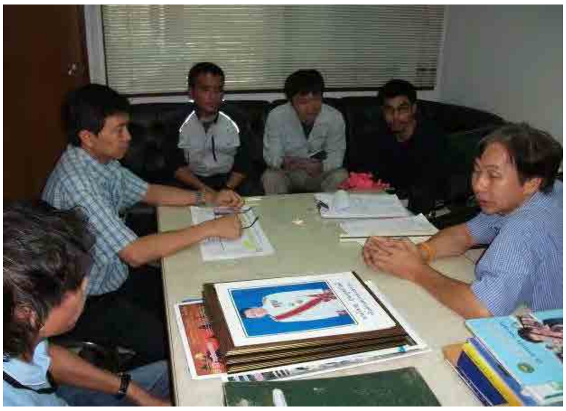
The office of Provincial Rural Road in Lop Buri

The patrol car used for inspections in Nakhon Sawan

Sing Buri SB3018 Road Traffic Sign
The signboards are basically placed at the starting and ending points of the routes controlled by DRR.



The cover of “Routine Maintenance Manual”
This is one of the road maintenance manuals in DRR and many provincial offices use this manual.



Interview survey in the office of Provincial Rural Road in Sukhothai

Interview survey in the office of Provincial Rural Road in Ang Thong

Photo 7.2.1 Interview survey of DRR provincial offices

7.2.2 Emergency Inspection

(1) Inspection method

1) Purpose of the inspection

Many damages caused by flood have been inflicted on the bridges in the rural area after the end of July 2011. As the first step, the target areas, routes and bridges need to be selected after collecting the information on the flood damages. Then, in order to grasp the extent and tendency of the damages on not only the target bridges but also its approach roads, revetments near the bridges, and riverbeds, the visual inspections are carried out.

2) Scope of the inspection

Scope of the inspection carried out this time is as follows.

・Bridge (Superstructure & Substructure)
・Revetment near abutments
・Riverbed around abutments & piers
・Approximately 50 meters of bridge approaches

3) Reference manuals

・Bridge inspection and evaluation manual on the Chao Phraya River crossing bridges; March 2011
・Road bridge repair handbook; Japan Road Association, February 1974
・Inspection guidelines for river management facilities, river embankments and river channel; River Bureau in the Ministry of Land, Infrastructure, Transport and Tourism, May 2011)

4) Inspection policy

・Visual inspection
・In case the target structures are inaccessible, binoculars are used.
・With respect to the target structures, the overviews from side, top and bottom, the damaged parts and the repaired parts are recorded by digital camera.
・The coordinate of longitude and latitude on the target bridges are recorded by digital camera.
・The inspection results are filled in on the specified form (See Appendix 2.2)

5) Inspection points

- Bridge (Substructure)
・ sinkage, sliding, inclination, scouring, erosion etc
- Approach Road
・ Sinkage, pothole, crack, damage of road shoulder, washing away road materials etc
- Revetment, Riverbed

- Damage, sinkage, collapse, scouring, erosion etc

(2) Selection of the target bridges

In regard to selecting target bridges for the emergency inspection, through discussing with the bureau of planning and the bureau of road maintenance in DRR, the bridges which were on the routes damaged severely by this flood and in the areas flooded in seven straight years were chosen. The details of the target routes and the location map are shown in Table 7.2.1 and Figure 7.2.1, respectively. Furthermore, Appendix 2.1 shows the details of the bridges' locations.

Table 7.2.2 List of the target routes

Target Province	Target Route	Number of Target Bridges
Sing Buri	3018, 4014, 3027, 5042(3008)	2
Lop Buri	1008, 1030, 1017	9
Nakhon Sawan	1111, 3104, 3103, 3009	4
Kamphaeng Phet	1029, 1023, 1008, 4014, 4039, 1028	6
Sukhothai	4046, 4022	2
Phichit	2040, 2029	3
Ang Thong	4002	1
Ayutthaya	4031, 4014	3

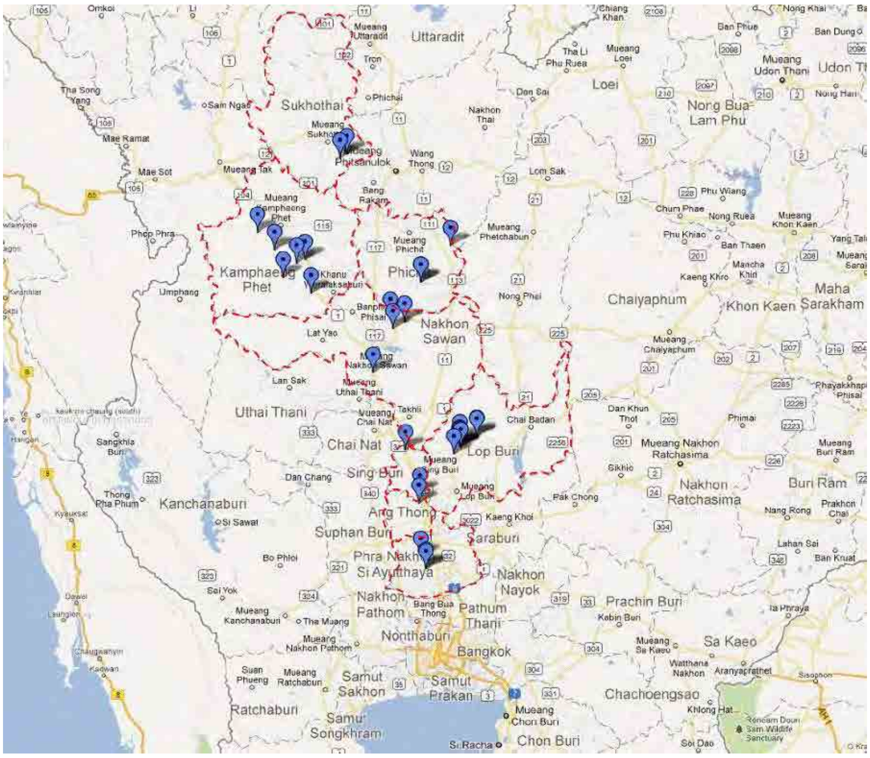


Figure 7.2.1 Location map of the target bridges

(3) Inspection Schedule

The inspection schedule is as follows.

Table 7.2.3 Inspection Schedule

Date	Province	Target Route
26 Jan	Sing Buri, Lop Buri	Sing Buri: 3018, 4014, 3027, 5042 Lop Buri: 1008, 1030
27 Jan	Lop Buri	1030, 1017, 4001
1 Feb	Nakhon Sawan, Kamphaeng Phet	Nakhon Sawan: 1111, 3104, 3103, 3009 Kamphaeng Phet: 1029, 1023, 1008, 4014
2 Feb	Kamphaeng Phet, Sukhothai	Kamphaeng Phet: 4039, 1028 Sukhothai: 4046, 4022
3 Feb	Phichit	2040, 2029
7 Feb	Ang Thong, Ayutthaya	Ang Thong: 4002 Ayutthaya: 4031, 4014

(4) Results of the emergency inspection

1) *Summary of the inspection results*

The 30 bridges damaged by flood in the target routes were detected in this inspection. The brief inspection results is shown in Table 7.2.4.

Table 7.2.4 List of the bridges inspected by JICA Study Team

No.	Province	Route Number	Bridge name (temporary)	Coordinates		Bridge Length (m)	Bridge Width (m)	Number of Spans	Damaged Parts				Inspection Date	Remarks
				Latitude	Longitude				A	B	C	D		
1	Singburi	3018	3018_1	N 15.3.15.31	E 100.19.13.67			7		✓	✓	✓	26/1/2012	
2		3027	3027_1	N 14.46.43.19	E 100.24.59.54	45.2	9.7	5	✓				26/1/2012	
3	Lop Buri	1008	1008_1	N 15.1.42.73	E 100.38.2.73	20.5	9.5	2	✓				26/1/2012	
4		1030	1030_1	N 15.4.25.59	E 100.40.42.41	20.0	9.0	3	✓				26/1/2012	
5		1030	1030_2	N 15.4.36.95	E 100.40.33.30	16.0	9.1	3	✓	✓			26/1/2012	
6		1030	1030_3	N 15.4.45.74	E 100.40.27.03	19.5	8.8	3	✓	✓	✓		27/1/2012	
7		1030	1030_4	N 15.4.51.65	E 100.40.16.50	19.3	8.8	3	✓	✓		✓	27/1/2012	
8		1030	1030_5	N 15.5.0.82	E 100.40.13.58	14.5	5.0	3	✓	✓			27/1/2012	
9		1030	1030_6	N 15.7.5.38	E 100.40.19.82	10.0	5.0	1					27/1/2012	
10		1017	1017_2	N 15.8.47.02	E 100.46.58.54	15.1	9.8	3	✓	✓			27/1/2012	
11		1017	1017_3	N 15.8.29.12	E 100.47.3.99	40.0	9.8	5		✓	✓		27/1/2012	
12	Nakhon Sawan	1111	1111_1	N 15.33.1.66	E 100.7.9.13	62.1	7.8	7		✓	✓		1/2/2012	
13		3104	3104_1	N 15.49.25.32	E 100.14.14.56	15.0	9.8	3	✓	✓	✓		1/2/2012	
14		3103	3103_1	N 15.52.21.44	E 100.18.54.85	80.0	9.8	8	✓	✓	✓		1/2/2012	
15		3009	3009_1	N 15.53.44.28	E 100.13.13.00	80.1	10.1	8	✓	✓			1/2/2012	
16	Kamphaeng Phet	1029	1029_1	N 16.3.1.16	E 99.42.49.61	21.1	8.8	3	✓	✓	✓		1/2/2012	
17		1023	1023_1	N 16.15.49.30	E 99.40.16.32	9.9	9.1	1	✓	✓			1/2/2012	
18		1008	1008_1	N 16.19.36.95	E 99.28.39.68	12.0	8.1	1	✓				1/2/2012	
19		4014	4014_1	N 16.14.23.57	E 99.37.5.98	8.0	10.0	1	✓	✓			2/2/2012	
20		4039	4039_1	N 16.9.5.01	E 99.31.41.09	30.0	8.0	3	✓	✓			2/2/2012	
21		1028	1028_1	N 16.26.5.09	E 99.22.5.53	10.0	7.1	1	✓	✓	✓		2/2/2012	
22	Sukhothai	4046	4046_1	N 16.54.7.73	E 99.54.4.16	20.2	5.0	2	✓		✓		2/2/2012	
23		4022	4022_1	N 16.55.56.49	E 99.56.29.36	18.1	9.8	3	✓	✓			2/2/2012	
24	Phichit	2040	2040_1	N 16.21.11.09	E 100.36.46.22	8.0	8.0	1	✓		✓		3/2/2012	
25		2029	2029_1	N 16.7.19.20	E 100.25.4.46	20.0	8.8	3	✓	✓	✓	✓	3/2/2012	
26		2029	2029_2	N 16.7.17.27	E 100.25.8.57	12.0	10.0	2	✓	✓	✓	✓	3/2/2012	
27	Ang Thong	–	Wat Bot	N 14.43.4.55	E 100.24.33.09	80.0	9.5	6	✓				7/2/2012	
28	Ayutthaya	4031	4031_1	N 14.22.31.01	E 100.25.23.76	22.0	9.0	3	✓	✓	✓		7/2/2012	
29		4014	4014_1	N 14.18.27.78	E 100.27.9.15	26.0	10.0	3	✓	✓			7/2/2012	
30		4014	4014_2	N 14.17.55.46	E 100.27.21.41	26.0	10.0	3	✓	✓	✓		7/2/2012	

(Damaged Parts by the flood) A: Riverbed, B: Behind Abutment, C: Approach Road, D: Riverbank

2) *Regional damage trend*

Thailand is broadly divided into four regions; North, Northeast, Central, South, and the provinces seriously damaged by this flood are located in the north and the central.

The north region is a mountainous terrain and tends to have severe flash floods in the rainy season. On the other hand, the central region has a broad fertile flatland called “the Chao Phraya Delta” and is one of the world’s leading rice-producing areas. Similarly, Irrigation canals widely spread in this region and the canals’ gradients are basically very gentle.

Considering the two regional characteristics, it is deemed that two types of flood; “flash flood” and “inundation” occurred in the north and the central, respectively and that the typical damages by the flood can be also divided into two types related to the regional characteristics.

However, the target bridges in the both regions have the same type of damages and the apparent difference of damage between the two regions could not be detected in this inspection, although the causes of the damages in the two regions might be different.

As a reason for that, it is considered that high-speed turbulent flow spread to the ground as a type of flash flood when the floodwater got across the roads even in the flatland and that the turbulent flow caused serious damages around the target bridges.

3) Damage trend by bridge type

Most of the bridges on the target routes are reinforced concrete bridges (hereinafter "RC bridge") with less than 100 meters in length and their span lengths are less than 10 meters.

However, there are a few bridges which are prestressed concrete ones with more than 100 meters in length over the major rivers such as Chao Phraya River. Those prestressed concrete bridges have secured sufficient vertical clearance under bridge and have no scars left by the flood. Therefore, no severe damages on the bridges, the approach roads and the revetments near abutments were detected in the field inspections. Moreover, according to the hearing investigation results of the Bureau of Rural Road 2 Saraburi, those relatively large bridges have been planned and designed by the Bureau of Location and Design mainly, including the studies on the flood high water levels and the sufficient vertical lengths under bridge. Incidentally, the local residents evacuated on the bridges during times of the flooding, as only the brides were not inundated despite the fact all the vicinities were inundated.

On the other hand, many RC bridges with 5 to 10 meters in length constructed by use of the standard design were inundated and overflowed during times of the flooding and have serious damages on their approach roads, revetments around abutments and riverbeds. Those small bridges have been planned and designed by the Bureau of Rural Road or the office of Provincial Rural Road, but the studies on the flood high water levels and the sufficient vertical lengths under bridge have not been properly carried out.

4) Typical damages resulting from the flood

The bridges which have some damages caused by the flood were basically designed in accordance with the standard design, as described in the previous section. Furthermore, most of the damages were mainly detected on the approach roads, revetments and riverbeds.

In regard to the bridge main bodies, the many riverbeds around the substructures have been seriously scoured and the pile caps and the pile heads have been exposed, although they have to be normally covered by soil to resist against horizontal force. In this case, those piles might have some damages, as superfluous bending moments have arisen in the piles. Moreover, if left unrepaired, the substructures would become skew and the bridges might collapse finally.

Besides, some damages on the bridges resulting from shoddy workmanship were also discovered, but they are not so urgent to repair.

The typical damages by the flood detected in the field inspections are as follows.

- Scouring riverbed around abutments & piers and exposing pile head
- Washing away backfill materials behind abutment
- Sinkage of road shoulder and damage & collapse of the slope of approach road
- Sinkage & washout of approach road
- Damage & collapse of river revetment
- Damages not caused by flood

In addition, some serious damages such as washout of road and erosion of road shoulder caused by inundation or overflow were discovered not only near the target bridges but also on the other parts of the routes. Some of those damages have been already fixed up or under repair, but other damages have been left as they are. As to even the repaired sites, they need to be repaired properly in the future as they were just done temporarily such as using sandbags.

a) Scouring riverbed around abutments & piers and exposing pile head

In regard to the target bridges, routine maintenance of riverbed has not been carried out and most of the riverbeds have been seriously scoured with one meter or two meter deeper than their original levels. Therefore, in some target bridge sites, pile caps or pile heads became exposed although they must be normally covered by soil to stabilize against horizontal force. In addition, some local scouring and disturbing flows have occurred on sites due to the fact that ex-piles and ex-abutments have still left on site.

Sing Buri SB3027 - Br1.
Scouring riverbed in front of the abutment

Sing Buri SB3027 - Br1.
The scouring depth is approximately 1 m.

Lop Buri LB1030 - Br2.
Scouring riverbed in front of the abutment,
also, localized deep scouring around the piers.

Lop Buri LB1030 - Br2.
The pile heads are exposed. The scouring depth is about 2.5m.

Lop Buri LB1030 - Br2.
The ex-piles & abutments still remain.
Serious localized scouring under the bridge exists.

Lop Buri LB1030 - Br2.
The ex-piles & abutments still remain.

Photo 7.2.2 Scouring riverbed around abutments & piers and exposing pile head (1)

Lop Buri LB1017 - Br2.
Scouring riverbed in front of the abutment.

Nakhon Sawan NS3103 - Br1.
Localized deep scouring around the pier.

Kamphaeng Phet KP1029 - Br1.
Scouring riverbed in front of the abutment.

Kamphaeng Phet KP1023 - Br1.
Scouring riverbed in front of the abutment.

Ayutthaya AY4014 - Br1.
Scouring riverbed in front of the abutment.

Ayutthaya AY4014 - Br2.
Scouring riverbed in front of the abutment. Sandbags are used for the protection works after flooding.

Photo 7.2.3 Scouring riverbed around abutments & piers and exposing pile head (2)

b) Washing away backfill materials behind abutment

Backfill materials behind abutment are washed away due to scouring riverbed around abutment, inundating & overflowing approach road, and collapse of revetment. The type of the target abutments is pile-bent which has a transverse wall in between piles in order to prevent backfill materials from running off. However, the setting depth of those transverse walls was not deep enough; namely, the walls were put in until the level of the original riverbed when constructed. Therefore, as the scouring of the riverbed progresses, the gaps underneath of the walls become bigger and more backfill materials are washed away from there.

 Lop Buri LB1030 - Br2. Backfill materials behind the abutment were washed away. Wooded piles are used as a temporary bank protection.	 Lop Buri LB1030 - Br3. Backfill materials behind the abutment were washed away from underneath of the abutment wall.
 Lop Buri LB1030 - Br4. Backfill materials behind the abutment were washed away from underneath of the abutment wall.	 Lop Buri LB1030 - Br4. Backfill materials behind the abutment were washed away from underneath of the abutment wall.
 Kamphaeng Phet KP1008 - Br1. Backfill materials behind the abutment were washed away from underneath of the abutment wall.	 Phichit PC2040 - Br1. Scouring riverbed in front of the abutment occurred and the gaps underneath the abutment wall generated.

Photo 7.2.4 Washing away backfill materials behind abutments (1)

Kamphaeng Phet KP1029 - Br1.
Backfill materials behind the abutment were washed away and the deep pothole was created on the shoulder of the road.

Kamphaeng Phet KP1029 - Br1.
The depth of the pothole is 2.3 meter.

Kamphaeng Phet KP4014 - Br1.
Backfill materials were washed away from underneath of the abutment wall. Wooden piles are temporarily used for the protection after flooding.

Kamphaeng Phet KP1023 - Br1.
Backfill materials were washed away from sides & underneath of the abutments' wall. Wooden piles are temporarily used for the protection after flooding.

Nakhon Sawan NS3103 - Br1.
Backfill materials under the approach slab were washed away by flood and the piles of the guardrail become visible.

Phichit PC2029 - Br2.
Backfill materials behind the abutment were washed away by flooding. The deep hole was temporarily backfilled but the compaction was not enough.

Photo 7.2.5 Washing away backfill materials behind abutments (2)

c) Sinkage of road shoulder and damage & collapse of the slope of approach road

Some road shoulders sank down and some slopes of the approach roads were damaged or collapsed because of washing away the road materials caused by inundating and overflowing the approach roads. In addition, the road materials were also washed away from underneath or sides of the abutment walls.

<table>
<tr>
<td>
Sukhothai ST4046 - Br1.
There is a crack with 5m long along the shoulder of the approach road and the shoulder sank down due to eroding or sliding the slope.</td>
<td>
Phichit PC2040 - Br1.
There are reticular cracks on the surface of the approach road because of the sinkage of the road shoulder.</td>
</tr>
<tr>
<td>
Nakhon Sawan NS3104 - Br1.
At the forehand approach road, the shoulder of the road was washed away. Meanwhile, the rearward approach road completely disappeared and the temporary bridge was built.</td>
<td>
Ayutthaya AY4014 - Br1.
The slope of the approach road was seriously damaged by flooding and temporarily repaired by sandbags.</td>
</tr>
<tr>
<td>
Ayutthaya AY4014 - Br2.
There are some cracks with 30m long along the shoulder of the approach road and the shoulder sank down due to eroding or sliding the slope.</td>
<td>
Ayutthaya AY4014 - Br2.
The slope was eroded and the shoulder of the approach road sank down. Similarly, the guardrail sand down and skewed.</td>
</tr>
</table>

Photo 7.2.6 Sinkage of road shoulder and damage & collapse of the slope of approach road

d) Sinkage & washout of approach road

Some target approach roads sank down and others washed out due to washing away the road materials caused by inundating and overflowing the approach roads. Temporary bridges were constructed where the approach roads completely washed out.

Nakhon Sawan NS3104 - Br1.
The approach road completely washed out by flooding and the temporary bridge was built.

Nakhon Sawan NS3104 - Br1.
Similarly, the river revetment completely collapsed.

Ayutthaya AY4031 - Br1.
The approach road completely washed out by flooding, and the approach slab also fell down. As an emergency countermeasure, the temporary bridge was built.

Ayutthaya AY4031 - Br1.
There is a water gate in front of the bridge. The floodwater overflowed on the approach road and washed the road away.

Lop Buri LB1017 - Br2.
The approach road sank down and the asphalt pavement disappeared.

Kamphaeng Phet KP1029 - Br1.
There are reticular cracks on the surface of the approach road because of sinkage of the road.

Photo 7.2.7 Sinkage & washout of approach road

e) Damage & collapse of river revetment

Some river revetments near the target bridges were seriously damaged by scouring because of the fact that the setting depth of the foot of the revetments was not deep enough.

Lop Buri LB1030 - Br4.
The slope was seriously damaged and the revetment collapsed at the downstream of the bridge. The erosion penetrates in the private land, collapsing the concrete walls. If left untreated, the house might also collapse in next flood.

Lop Buri LB1030 - Br5.
The stone pitching revetment collapsed due to washing away backfill materials behind the revetment. Wooded piles were temporarily used for the protection of the slope.

Sukhothai ST4022 - Br1.
Scouring in front of river revetment. The river revetment collapsed during the flood.

Sukhothai ST4022 - Br1.
The river revetment in front of the abutment was severely damaged by flooding.

The revetment in front of the abutment partly collapsed due to severe scouring. The depth of the scouring is 1.8m.

Backfill materials behind the revetment were washed away by flooding and the revetment completely collapsed.

Photo 7.2.8 Damage & collapse of river revetment

f) Damages on the target road by flood

In the target routes, many damages which resulted from inundation & overflow were detected. Some repairing works have already done or been in progress, but others have not started yet.

Sing Buri SB4014
50-meter section of the road was overflowed and washed out. The repair works is in progress and geotextile is used on the slope of the road.

Sing Buri SB5042
Roadbed materials were washed away, the shoulder of the road sank down and the severe cracks happened on the pavement. The cracks are about 15 meter long and 10 cm wide. Wooded piles are temporarily used for the protection of the road during the flood.

Lop Buri LB1017
The shoulder of the road seriously damaged and the road is not repaired yet.

Nakhon Sawan NS1111
The shoulder of the road seriously eroded. The damaged section is about 200 meter long and the height of the erosion is 1.7 meter.

Sukhothai ST4046
The shoulder of the road seriously eroded. The damaged section is about 30 meter long and the height of the erosion is 4 meter.

Ang Thong AG4002
The shoulder of the road eroded. The damaged section is about 20 meter long and the height of the erosion is 0.7 meter.

Photo 7.2.9 Damages on the target road by flood

g) Damages not caused by flood

There are some damages on the target bridges caused by shoddy workmanship or traffic accidents. They are not so urgent to repair, but in terms of a medium- and long-term bridge maintenance, these damages should be repaired in the near future.

 Lop Buri LB1008 - Br1. Cracks on the underneath of the deck	 Lop Buri LB1008 - Br1. Honeycombs on the underneath of the deck
 Lack of covering and re-bar corrosion on the pile bent pier	 Lack of covering and re-bar corrosion on the pile bent pier
 Lop Buri LB1017 - Br2. Defects of construction joint of piles	 Sukhothai ST4046 - Br1. Collapse of the concrete post of the handrail

Photo 7.2.10 Damages not caused by flood

7.3 Analysis of the Flood Damages

Considering the typical damaged parts on sites, the characteristic features of the target rivers or canals, and the results of the interview survey of the local residents, the proceedings of the flood damages detected on sites can be generally divided into the four cases as follows.

7.3.1 Pile outcrops caused by scouring riverbed around substructures (Case 1)

Some pile heads are exposed in the target bridges because the riverbeds around the substructures were severely scoured. Therefore, those piles might have some damages as superfluous bending moments have arisen in the piles. In addition, if left unrepaired, those substructures would become skew and the bridges might collapse finally.

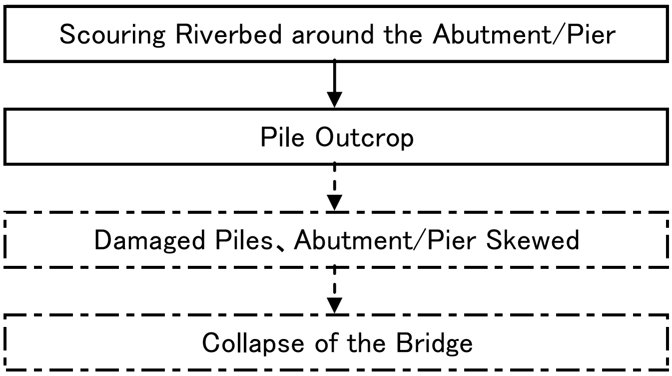


Figure 7.3.1 Damage proceeding (Case 1)

 Lop Buri LB1030 - Br1. The riverbed around the pier was locally scoured and the pile heads have been exposed. Moreover, some floodwoods have still left on the pier upstream and disturbs the flow.	 Lop Buri LB1030 - Br2. The pile heads are exposed. The scouring depth is about 2.5m.

Photo 7.3.1 Pile outcrops caused by scouring riverbed around abutments/ piers

7.3.2 Damages & collapse of river revetments near abutments (Case 2)

Some river revetments have serious damages or collapsed near the target bridges. It is considered that those damages resulted form washing away backfill materials behind the revetments by flood. Similarly, it is pointed out that the setting depth of the toe of the revetments was shallow and that the foot protection of the revetments was not constructed adequately. The damage proceeding is shown in Figure 7.3.2.

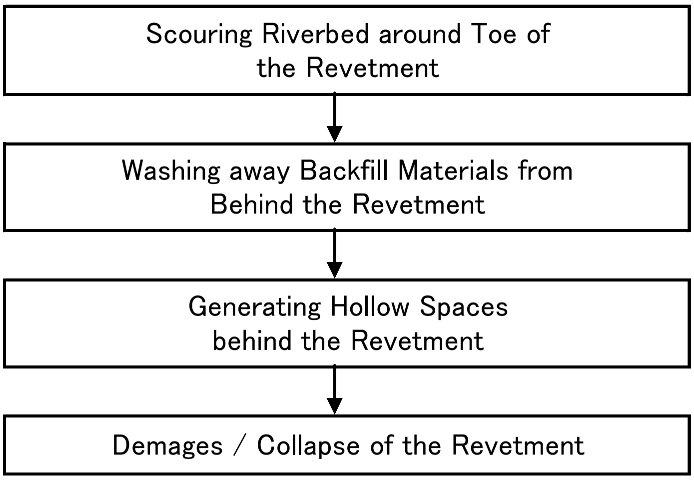


Figure 7.3.2 Damage proceeding (Case 2)

 Nakhon Sawan NS1111 - Br1. Backfill materials behind the river revetment were washed away and the revetment partly collapsed.	 Phichit PC2029 - Br1. The foot of the revetment eroded and the revetment slid down and collapsed.

Photo 7.3.2 Damages / collapse of river revetments near abutments

7.3.3 Sinkage & cracks on approach road caused by washing away backfill materials behind abutments (Case 3)

Most of the target bridges were constructed by use of the standard design for bridges and the type of those abutments is pile-bent which has a transverse wall in between piles in order to prevent backfill materials from running off. However, scouring of riverbed around the abutments has still progressed and backfill materials behind the abutments have been washed away so that the planned setting depth of those transverse walls was quite shallow. Some bridge sites have large gaps with about 1 meter deep underneath the approach roads and serious cracks on the roads. The damage proceeding is shown in Figure 7.3.3.

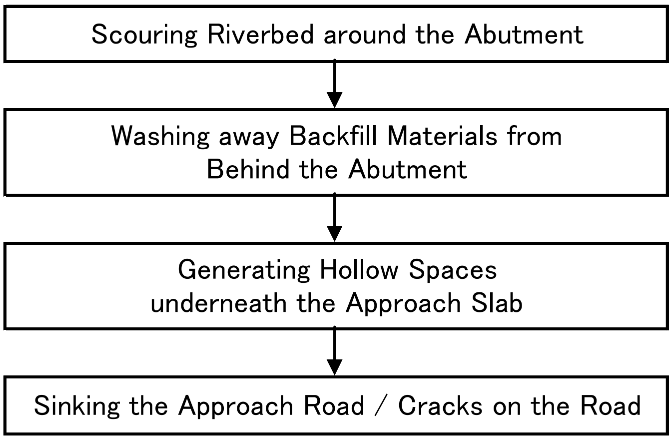


Figure 7.3.3 Damage proceeding (Case 3)

 Nakhon Sawan NS3103 - Br1. Backfill materials behind the abutment were washed away and the gap underneath the approach slab generated. The gap is about 6 m long in the direction perpendicular to the bridge axis and 15 cm high.	 Kamphaeng Phet KP1028 - Br1. There is a severe crack on the approach road with 1.1 meter deep. There may be a big gap under the pavement.

Photo 7.3.3 Sinkage of approach road & cracks on the road caused by washing away backfill materials behind abutments

7.3.4 Collapse of slope & washout of approach road caused by inundation & overflow (Case 4)

The floodwaters infiltrated into the embankments and roadbeds when the approach roads had been inundated and overflowed. This infiltration, which resulted in a decrease in the cohesion of the embankments and the hydraulic pressure fluctuation, led to eroding the slopes and the slope sliding on the approach road. Moreover, serious erosion from the top of the slope also arose behind the wing walls of the abutments and on the approach road. Figure 7.3.3 shows the damage proceeding.

Inundating & Overflowing the Approach Road

↓

Infiltrating Floodwater into the Embankment/Roadbed
Decreasing Cohesion of the Embankment

↓

Eroding the Slope, Slope Sliding,
Erosion from the Shoulder of the Approach Road

↓

Collapse of the Slope, Washout of the Approach Road

Figure 7.3.4 Damage proceeding (Case 4)

	
Ayutthaya AY4014 - Br1. The floodwater overflowed on the approach road, the slope of the road seriously damaged. As an emergency countermeasure, sandbags are used for the slope protection.	Kamphaeng Phet KP4039 - Br1. One lane of the approach road washed out by flood. The damaged part was temporarily fixed up.

Photo 7.3.4 Collapse of slope & washout of approach road caused by inundation & overflowing

7.4 Problematic issues on Bridge Maintenance and Management when flooding

DRR is now implementing the restoration project of road and bridge structures, which were damaged by the flood in 2011, under the approved budget (4,000 Million Baht). At present, the project is conducted to rehabilitate the damaged structures to the previous conditions before the flood, however, the repairing methods are responsible of each regional bureau or provincial office, and the project is generally carried out based on the knowledge and past experiences of their staffs.

Although the damaged structures are repaired to the original conditions, they may be affected by flooding in the future and similar damages would repeatedly occur. In view of an effective use of budget, DRR is aiming to enhance the durability of existing structures, bridges and approach roads, so that the flood damages would be minimized or not likely to occur. In this regards, a request has been made by DRR to provide technical advice on the repairing methods of damaged structures.

From the results of inspection of damaged bridges and approach roads due to the flood, the observed typical damages are as follows:

・river bed scouring

・erosion from the backward of the abutment

・damage and collapse of river bank

・damage (slide) of bank slope and subsidence of pavement on approach road

・collapse of approach road

To presume the causes of those damages and to develop the repairing methods to enhance the durability of damaged structures are the key issues for DRR..

Chapter 8 Flood disaster prevention approach

8.1 Pilot bridge for flood disaster prevention approach

The pilot bridge was selected for technical transfer for the Kingdom of Thailand through the construction of flood disaster countermeasure study.

The construction expense which applied from budget for DRR was decided based on the discussion in consideration of detail step for construction and selection step for flood countermeasure.

Two bridges were selected as pilot bridge under two times discussion included the proposition of DRR from 30 bridges in eight prefectures which inspected urgently..

The overall flow of selection of pilot bridge and development of design and construction technique of flood prevention approach is shown in **Figure 8.1-1.**

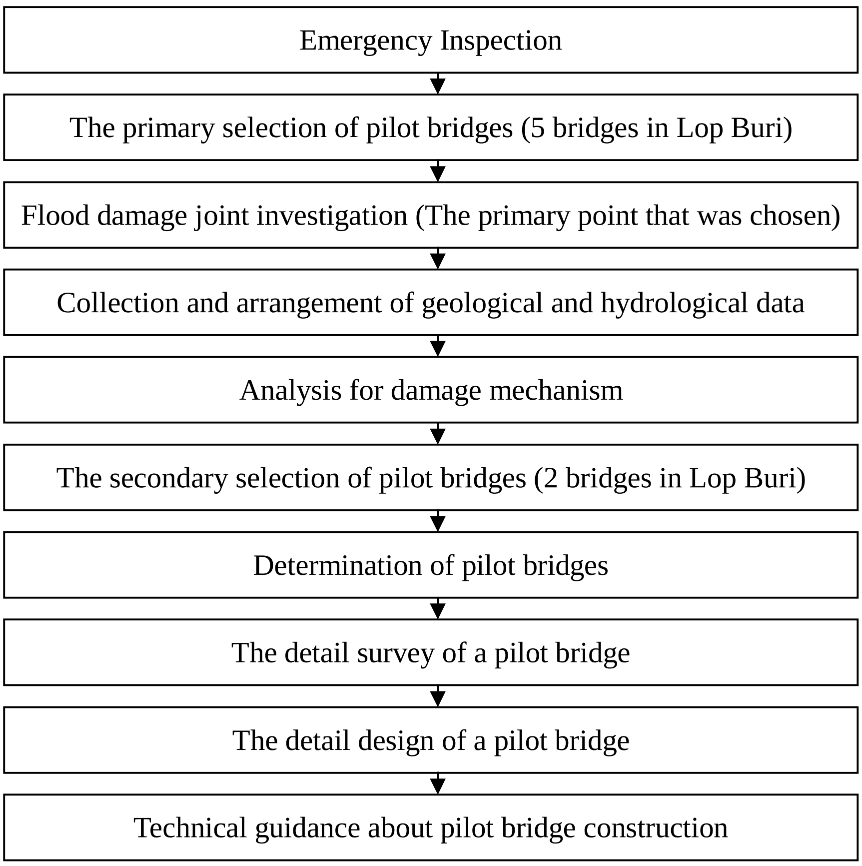


Figure 8.1-1 Flow of selection of a pilot bridge and flood prevention approach

8.1.1 Preliminary selection of pilot bridge

Procedure for preliminary selection was discussed with the representative of “Bureau of Planning”, “Bureau of Location and design” and “Bureau of Road Maintenance” at the DRR headquarters on May 4, 2012. As consequent of the discussion, the 5 bridges was selected as preliminary bridge for study from 30 bridges in eight prefectures under carried out the urgently inspection.

(1) Selection procedure

To analyze the mechanism of flood disaster was defined as first step for technical translation based on brief survey.

4-5 location was decided by discussion with DRR due to investigate the site situation of flood measurement from **Table 8.1-1**.

The preliminary selection candidate list of pilot bridge was suggested to DRR as follows;

- ✓ Site with many damage parts
- ✓ The site where flood disaster damage is serious

Table 8.1-1 Pilot bridge candidate list

A Pilot Bridge Candicate's Selection Table by JICA Study Team

No.	Province	Route Number	Bridge name (temporary)	Coordinates		Bridge Length (m)	Bridge Width (m)	Number of Spans	Sluice Proximity	House Proximity	Bridge length of not less than 30 m	Distant Place	Abutment Involvement Revetment	Abutment Continuation Revetment	Overflow at the time of a flood	Damaged Parts & Huge Damaged Parts: A		B		C		D		E		Check Number	Urgency for Examination	Candicate for Revetment Examination	Candicate for Approach Road Examination	Inspection Date	Remarks
				Latitude	Longitude											Part	Huge Damage	Part	Huge Damage	Part	Huge Damage	Part	Huge Damage	Part	Huge Damage						
1	Singburi	3018	3018_1	N 15.3.15.31	E 100.19.13.67			7	✓					✓						✓	✓	✓	✓	✓	✓	6				26/1/2012	
2		3027	3027_1	N 14.46.43.19	E 100.24.59.54	45.2	9.7	5			✓			✓	✓			✓								1				26/1/2012	
3	Lop Buri	1008	1008_1	N 15.1.42.73	E 100.38.2.73	20.5	9.5	2						✓				✓								1				26/1/2012	Damage influence is low
4		1030	1030_1	N 15.4.25.59	E 100.40.42.41	20.0	9.0	3						✓	✓			✓								1	④	✓		26/1/2012	
5		1030	1030_2	N 15.4.36.95	E 100.40.33.30	16.0	9.1	3					✓					✓	✓	✓						3	②	✓		26/1/2012	
6		1030	1030_3	N 15.4.45.74	E 100.40.27.03	19.5	8.8	3		✓				✓				✓		✓				✓		3				27/1/2012	
7		1030	1030_4	N 15.4.51.65	E 100.40.16.50	19.3	8.8	3		✓				✓	✓			✓		✓		✓				3				27/1/2012	
8		1030	1030_5	N 15.5.0.82	E 100.40.13.58	14.5	5.0	3		✓				✓				✓		✓						2				27/1/2012	
9		1030	1030_6	N 15.7.5.38	E 100.40.19.82	10.0	5.0	1					✓													0				27/1/2012	Damage influence is quite low
10		1017	1017_2	N 15.8.47.02	E 100.46.58.54	15.1	9.8	3						✓				✓		✓						2	③	✓		27/1/2012	
11		1017	1017_3	N 15.8.29.12	E 100.47.3.99	40.0	9.8	5			✓		✓		✓					✓				✓		2				27/1/2012	
12	Nakhon Sawan	1111	1111_1	N 15.33.1.66	E 100.7.9.13	62.1	7.8	7			✓		✓		✓					✓				✓		2				1/2/2012	
13		3104	3104_1	N 15.49.25.32	E 100.14.14.56	15.0	9.8	3					✓					✓		✓	✓			✓		4	①	✓		1/2/2012	
14		3103	3103_1	N 15.52.21.44	E 100.18.54.85	80.0	9.8	8			✓		✓		✓			✓		✓				✓		3				1/2/2012	
15		3009	3009_1	N 15.53.44.28	E 100.13.13.00	80.1	10.1	8			✓		✓		✓			✓		✓						2				1/2/2012	
16	Kamphaeng Phet	1029	1029_1	N 16.3.1.16	E 99.42.49.61	21.1	8.8	3				✓		✓				✓		✓				✓		3	②'	✓		1/2/2012	
17		1023	1023_1	N 16.15.49.30	E 99.40.16.32	9.9	9.1	1				✓	✓		✓			✓		✓						2				1/2/2012	
18		1008	1008_1	N 16.19.36.95	E 99.28.39.68	12.0	8.1	1				✓		✓				✓								1				1/2/2012	
19		4014	4014_1	N 16.14.23.57	E 99.37.5.98	8.0	10.0	1				✓		✓				✓		✓						2				2/2/2012	
20		4039	4039_1	N 16.9.5.01	E 99.31.41.09	30.0	8.0	3			✓	✓		✓				✓		✓						2				2/2/2012	
21		1028	1028_1	N 16.26.5.09	E 99.22.5.53	10.0	7.1	1				✓	✓					✓		✓				✓		3	②'	✓		2/2/2012	
22	Sukhothai	4046	4046_1	N 16.54.7.73	E 99.54.4.16	20.2	5.0	2				✓	✓		✓			✓						✓		2				2/2/2012	
23		4022	4022_1	N 16.55.56.49	E 99.56.29.36	18.1	9.8	3				✓		✓				✓		✓						2				2/2/2012	
24	Phichit	2040	2040_1	N 16.21.11.09	E 100.36.46.22	8.0	8.0	1				✓		✓				✓						✓		2				3/2/2012	
25		2029	2029_1	N 16.7.19.20	E 100.25.4.46	20.0	8.8	3				✓	✓		✓			✓		✓		✓		✓		4	①'	✓	✓	3/2/2012	A whole repair plan exists
26		2029	2029_2	N 16.7.17.27	E 100.25.8.57	12.0	10.0	2				✓	✓		✓			✓		✓		✓		✓		4	①'	✓	✓	3/2/2012	A whole repair plan exists
27	Ang Thong	-	Wat Bot	N 14.43.4.55	E 100.24.33.09	80.0	9.5	6			✓			✓				✓								1				7/2/2012	
28	Ayutthaya	4031	4031_1	N 14.22.31.01	E 100.25.23.76	22.0	9.0	3	✓				✓		✓			✓		✓				✓		3				7/2/2012	
29		4014	4014_1	N 14.18.27.78	E 100.27.9.15	26.0	10.0	3	✓					✓				✓		✓						2				7/2/2012	
30		4014	4014_2	N 14.17.55.46	E 100.27.21.41	26.0	10.0	3	✓					✓				✓		✓				✓		3				7/2/2012	

(Damaged Parts) A: Riverbed or Around Abutment, B: Behind Abutment, C: Riverbank, D: Approach Road

The item applicable to a factor severe within this project, in order to inquire（※When it corresponded to this item, it classified into the outside for examination.）

The item which is a distant place from Bangkok, and is not classified into the candidate for examination in the first step since it is inferior to workability

Structure assumption by field survey（※Abutment Involvement Revetment:Structure where river width contracts in a bridge part and revetment involves in abutment , Abutment Continuation Revetment:Structure of having revetment by fixed river width)

Attachment revetment of a bridge circumference part made applicable to examination within this project（※Urgency is ranked by the numerousness of the numbers of damage items.）

The approach road made applicable to examination within this project

Revetment of a bridge neighboring part made applicable to examination within this project（※Urgency is ranked by the numerousness of the numbers of damage items.）（※The assumption part when not denying only for the reason of a long distance ）

(2) Selection result

JICA study team discussed the location of flood countermeasure with DRR counterparts. And the preliminary pilot bridge was selected by three sections (Planning, Location and design, Road maintenance) of the DRR headquarters on May 4, 2012.

Five bridges in Lop buri were selected as pilot bridge based on following reasons;

- ✓ The prioritization of the flood disaster
- ✓ The relation between DRR headquarters and the local office

Table 8.1-2 five pilot bridges in the Lop Buri prefecture

	Bridge Name	Bridge Length(m)	Road Width(m)	Number of Spans
1	1017-2	15.1	9.8	3
2	1030-1	20.0	9.0	3
3	1030-2	16.0	9.1	3
4	1030-3	19.5	8.8	3
5	1030-4	19.3	8.8	3

Photo 8.1-1 Meeting for selecting pilot bridge (2012/5/4)

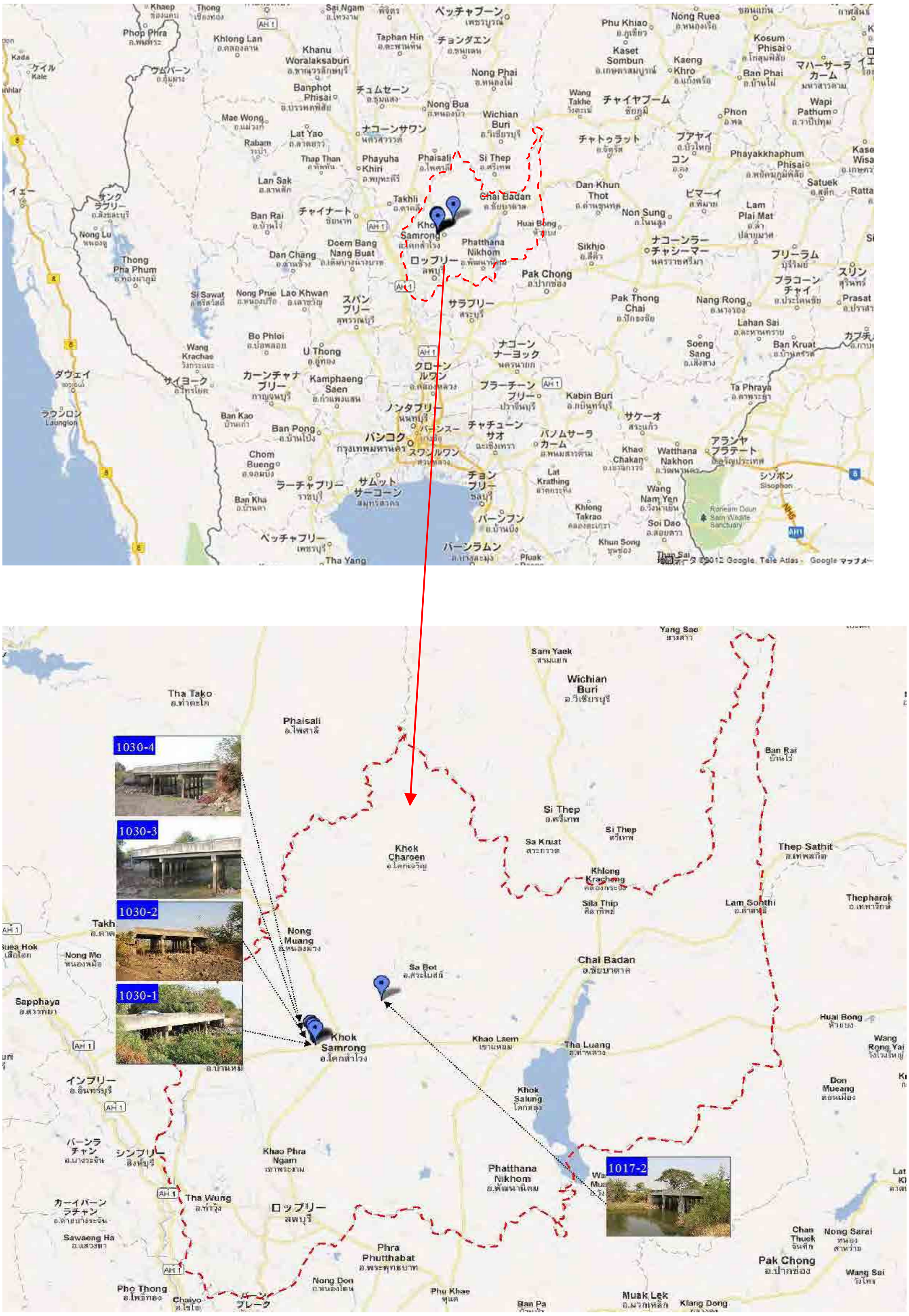


Figure 8.1-2 Locality map of the pilot bridge selected primarily

8.1.2 Joint inspection on flood disaster damage

The joint investigation in five locations, which selected as preliminary pilot bridge was carried out by JICA study team and DRR staff.

The joint investigation was carried out to measure river section and calculated for design velocity by brief survey.

(1) Procedure

- ✓ Investigation of area for flood disaster and the situation of riverbed scouring by the flood disaster by using brief surveying instrument (pole, staff, and tape).
- ✓ Usage of the laser telemeter was introduced by JICA study team. That instrument is able to measure easily disaster area, length and so on under flood condition.
- ✓ JICA study team held the lecture in order to identify the calculation method of the velocity and the flood disaster situation before performing a local joint investigation.

1) Check item

The items that confirmed in a joint investigation are as follows:

- ✓ Disaster extension
- ✓ Cross-sectional change part
- ✓ The depth of scouring
- ✓ Existing structure(eg. abutment , pier)

2) Guideline

The documents that referred to in a joint investigation are as follows:

- *Guideline for taking photographs of the damaged public civil structures after disaster* (June 1993, Ministry of Land, Infrastructure, Transport and Tourism, Japan),
- *Basic guideline for restoration after disaster* (June 2006, Ministry of Land, Infrastructure, Transport and Tourism, Japan), and
- *Draft of guideline for inspection on river course and river management facility including riverbank* (June 2011, Ministry of Land, Infrastructure, Transport and Tourism, Japan).

(2) Time schedule

Schedule of brief field survey for flood disaster was decided by DRR headquarters and a local road office.

Table 8.1-3 Time schedule

Date and Time		Bridge Name
2012/5/15	morning	(Lecture for investigation)
	afternoon	1017-2
2012/5/16	morning	1030-1
	afternoon	1030-2
2012/5/17	morning	1030-3
	afternoon	1030-4

Photo 8.1-2 Prior lecture of the brief field survey (2012/5/15)

(3) Field work

The field measurement in damaged area was carried out along with three technicians from the Lopburi district road office.

They have much experienced in such measurement work and the measurement was performed efficiently.

Other DRR members also helped doing the measure work cooperatively.

Photo 8.1-3 Measurement of the disaster extension with the tape

Photo 8.1-4 The measurement of the flood damage change point section with the pole

At two days in a beginning of the brief survey, JICA study team performed the instruction about flood disaster confirmation work for a technician.

The last day, a chief engineer of the Lopburi district road office mainly instructed brief survey. The brief survey was completed by his instructions.

Through all three days, DRR staff replied to questionnaire about brief survey for flood disaster countermeasure.

Photo 8.1-5 The measurement of riverbed scour, existing abutment and pier

Photo 8.1-6 The questionnaire entry for the confirmation work after the brief survey

(4) Inspection result

Because there was not the general plan in the local site where investigated by JICA study team and DRR staffs, JICA study team made the sketch of general plan. Moreover, brief survey result was drawn by using CAD.

Refer to Appendix (the work situation and the CAD figure in 5 local bridges where joint investigation was carried out).

8.1.3 Flood damage mechanism analysis

The index* of stability for bridge foundation was evaluated by "possibility of scouring of the bridge foundation and stability of the abutment and the stability of the foundation" in Japan.

The typical scouring contents are shown in **Table 8.1-4**.

Table 8.1-4 List of factors to contribute to stability for scouring of the bridge basics

Item	Content
General	➢ Characteristic of the river channel ✓ Bed slope ✓ Cross-linked position (water colliding front, deep drilling)
	➢ Structure of the bridge ✓ The construction generation ✓ Minimum span length ✓ The blocking rate of cross sectional area ✓ Bridge clearance hight
	➢ Disaster outbreak frequency
Abutment	➢ Separation with foot of slope of pier and bank
	➢ Setting position of the abutment
	➢ Stability for scouring (depth of embedment)
	➢ The front of a bridge pier, surrounding revetment
Pier	➢ Structure of pier
	➢ Intersection corner of flow direction and pier
	➢ Stability for scouring (depth of embedment)
	➢ Scouring countermeasure

*Reference)

It is available from Japanese HP (http://www.geocenter.jp/lec-road/index.html)

A characteristic difference in flood disaster was shown in **Table 8.1-5**. The most remarkable difference was "flow direction and intersection angle".

In a local joint investigation, it was confirmed that "pile vent structure was applied to all bridges". In Japan, pile vent structure was prohibited in principle.

The prohibited reason is shown below;

- ✓ It is apt to raise a whirlpool under flood condition.
- ✓ It is apt to occur local scouring around pier.
- ✓ It is unfavorable from the stability of pier.

However, the pile vent structure is recognized as a standard design of Thailand. It is desirable for existing standard design to be modified for flood countermeasures about the new bridge.

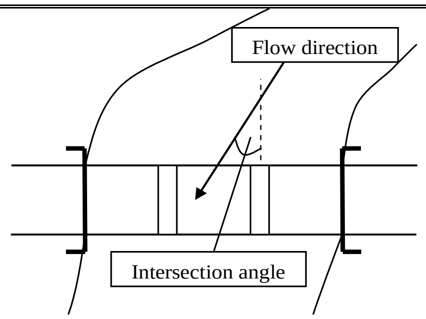
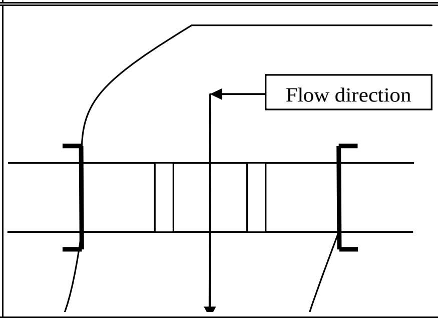
It is confirmed that the blocking rate of cross sectional area was not consider in design of bridge structure.

In other words, "Abutment pier and foundation pile had been left behind at existing bridge under reconstruction stage".

At the result of hearing from DRR staff, the following matters were not considered.

- ✓ Study of location for bridge
- ✓ Study of design drainage discharge
- ✓ Study of bottom edge of girder

Table 8.1-5 Difference in typical damage

	Type 1	Type 2
Outline map		
Outline	An intersection corner of flow direction and the whole bridge is degree more than 10 degrees	Flow direction is at right angles to the bridge
Applicable bridge	✓ 1017-2 ✓ 1030-1 ✓ 1030-3	✓ 1030-2 ✓ 1030-4

8.1.4 Final selection of pilot bridge

At first, the discussion of pilot bridge selection was planned to hold on DRR headquarters. However, it was difficult for the DRR local office staff to participate in a meeting at the DRR headquarters.

Therefore, two bridges were selected as a pilot bridge through a discussion in district road region 2 (2 Bureau of Rural road Saraburi) which had jurisdiction over Lopburi where has 5 bridges of the candidate pilot bridge existed by the preliminary selection.

(1) Selection procedure

The five bridges are carried out to distinguish two patterns in accordance with flood area and flood disaster condition by JICA study team.

Figure 8.1-3 Jurisdiction range of "DRR district road part 2" and position figure of the pilot bridge

(2) Selection result

Final pilot bridge was decided by discussion between with counterparts, all of the DRR headquarters (Planning, Road maintenance) and the jurisdiction district road office staffs of local road part 2 on May 22, 2012.

A director of local road part 2 played a key role of the discussion. And he adjusted an opinion and the demand of each local road office staff. Finally he compiled a demand of DRR.

Two locations finally selected for pilot bridge are shown in **Table 8.1-5**. The technical guidance will be performed through detail survey, design and the construction of pilot bridge. Finally, flood countermeasure manual will be described by JICA study team.

DRR staff will design three bridges in accordance with the flood countermeasure manual except two bridges which selected on final selection.

JICA study team support them so that they will be performed the design for flood countermeasure.

Table 8.1-5 The secondary selection result of a pilot bridge

	Bridge Name	Bridge Length(m)	Road Width(m)	Number of Spans
1	1030-2	16.0	9.1	3
2	1030-3	19.5	8.8	3

Photo 8.1-7 Conference of pilot bridge secondary selection (2012/5/22)

8.1.5 Detail survey for pilot bridge

(1) The survey method

C/P of DRR local road part 2 directed a technician and, with a surveying apparatus (total station), carried out surveying of the present situation topography.

C/P made the local surveying result a figure by the CAD, and a report was carried out by mail to C/P of the DRR headquarters.

JICA study team received the local surveying CAD data of the pilot bridge by mail from C/P of the DRR headquarters.

(2) The survey schedule

In three days of 2012/6/4 - 6/6, DRR carried out the local surveying of the pilot bridge 2 bridge.

(3) The survey result

JICA study team confirmed the CAD data contents which received from C/P of the DRR headquarters and pointed out that the removed old piers were not reflected by a surveying drawing.

Because DRR(local road part 2) staff were advised to remove old piers in order not to inhibit a flow at the time of a flood, they used an emergency budget and removed it by human power from C/P.

JICA study team confirmed that the old piers were removed at the time of July, 2012. (cf. picture 8.1-8)

JICA study team confirmed the following things in C/P of DRR local road part 2 which commanded surveying. "It is slightly difficult to be usually different from duties contents and felt the detailed surveying, but there are not a trouble and the problem that it is particularly".

Using the CAD data which JICA study team received by mail from the DRR headquarters, we made the design drawing for two pilot bridges.

Please refer to Appendix for detail survey and so on.

Photo 8.1-8 Comparison of the removal situation at the pilot bridge (1030-2)

8.1.6 Detail design for pilot bridge

JICA study team considered that detail design for pilot bridge is based on the flood countermeasure manual, because it is necessary for DRR staff mainly to utilize the manual.

There was not "flood countermeasure manual" in DRR. Therefore, JICA study team considered the fact of Thailand by this project and made "flood countermeasure manual" after discussion of DRR with C/P.

JICA study team made a "flood countermeasure quick manual" which was for all DRR staff quickly and easily to use.

Please refer to Appendix for flood countermeasure manual and quick manual.

(1) The design method

It was based on flood countermeasure quick manual.

(2) The design drawing

Refer to Appendix.

(3) The design quantity

Refer to Appendix.

(4) The construction method

Refer to Appendix.

(5) The estimation for construction cost

Refer to Appendix.

8.1.7 Technical Assistance for Construction Supervision on Pilot Bridges

For the period from June 10 to June 29, 2013, JST carried out the technical assistance for construction supervision to the DRR officers over the pilot projects located in Lopburi and the technical seminars in BRR2 office at Saraburi.

Similarly, on June 13, 2013 before the pilot projects started, JST participated in an explanatory meeting for the local residents as a observer, which was mainly organized by BRR2 and the contractor. In the meeting JST supplementally advised BRR2 as to the technical questions from the local residents. Through the discussion with the residents, it is confirmed that the pilot projects should finish before the end of August, as there are floods often in September.

(1) Technical Assistance regarding Temporary Works

On June 14, 2013, the following things regarding the construction schedule and the plan for temporary works submitted by the local contractor were advised to BRR2.

- As the local contractor has little experience in gabion works, it seems to be difficult for them to complete the gabion protection works for 2 bridges by the end of August. Therefore, to avoid a risk, it is advisable to commence one bridge only and finish the works before the rainy season starts. Accordingly, the gabion works of the other bridge should commence after finishing this coming rainy season.
- It is necessary to prepare temporary roads for the works at appropriate positions, based on the construction schedule.
- Temporary works should be carefully and appropriately planned so as not to obstruct the lives of local residents.

Photo 8.1-9 The explanatory meeting for the local residents held on June 13, 2013

(2) Technical seminars regarding gabion works

The seminars regarding the key points of supervising gabion works were held twice for BRR2 office staff and their regional staff to increase their understanding of the gabion works selected as a flood countermeasure.

Also, after confirming the inspection of materials for gabion works and instructions to the contractor on how to assemble a gabion basket carried out by the BRR2 staff, JST supplementally advised BRR2 as to some key points for supervising the gabion works. (*Key points for supervising gabion works are shown in Appendix.)

Photo 8.1-10 Technical seminar for supervising gabion works held on June 19, 2013

Photo 8.1-11 Material inspection of gabion works performed by BRR staff

(3) Construction Supervising Gabion Protection Works on Pilot Bridges

From June 15, 2013, the local contractor commenced the works for the temporary roads, leveling the riverbeds and placing gabions in order. The construction supervision for the above works carried out by the BBR2 was observed by JST at each stage and JST pointed out the issues and advised BRR2 as to the following improvements.

- As for appurtenant works such as gabion revetment works, BRR2 has few staged inspections carried out and no inspection sheets on appurtenant works at each stage exists in BRR2. Therefore, BRR2 has no record for quality control on the works. In order to supervise the above works properly and do maintenance on the works in future, BRR2 should prepare some standard forms for staged inspection on the appurtenant works.
- As there were few daily meetings held with the contractor, namely, less communication with the contractor, BRR2 could not grasp the work schedule adequately. Moreover, it could lead to poor quality of the works. Therefore, BRR2 should establish a daily meeting system and instruct the contractor to inform daily progress, the next day's schedule and issues related on the project in the daily meetings.

Photo 8.1-12 Construction supervision carried out by BRR2 staff (1/2)

Photo 8.1-13 Construction supervision carried out by BRR2 staff (2/2)

8.2 Consideration of Flood Measures for Existing Bridges

8.2.1 Classification of Damage Conditions

As for damage condition, it is classified under the damage that due to (1) erosion of riverbed, (2) scouring around abutment, (3) poor maintenance of revetments and (4) inadequate setting of design current velocity, the bridge section becomes a big vena contracta section which causes the access road overflowed. (*For the details of the damage due to the flood, please refer to Chapter 7.)

8.2.2 Selection of Construction Method Considering Local Attributes

Flood damage condition changes dramatically depending on the local attributes. Therefore, factors of the damage condition and importance of selecting construction method are mentioned in the Flood Disaster Measures and Rehabilitation Manual.

8.2.3 Proposal of Construction Method

As for proposal of specific construction method for flood measures, detailed design drawings for the two bridges, which are subject to the pilot project, are prepared. The proposal of construction method is summarized in the following 6 items.

(1) Consideration of Measures against Erosion of Riverbed

The importance of foundation reinforcement and embedment of revetment toe are described in the Flood Disaster Measures and Rehabilitation Manual. (*In the conventional DRR design standard, there was no concept of designing embedment.)

(2) Consideration of Measures against Scouring of Abutments

In the Flood Disaster Measures and Rehabilitation Manual, it is mentioned that the front side of abutments requires a revetment protective works so as to resist assumed current velocity.

(3) Consideration of Measures against Sediment Run-off

In the Flood Disaster Measures and Rehabilitation Manual, it is mentioned that appropriate revetment protective works should be performed according to current velocity category and the revetment needs to be developed within a range of 10m upstream and downstream of the abutment.

(4) Consideration of Measures against Overflow of Access Road

In Japan, basically, access roads are not overflowed. Therefore, in the Flood Disaster Measures and Rehabilitation Manual, slope protective works for the top of revetment slope is introduced and described.

(5) Consideration of Measures against Permeation of Access Road

In Japan, basically, access roads are not overflowed. Therefore, the design standard regarding protective works for the top of revetment slope to allow the overflow in Australia is introduced as reference.

(6) Consideration of Measures against Run-off of Access Road

It is mentioned that appropriate revetment construction should be developed for the access road that parallels the current.

8.3 Preparation of Flood Disaster Rehabilitation Manual

When preparing the Flood Disaster and Rehabilitation Manual, we adopted "Basic Policy for Disaster Rehabilitation to Protect Beautiful Mountains and Rivers" (June 2006) and "Draft of Detailed Inspection Guideline of Facilities such as Dikes etc. in the Management of Water Resources and Floodways (May 2011)" of the Ministry of Land, Infrastructure, Transport and Tourism as a basis for considerations.

The Flood Disaster Rehabilitation Manual explains inspection on normal time as flood disaster measures, inspection on abnormal condition, flood disaster assessment method, and method of designing flood disaster measures. In the last Chapter, as examples for designing, we elaborated about two bridges selected as pilot projects among the 30 bridges urgently inspected in this project.

Also, in response to the strong request by DRR, we prepared a quick manual in which important points are summarized for the purpose that all DRR staff can easily gain the knowledge about flood measures and utilize such knowledge.

The contents of the Flood Disaster Rehabilitation Manual and the Quick Manual reflect the questions and answers and requested items in the confirmation with C/P and in the seminars.

(*) For the details of the Flood Disaster Rehabilitation Manual and the Quick Manual, please refer to Appendix.

8.4 Comments to Standard Design

8.4.1 Problems of DRR Standard Design

Looking at the characteristics of the damage to DRR bridges, there are cases where the damage is caused due to the problems of the standard design. These below are the characteristics of the damage and the countermeasures to prevent recurrence.

(1) Problems in Bridge Planning

In the DRR standard design, there is no regulation on obstruction ratio of the cross-sectional area; therefore, in some cases, the bridge span is set too narrow for the river width without much consideration. Also, with regard to local bridges, because of the climate in Thailand, there are many small rivers whose water flow completely disappears in dry season, which causes problems in bridge planning.

The problem of scouring due to making the river width extremely narrow is already acknowledged by DRR. As shown in the image 8.4-2, DRR says that in the District (No.13) we visited, there are 3 cases where repair works were needed to assure enough river cross-sectional area. Although it has been 2 years after this bridge was repaired and the bridge experienced the floods last year, there seems no sign of the progress of scouring by the look of paving stone. Also, it seems that DRR leads planning and designing, including considering high water level, bridge clearance, etc. for the relatively large bridges; however, for RC bridges (span length 5 -10m) built by the standard design, high water level or bridge clearance are not considered so much.

Based on the above, proposals to reduce the obstruction ratio of cross-sectional area and basic ideas of the restrictions on the river management are shown as below.

a) Obstruction ratio of cross-sectional area

Obstruction ratio of cross-sectional area is defined as the proportion of the total width of piers to the river width. Here, river width and total width of piers represent the following.
(1) River width: the distance between the points where design high water level, measured at right angles to flow direction, intersects the slope face of banks.
(2) Total width of piers: The total width of the piers at the point of design high water level measured at right angles to flow direction.
A standard value of obstruction ratio in cross sectional area is within the following range.
(3) General bridges: basically within 5%.
(4) Shinkansen railway bridges and national expressway bridges: within 7% (special case)

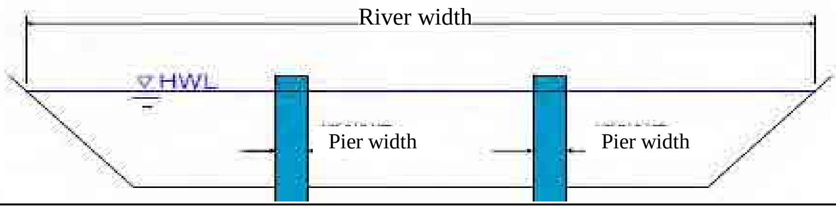


Image 8.44-1 Image of river width and pier width

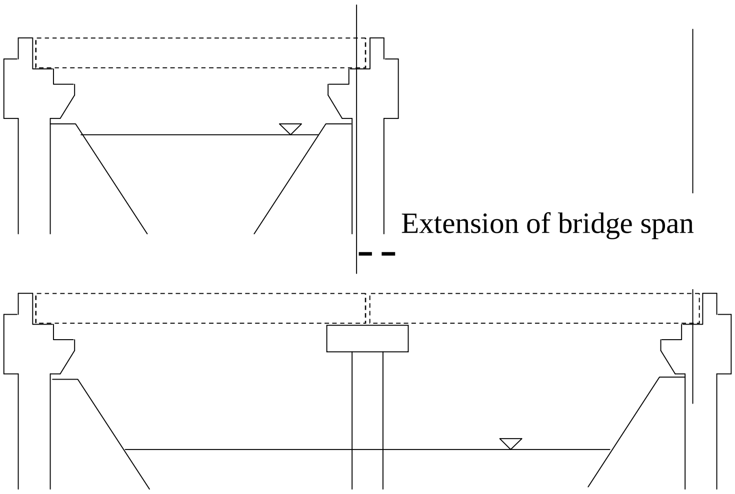


Image 8.4-2 A case where obstruction ratio of the cross-sectional area is improved by extending the bridge span (District No.18)

b) Direction of the Placement of Piers

The direction to place piers shall be parallel to the flood-water flow direction when design flood discharge is achieved, and special care should be taken to minimize the ratio of obstruction width by the piers in cross-sectional area.

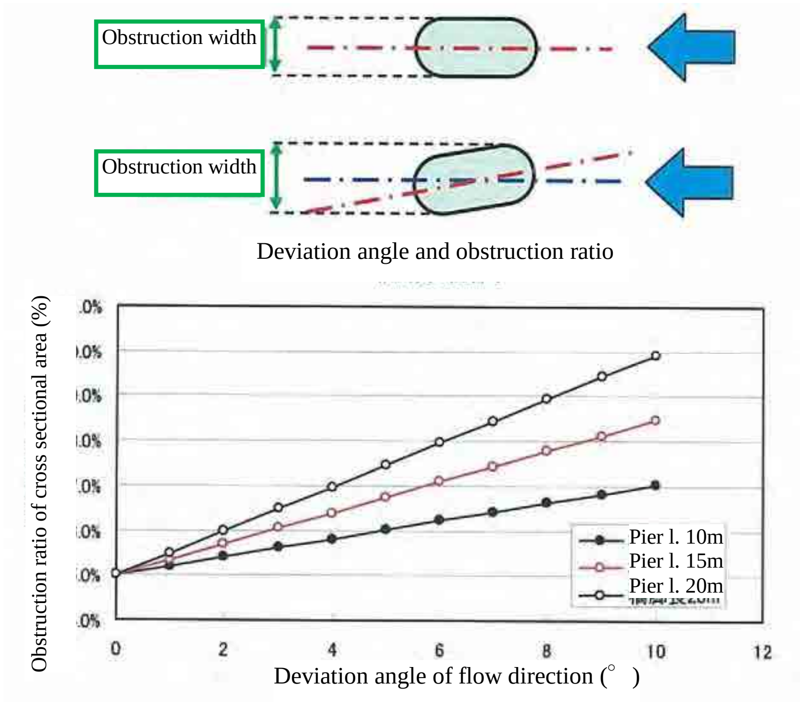


Image 8.44-3 Image of obstruction width by piers when the direction of piers is not parallel to flood-water flow direction

Also, for the shape of piers, we propose oval-shaped piers, whose features are that those piers facilitate the water flow and reduce the obstruction ratio of cross-sectional area.

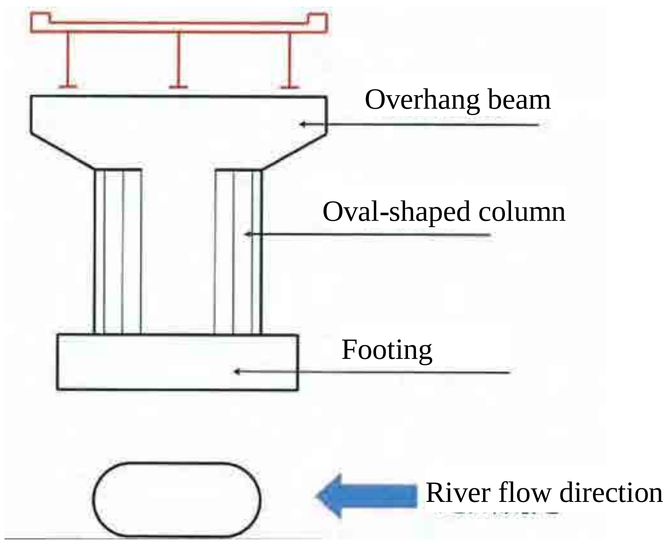


Image 8.44-4 Image of the shape of piers

c) Restrictions on river management

- The clearance height of a bridge should exceed design high water level (H.W.L.) plus design freeboard.

Table 8.44-1Freeboard

Design high-water discharge (m3/sec)		Value to be added to H.W.L. (m)
less than 200		0.6
200 and above	less than 500	0.8
500 and above	less than 2,000	1.0
2,000 and above	less than 5,000	1.2
5,000 and above	less than 10,000	1.5
10,000 and above		2.0

- To avoid the river's weakness when flooding

- Any section where the river flow changes, such as narrow pass, water colliding front, confluence section, bend, etc.
- Any section where the riverbed changes greatly (changing point of riverbed change)
- Any point where a dike break occurred, any place where a river used to be.

These are the points where the water flow becomes complicated during flooding and listed in the light of avoiding those points which are difficult to predict the spatiotemporal change of the river. Especially, narrow pass except narrow pass in the mountains, water colliding front, junctions of tributaries, and section where the riverbed change is big (changing point of the slope of riverbed) should be avoided. (Standards of permission for establishment of structures Article 31, 1

(2) Problems of the Structures of Piers and Abutments

Scouring is recognized nationally. The cause is that the structure of the abutments and piers of the standard design is vulnerable to scouring. Therefore, even now, bridges which are easily affected by scouring are being built. For the abutments, pile bent method, which is same as for piers, is adopted so as not to be affected by earth pressure as much as possible; however, the poorness of shoreline protection works on revetment lets the water in the backside during flooding and makes the back fill run off. For the piers, the standard is pile bent method, which is likely to cause scouring due to swirls. Also, as the bottom surface of the footing (beam) comes to the riverbed when designed, and the foot protection works are not enough, there are many bridges whose piles are exposed.

Repair methodology for existing bridges are as proposed in Clause 8.1, but in case of new bridges, it is advisable to establish some standard such as River Law or Cabinet Order concerning Structural Standards for River Management Facilities, etc in Japan and to design taking countermeasures against scouring into account.

As examples for reference in Japan, image of position of the bottom surface of abutment, image of embedment depth of piers, basic ideas of shoreline protection works, foundation reinforcement works, etc. are shown below.

a) Bottom surface of abutment

- The bottom surface of the abutment placed in the embanked reach of river should be lower than the ground level.
- “Ground level of a bank” is deemed to be, in case of embanked reach, the line connecting the toe of front slope and the toe of back slope of a bank, and in case of excavated river channel, the line connecting the point of width corresponding to the width of top surface of the bank and the toe of front slope.
- When the ground is solid rock, etc. and it is clearly distinguished from the foundation of the bank, it may be placed lower than the ground (the solid rock, etc.).

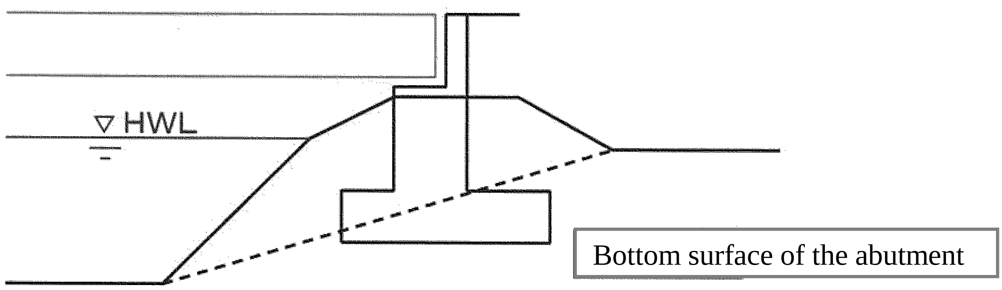


Image 8.44-5 Image of the position of bottom surface of abutment

b) Embedment depth of piers (height of top surface of foundation)

As for the height of top surface of the foundation, it is necessary to be placed deeper than the depth corresponding to the depth of scour during flooding, and to be fixed according to the following regulations.

① Piers in low water channel section: “design riverbed height (or height above deepest riverbed) minus more than 2m”

② Piers on high water bed:

- ➢ Piers placed within a range of 20m from the top of slope of riverbank : same as the condition to low water channel
- ➢ Piers placed outside the range of 20m: “Design height of high water channel – more than 1 m”

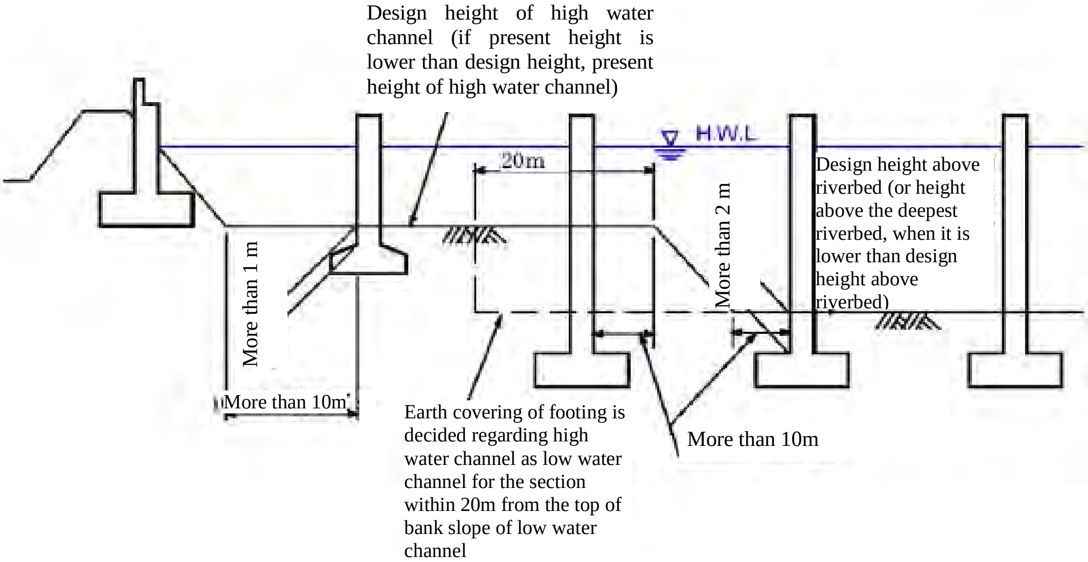


Image 8.44-6 Image of restrictions on position of piers and embedment of foundation of piers

c) Revetment protective works

Placement of abutments and piers may cause turbulence and imbalance of flood flow, and abutments may create weak points in the bank against seepage failure. Therefore, banks, high water bed and riverbed should be protected properly.

The scope of the revetment to be placed is as shown in Images 8.4-7 and 8.4-8.

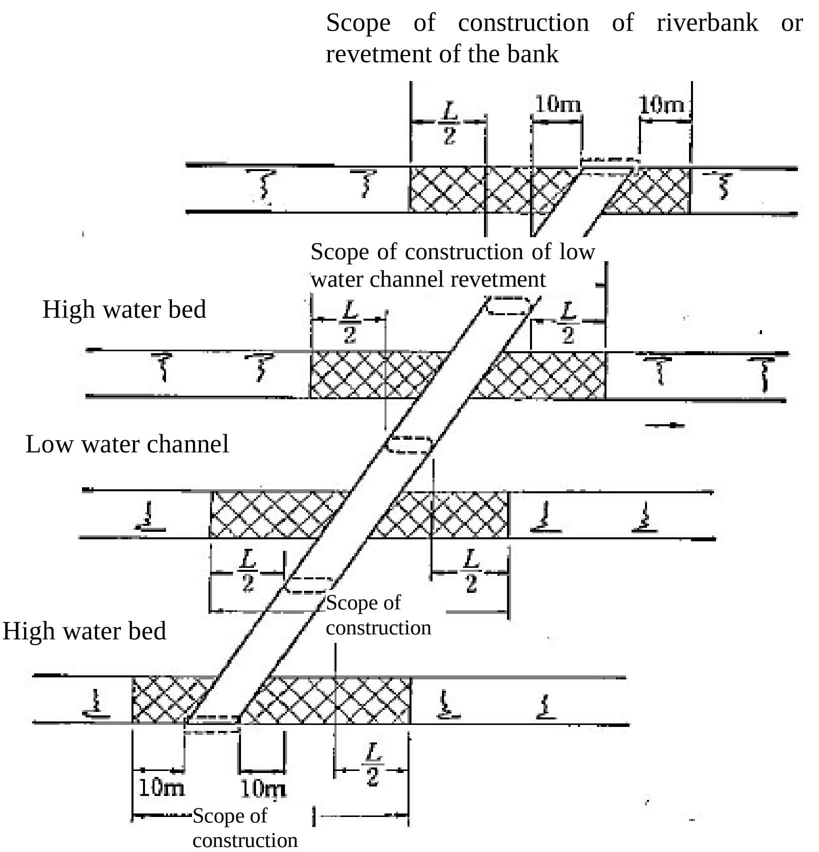


Image 8.44-7 Length of revetment necessary for the establishment of a bridge

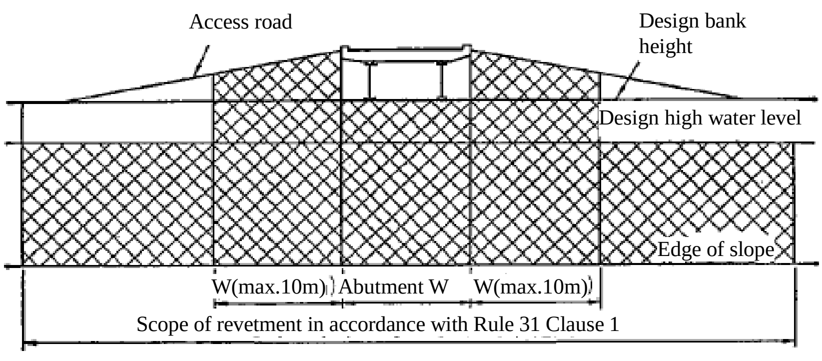


Image 8.44-8 Height of revetment necessary for establishment of a bridge

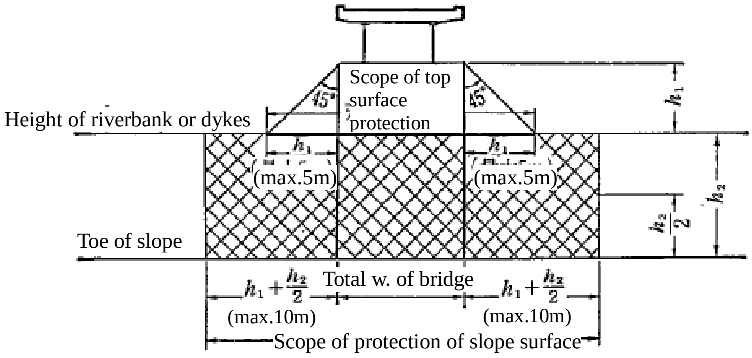


Image 8.44-9Scope of protection of riverbank below a bridge or banks

d) Scour prevention works around piers

The depth of embedment of the foundation when placing the piers is regulated as Image 8.4-8 shows. Also, since the height of pier foundation affects the construction cost of the piers, there are few cases where the foundation of pier is placed considering the maximum depth of scour, and if the assumed maximum depth of scour due to water flow is deeper than the envelope curve of the deepest riverbed minus 2 meters, in many cases, foot protection blocks or gravels are placed as scour prevention works of piers.

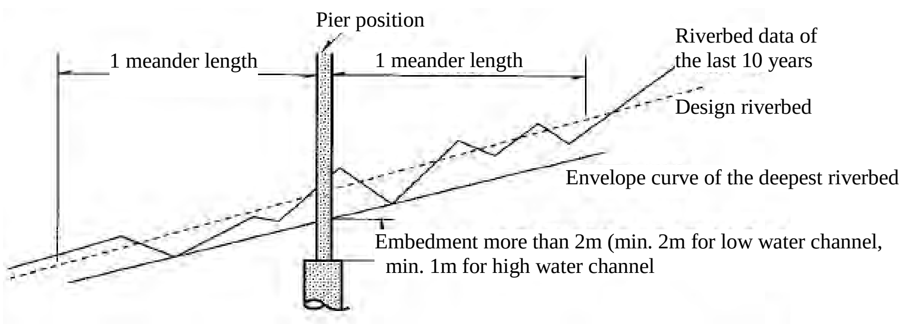


Image 8.44-10Depth of embedment of a pier

The depth of placement of the foundation reinforcement is above the foundation, considering scours due to piers. However, if the depth of placement is too shallow, the water flow drifts greatly due to the piers, which makes the scour bigger. Then, when placing the foundation reinforcement, as is shown in Image 8.4-9, depth of placement which enables the scope of placement of the reinforced foundation smaller is desirable, by allowing to some extent scouring due to piers, softening the flow due to piers and reducing the area of scouring.

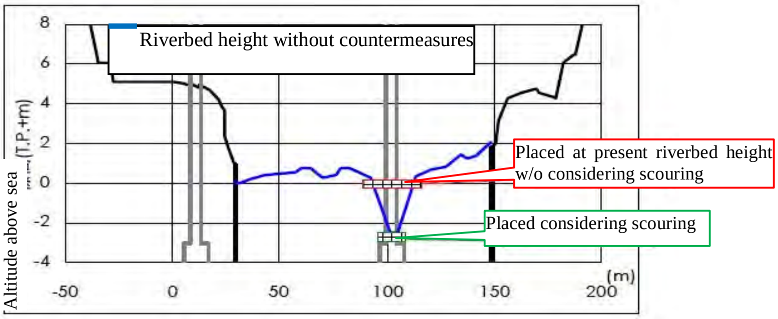


Image 8.44-11 Example of depth of placement for foundation reinforcement

(3) Technical Advice considering the Aspects of Disaster Prevention such as Floods

Looking at the characteristics of damages to bridges, it can be found that the cause is scours in riverbed. In DRR standard design, the structure of abutment has the function of banks, which results in a weak point of the structure, such as causing collapse of revetment during flood. Designing the abutment in a proper place may increase initial cost but enables to reduce life cycle cost of the structure. In Japan, when deciding the position of abutment, it does not exceed the top of waterside slope toward the river, which separates the function of abutment from that of banks.

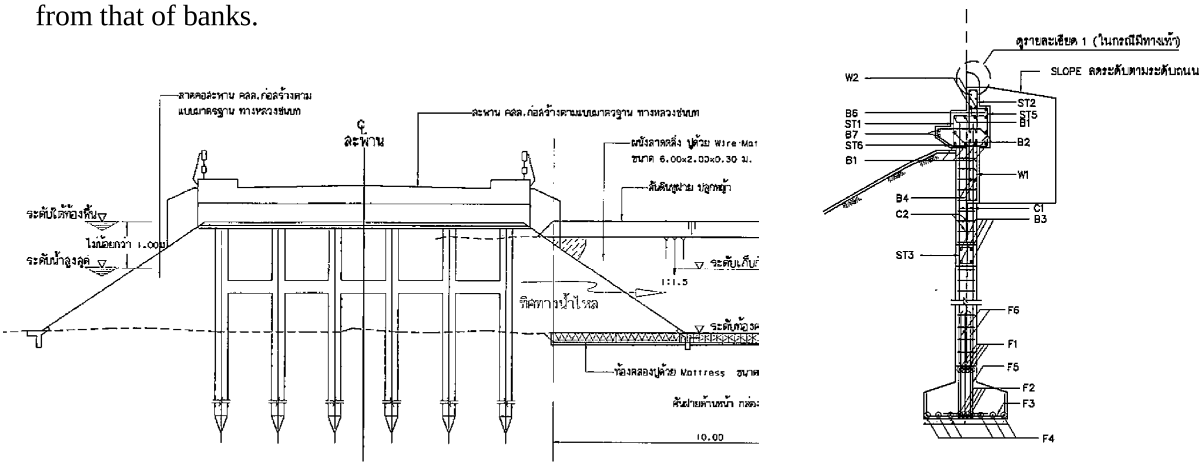


Image 8.44-12 DRR standard design- position of abutment

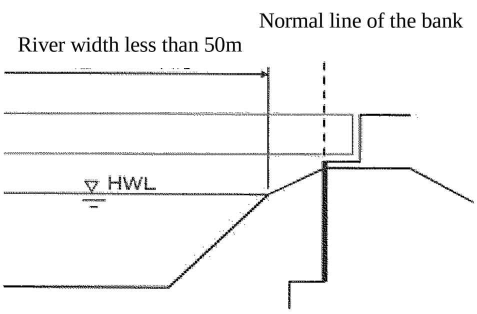


Image 8.44-13 Image of abutment position

8.4.2 Comments to New Bridges

Regarding the repair plan of the bridges damaged due to the flood in northeast region, we gave advice from the viewpoint of flood prevention. Please refer to Appendix 9-1 for the details of the comments.

8.4.3 Comments to Improvement Plan of Existing Bridges

Regarding the repair plan of the bridges damaged due to the flood in northeast region, we gave advice from the viewpoint of flood prevention. Please refer to Appendix 9-2 for the details of the comments.

8.5 Proposal of Maintenance and Management Method during Flooding

8.5.1 Introduction of River Register

During the seminar, we introduced the River Register utilized in Japan for the continuous river management.

8.5.2 Introduction of Emergency Inspection Manual

As for the post-flood emergency inspection method, we introduced, during the seminar, some cases of disaster rehabilitation in Japan, and added such cases in the Quick Manual.

8.6 Introduction of Flood Damages and Rehabilitation Examples in Japan

8.6.1 Introduction of Flood Damage Cases

During the seminar, we introduced some cases of damage due to floods in Japan caused every year by unusual weather and also its countermeasures.

8.6.2 Introduction of Flood Rehabilitation Example

As for flood disaster, we introduced, during the seminar, some examples such as countermeasures in prevailing designs, empirical methods, and cases where factors of the disaster are clarified and always updated to consider flood countermeasures.

Chapter 9 Review of Master Plan on New Local Bridge Construction and Procedure of FS

9.1 Review of Procedure of DRR Bridge Master Plan

9.1.1 Introduction

Department of Rural Roads (DRR), a roadwork agency under Ministry of Transport, Thailand developed the model to theoretically identify potential area for necessary of new bridge construction. DRR formulated the bridge master plan in Thailand under the developed model.

In the bridge master plan, the high potential areas for new bridge construction were selected on the rural roads in Thailand. The selected locations by the model were compared to the locations requested from the local community. The results in the selection are evaluated in the model. Finally, the number of new constructed bridges in future by the model is formulated in the master plan.

DRR selected the high potential areas with a bridge rank of 1-50 from the master plan. The bridge feasibility study is carried out in the 25 bridge locations selected from the ranks of 1-50 under the collection of the more detailed data of 7 factors in those areas. DRR intends to continuously carry out the feasibility study for the remaining 25 locations for which the feasibility study are not carried out.

Since DRR doesn’t have the standard manual for process of decision for location of new bridge construction, the criteria of selection in the local offices of DRR are not uniform. Therefore, the purpose of the developed model is to construct the theoretical selection process for a new bridge.

DRR proposed the method (model) to theoretically identify potential area for necessary of new bridge construction. The high priority areas for the bridge construction are selected on the rural roads in Thailand. The bridge master plan is formulated for the next decade.

In Chapter 9, the plan procedure of the model of the bridge selection for FS of the bridge master plan which DRR developed, and a latent high area is reviewed, and extract subjects. Then, technical advice is provided about the extracted subject of the model.

Furthermore, in order to improve the accuracy of a bridge master plan and the bridge selection technique as part of technical advice, the procedure of the cost benefit analysis is provided in appendix. Especially introduction of the cost benefit analysis is the item which had the request from DRR.

9.1.2 Outline of DRR model to identify potential area for necessity of new local bridge construction

DRR made a bridge master plan to analyze the data to affect on potential of bridge construction, to select the location of bridge construction and to plan the number of bridges constructed during 10 years. The development method of bridge construction is made by DRR.

Although the concept of this method can be understood from a master plan final report (Thai language) and presented paper, about a concrete technique, description is not sufficient to understand detail. The method is reported based on mainly on the information acquired from the person in charge of development in this section. The outline of the bridge master plan which developed by DRR is shown in this section first.

The development method is classified into three (3) steps, where are:

1) Pre-Processing step: preparing data for analysis to select 7 main factors.
2) Intermediate-Processing step: making spatial analysis and getting an appropriate location for developing the bridges in the future.
3) Post-Processing step: prioritizing the importance of the appropriate bridges to make a master plan. (Select a alternative bridge location for FS)

And finally, the master plan is formulated the order of new construction bridges and mention about necessity number of new construction bridge. Analysis process is summarized in Figure 9.1-1.The detailed processing in each step shows in next Section.

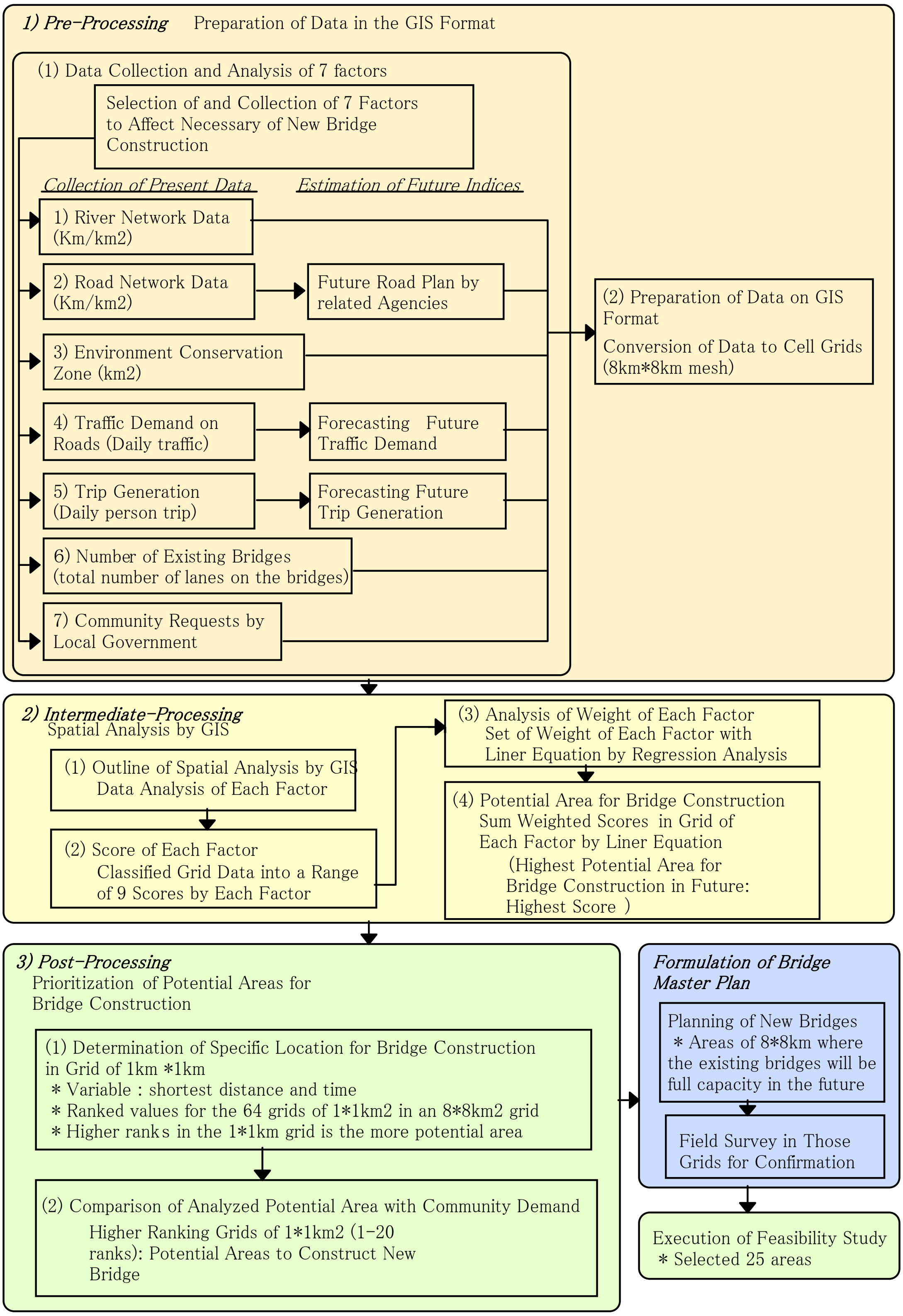


Figure 9.1-1 Outline of DRR Model

9.1.3 Review of Pre-Processing (Preparation of Data in the GIS Format)

(1) Data Collection and Analysis of 7 Factors

1) River Network Data

River network as well as road network affects a new bridge construction since in general, the bridge is constructed over a river in Thailand. The higher the density of rivers is, the higher the necessity of bridges is. Therefore, it is indispensable to take into account river network into 7 main factors. The river network is expressed in terms of the density of the river in area in the DRR model.

River network consists of large river, medium river, small river, man-made and irrigation canals. The data of those rivers are updated by used the satellite photograph from Google Earth and Point Asia. Its figures are a total length of approximately 475,000 km.

At the data processing to convert into an 8*8km grid (see Section 9.3.2), only river length is taken into account but river width. The river width is taken into consideration in the feasibility study in 2011 by DRR when the bridge location is identified, after the selection of potential area in the DRR model. In the feasibility study, the locations with a width of over 50m give a higher priority for a new bridge construction.

2) Road Network Data

Road network also affects a new bridge construction since in general, the bridge is constructed on roads. The higher the density of roads is, the higher the necessity of bridges is. Therefore, it is indispensable to take into account road network into 7 main factors. The road network is expressed in terms of the density of the road in area in the DRR model.

Road network consists of national roads, rural roads, and local roads by DOH, DRR and Local government, respectively. Future road network plans of Bureaus or Offices such as DOH and DRR are included. The total road length is approximately 450,000 km.

3) Environment Conservation Zone

When a new bridge is constructed in an area, it is necessary to consider the environmental aspects, especially environment conservation zones. In general, when road will be planned, road alignment avoids in the environmental protection area. Therefore, it is indispensable to take into account environment conservation zone into 7 main factors. The environment conservation zone is expressed in terms of the area of the zone in area in the DRR model.

Environment conservation zones are watershed class 1A, reserved forest, national park, wetlands, etc. controlled by Department of Environment Quality Promotion and Department of National Park, Wildlife, and Plant Conservation.

4) Traffic Demand on Roads

Traffic volume affects the demand of new bridge construction on roads as well as the proposed factors. Among them, since traffic volume on road is directly influence on the transport service level in the study area, the area with higher traffic demand has higher potential of bridge construction. Therefore, the traffic demand is employed in the seven (7) factors of the DRR model.

The traffic demand in the DRR model is forecasted by NAM model (National Model) which is developed in Urban Transport Database and Model development project (UTDM), which is to forecast the transportation of person and cargo between provinces, and is used to forecast the traffic volume by cars, railways, air, and ships. NAM model is continuously improved in accuracy, extension of application areas and integration of Cube cargo application software in goods transportation model. In the Master Plan study, Transport Data and Model Center phase 5 (TDMC V) in 2006 in which the structure of the model is improved by using cube cargo in goods transportation model is used.

Figure 9.1-2 shows the forecast process of traffic demand on roads which consists of projection by traffic demand model (NAM model), selection of survey location to collect latest traffic volume, calibration of NAM model and projection of future travel demand. The detailed is shown next.

Travel demand in the study area is forecasted by NAM model. Present socioeconomic data such as population and gross province product (GPP), transport network data composed of road, railway, marine and airway line, existing traffic conditions included traffic volume on each mode, and traffic flow data are inputted in the NAM Model. NAM model is 4 step-model integrated Cube cargo application with 926 traffic zones and 11 zones of outside area. And then, the present traffic volume on existing bridge is forecasted. In this step, since existing traffic condition data, especially traffic volumes on roads are not latest, it is necessary to update the existing traffic data for more accurate estimation. The input of the latest traffic volume data in NAM model brings the results to be more accuracy in calibration step.

Therefore, in order to collect latest traffic volume on road, more optimum locations must be selected in the study area. The survey locations must be representative of the transportation in each region, which consisted of 3 locations in each region (North, Northeast, Central, and South) which is total 12 locations. The existing traffic count data is collected from related Bureaus or Offices such as DOH and DRR, and analyzed on the traffic volume and its frequency distribution, and finally classified into 3 groups. Based on these analyses, the 12 survey locations are selected by 3 traffic groups and by 4 regions. The traffic survey composed of traffic count and roadside interview was carried out and those data use for calibration of NAM model.

In the calibration of NAM model, the traffic volume estimated by NAM model is compared to the traffic data counted on 12 locations and reviewed in consideration of the latest transportation condition.

Based on the result of the calibration of NAM model, the future socioeconomic data and transport network plans are inputted in the NAM Model and future traffic demand on bridges is forecasted. These demand data are used for the spatial analysis by GIS.

The DRR model was developed to formulate the bridge Master Plan in which the potential areas for construction of new bridges are estimated based on the 7 factors, and number of bridges constructed and the locations are planned. And then, feasibility study was continuously carried out by DRR for execution of further study. For the estimation of traffic demand in the feasibility study, the extended Bangkok City Model (eBUM) was used instead of NAM model. This is because the review of the Master Plan projects was carried out and DRR selected the areas in Central region for the higher potential areas of construction of new bridges. Therefore, the eBUM was applied in Central area.

The eBUM has been developed by the Urban Transport Database and Model development project (UTDM) in 1995 with total zones of 505 in the study area and continues developing. The eBUM has been used extensively in evaluating and planning the project of each office related to traffic and transportation in the present.

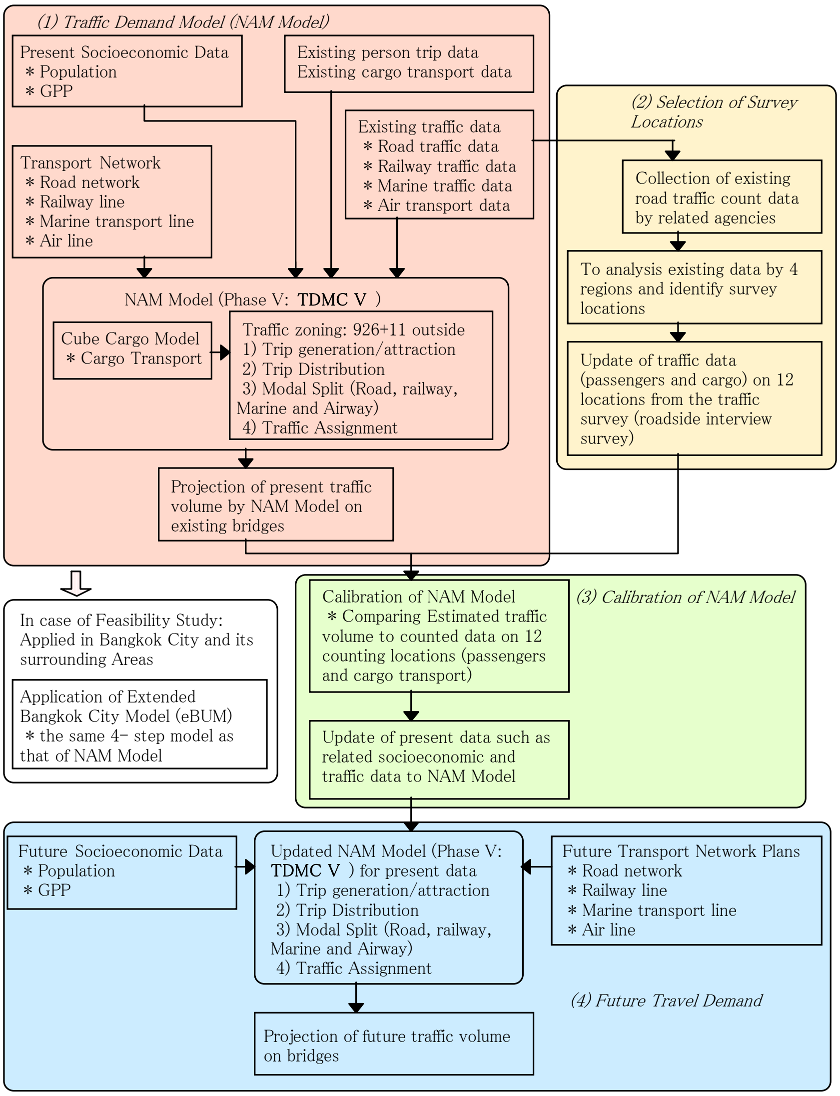


Figure 9.1-2 Flowchart of Forecasting Future Travel Demand

5) Trip Generation

Trip generation is the prediction of the number of trips produced by and attracted to each zone, that is, the number of trip ends ‘generated’ within the area. In the other words, the trip generation phase of the analysis predicts total flows into and out of each zone in the study area, but it does not predict where these flows are coming from or going to. This also affects the demand of new bridge construction on roads. Therefore, the trip generation is employed in the seven (7) factors of the DRR model.

The trip generation was forecasted in the DRR model in which trip production rate (trip/person) within the area is estimated by analyzing river network, road network, population, traffic demand, and current bridge location.

Figure 9.1-3 shows the estimation process of trip generation in area which consists of classification by area in 8*8km grid into similar characteristics from the viewpoint of trip rate, selection of survey location to collect trip data, calculation of trip generation at the present, and estimation of future trip generation. The detailed is shown next.

The collected data of river network, road network, population, traffic demand, and current bridge location are prepared on GIS format of 8*8km grid. Those grid data are analyzed by the spatial analysis method in which layer analysis for each factor is made, and the weights between each factor are estimated by regression analysis. Then the spatial analysis through GIS system is made and the grids score in a range of 3 in classification by similar characteristics for trip rate.

The survey areas are decided based on the scores of 3 ranges. The 12 survey areas are selected by 3 ranges and by 4 regions. The home interview survey was carried out, whose interview items are number of trips, vehicle owned, income level, origin and destination, etc. The trip rate is estimated by survey area from analysis of the interview data.

The trip generation is multiplied population in 8*8km grid by the trip rate. The future trip generation is estimated by substitution of future population in 8:8km grid. And then, the trip generation is used for the spatial analysis by GIS.

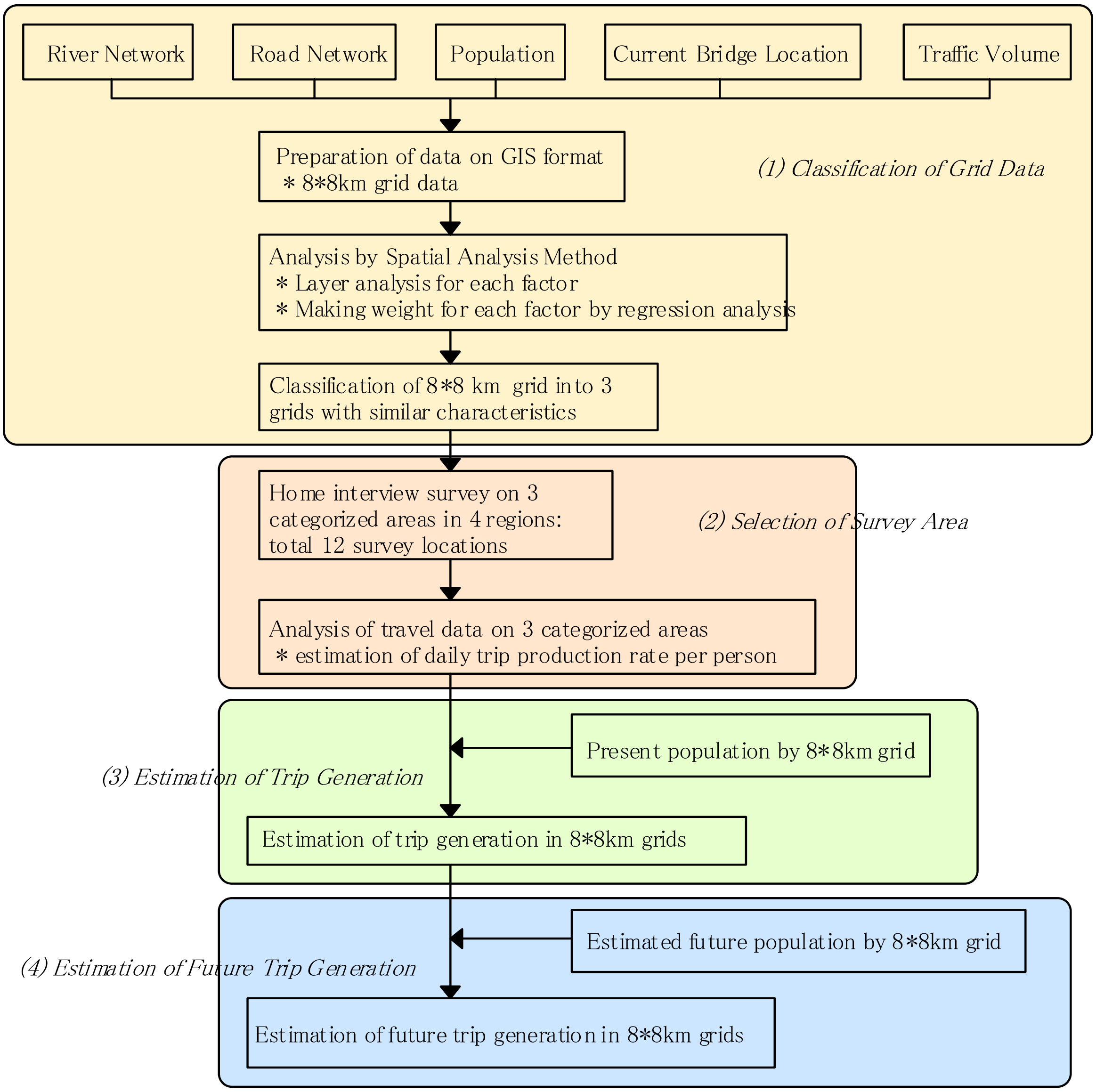


Figure 9.1-3 Flowchart of Estimation of Trip Generation

6) Number of Existing Bridges

In generally, since bridge is constructed according to traffic demand or geographic conditions, number of existing bridges in area relates to those conditions. However, it is difficult to conclude the future potential of a new bridge construction by measure of existing bridges. It is certain that number of existing bridges affects on a new bridge construction in area. Therefore, it is necessary to take into account number of existing bridges into 7 main factors. The existing bridges are expressed in terms of the total number of lanes on existing bridges in area in the DRR model. The data processing is carried out on the assumption that the number of lanes on existing bridges on DRR roads is 2 lanes and 4 lanes for DOH.

Existing bridges consists of bridges in responsible of DOH, DRR, and Local Offices. Since those agencies have not enough data, the existing bridge data such as location and number of lanes are supplied from satellite photograph on Google Earth and Point Asia, and from the map of Royal Thai Survey Department with a scale of 1:50,000. Those bridge data collected from satellite photograph are classified by related agencies according to the locations of the bridges on the roads by related agencies. There are 29,420 bridges in total as shown in Table 9.1-1. However, the procedure of which an intersection between river and road networks is bridge location, is not employed in the DRR model because the locations identified by maps do not coincide with actual places. However, the bridge data collected by maps is used for analysis which identifies an appropriate area to construct the new bridges in the future.

Table 9.1-1 Number of Existing Bridges by Agencies

Province	DOH bridges*	DRR bridges	Local bridges
Total	8,473	8,319	12,628
Grand Total	29,420		

Remarks: 1.* Bridges in responsible of DOH are not completed because didn't received information from some provinces, so added more bridges by the satellite photograph

7) Community Requests by Local Government

Community requests by local government are also important on judgment whether a new bridge is constructed, or not. A plan for bridge constructions on rural roads across rivers in Thailand has conventionally been implemented based on availability of requests and budgets. This is not effective and neglectful in bridge planning. However, it is necessary to take into account community request into 7 main factors. The community request is expressed in terms of a value of 1 for requested and 0 for not requested by the questionnaire from local government in the DRR model.

The community requests by local government for demand of bridges are collected from questionnaire for necessity and its location. However, in the master plan study, the weight of demand of bridge in community is set a value of 0. The community request is neglectful in evaluation, because only 10% of sent questionnaire is collected from the local government. DRR concluded that the collected ratio of questionnaires is not enough.

(2) Preparation of Data on GIS Format

After the database of 7 factors as shown below is prepared, the X1 to X7 data is meshed into cell grids of 8*8km.

X1: River Network

X2: Road network (existing and future plans)

X3: Environment conservation zone

X4: Traffic demand on roads (at the present and in future)

X5: Trip generation ((at the present and in future)

X6: Number of existing bridges

X7: Community requests by local government

1) Cell Grid Size

Based on the analysis of the size of the cell grid, the size of the appropriate cell grid is 8 km x 8 km which is equivalent to the average size of the district around the country. This is that the average area of the sub-district size all over the country is approximately 68km2, and the area is made approximation to 8*8km grid as shown in Figure 9.1-4.

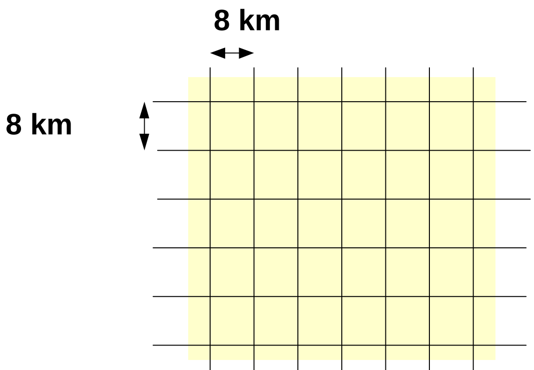


Figure 9.1-4 Illustration of 8*8km Grid

2) Data Conversion of Traffic Volume to 8km Cell Grid

Data conversion

Out of the 7 factor data, figures of data by administrative unit such as environment conservation zone and trip generation is converted from administrative unit to cell grid in proportion to ratio of area each other.

Traffic demand on roads: X4

Traffic volumes on roads are obtained from the traffic assignment model in the 4-step model by NAM model or eBUM. The traffic volume data is a type of link, not area. As for the conversion to cell grid for traffic volume data, the layer of road network data and cell grid are superimposed and traffic volumes within grid are summed as shown Figure 9.1-5.

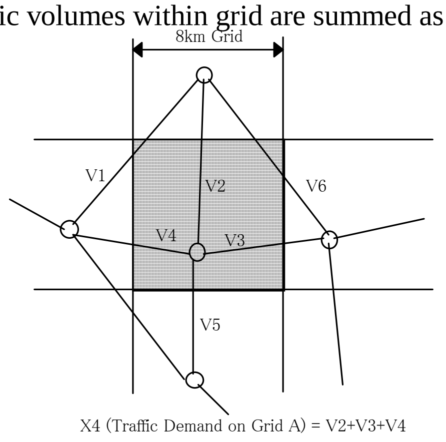


Figure 9.1-5 Procedure of Data Conversion from Network to Grid Data

9.1.4 Review of Intermediate- Processing (Spatial Analysis by GIS)

(1) Outline of Spatial Analysis by GIS

In the previous Section, the data of 7 factors are prepared to GIS format in the DRR development model. In order to find out the location to construct the bridges over the river all over the country, the collected data is analyzed. The DRR model uses 'Spatial Analysis method' to find out the higher potential area of new bridge construction. The spatial analysis is Potential Surface Analysis (PSA) technique, which is used in analyzing the potential area in "Nottinghamshire /Derbyshire Sub-regional Study" in 1969. PSA has more advantages than Overlay Technique. The spatial analysis analyzes each factor that gives impact on bridge demand. The grid with higher scores estimated by the spatial analysis indicates an appropriate location for developing the bridges. The spatial analysis is carried out in the following steps.

1) The data of each factor in the 8*8km grid is classified into the score ranges of 1 to 9 after data analysis of each factor is conducted.
2) By the liner equation with 7 variables (= 7 factors), the existing number of lanes of bridge is evaluated. The weights of variables are estimated by the regression analysis. In the DRR model, the total of weight is equal 100. he weight to analyze the T changed when the policy or is potential in improving the areahypothesis in improving is changed.
3) Finally, the weighted scores in grid of each factor are summed, and the higher the total scores are, the higher the potential of bridge construction in area is.

(2) Score of Each Factor

The data of each factor is classified into 9 scores. The method for division into 9 scores is as follows:

1) Calculate the average of each factor
2) Calculate the width of the data which is the average value multiplied by 2
3) Divided the width by number of the specified score which is 9

The data analysis shows that data of each factor is covered within a range of 90% of all data in the width. The data of 90% is equally divided into 9 scores, and the rest 10% are in opened end from the distribution of the data. Therefore, the data over the width is merged to the score 9.

(3) Analysis of Weight of Each Factor

In analysis the weight of each factor, the data in the area that have bridges at the present is only selected from among the all data included the areas without the existing bridges, and used to understand the relationship between the 7 factors. The analysis of the factors in the areas with bridges can see the intensity of the impact of constructing the bridge in each area.

Out of total 8,782 grids in a grid of 8 km x 8 km all over the country, 5,591 grids have the areas with bridges, which is equivalent to 64% of total grids. These grid data are used for analyzing the weight of each factor.

The equation representing total number of lanes on existing bridges in the grids set up with variables of 7 factors. DRR carried out the sensitivity analysis for three (3) types of equations: linear, exponential, and logarithmic equations. And then, linear equation with the weight parameters is suitable in higher correlation coefficient as shown below.

$$\Delta Y = a * X_1 + b * X_2 + c * X_3 + d * X_4 + e * X_5 - f * X_6 + g * X_7$$

Where,

ΔY	=	Appropriate number of lanes – present number of lanes
X_1	=	Density of river network
X_2	=	Density of road network
X_3	=	Environmental area
X_4	=	Travel Demand on roads
X_5	=	Trip generation within the area
X_6	=	Number of lanes on existing bridge
X_7	=	Demand of bridges in community

The weights of parameters are estimated by the regression analysis and the coefficient value for the equation is calculated. In the steps, the weight parameters in the equation with higher coefficient value are selected. Table 9.1-2 shows the estimated weights and coefficient value. As can be seen in Table 9.1-2, the higher weight scores are density of river network, environmental area and traffic demand on roads, while density of road network, trip generation number of lanes on existing bridge are somewhat lower in the weight. This means that the former factors are effective in the potential of new bridge construction.

Table 9.1-2 Estimated Weights and Coefficient Value

Coefficient	Coefficient value	Weighted scores	R^2
a	6.807	20	0.967
b	1.162	10	
c	6.292	20	
d	9.655	30	
e	4.901	15	
f	1.004	5	
g	0	0	

In feasibility study, however, the estimation of weight is carried out by Analytic Hierarchy Process (AHP) instead of the regression analysis mentioned above. AHP is the mathematic method to compare and find the importance rank of each factor in decision making process. The weight values are different between the figures in the master plan and feasibility studies.

(4) Potential Area for Bridge Construction

After the weight parameters are estimated, of every grid scores in each the weighted as a result of 9-1scores from The each grid have .med in the equationumare s factor in area the most potential is (9 =Scores)highest scores the with The grid .analysis .constructing the bridge

cted to find the potential area for constructing thes conduwa The spatial analysis that The analysis found .(years later 10) 2019and (ateryears l 5) 2014 ,2009bridges in on the assumption of in constructing the bridges expand in the future spotential area the areas with a score of over 6.

9.1.5 Formulation of Bridge Master Plan

In the DRR model, prioritization of potential areas for making a plan for new bridge construction during a decade is summarized on the following processes: 1) ranking grids of 8*8km by the spatial analysis scored from 9 to 1, 2) ranking the same group in 1) by the measure of traffic volume- distance in 1*1km grids obtained in the travel demand concept, 3) making the bridge master plan in the next 10 years in consideration of grid areas of 8*8km where the traffic capacity on existing bridges will exceed. Based on this prioritization, Thailand will need to have 1,433 new bridges for next decade.

In the master plan stage, the necessity of new bridges is examined from the potential areas in 8*8km grids. In case of that the traffic demand on bridges at the present exceeds the traffic capacity in the analysis, a new bridge will be constructed in future. At the beginning, total is km area8km x 8demand in traffic that support the in future number of lanes The .otal number of lanes on the existing bridges is caluculatedThe t .caluculated necessity number of lanes on bridges in future is caluculated as difference between the in consideration of bridges with a ,Moreover .former and latter figures .bridges need the construction in next decade 1,433 ,1.0capacity ratio of over -volume

9.2 Technical issues and advice for procedure of DRR Master Plan

DRR regards the developed model in consideration of the 7 factors (predicted traffic demand and other factors) estimates the necessity of bridges more effectively rather than that of only requests from communities. The spatial analysis can be well used in analysis of a large area (8*8km grid). However, the determination method of specific location for bridge construction in the fine 1*1km grid level has several issues in its method for the selected variables. Since the Feasibility study need to identify the more reasonable bridge location to be constructed in the higher potential area, the selection of appropriate bridge location is quite different in method to that in the Master plan study. The method in the Feasibility study employs the similar method as a process of road network plan which is more realistic.

In this Section, the several issues in the DRR model are discussed as shown below.

(1) Issue of Pre-Processing and technical advice

The issues in the Pre-Processing step are shown in Figure 9.2-1 in which necessity and issues of the selected 7 factors are mainly discussed.

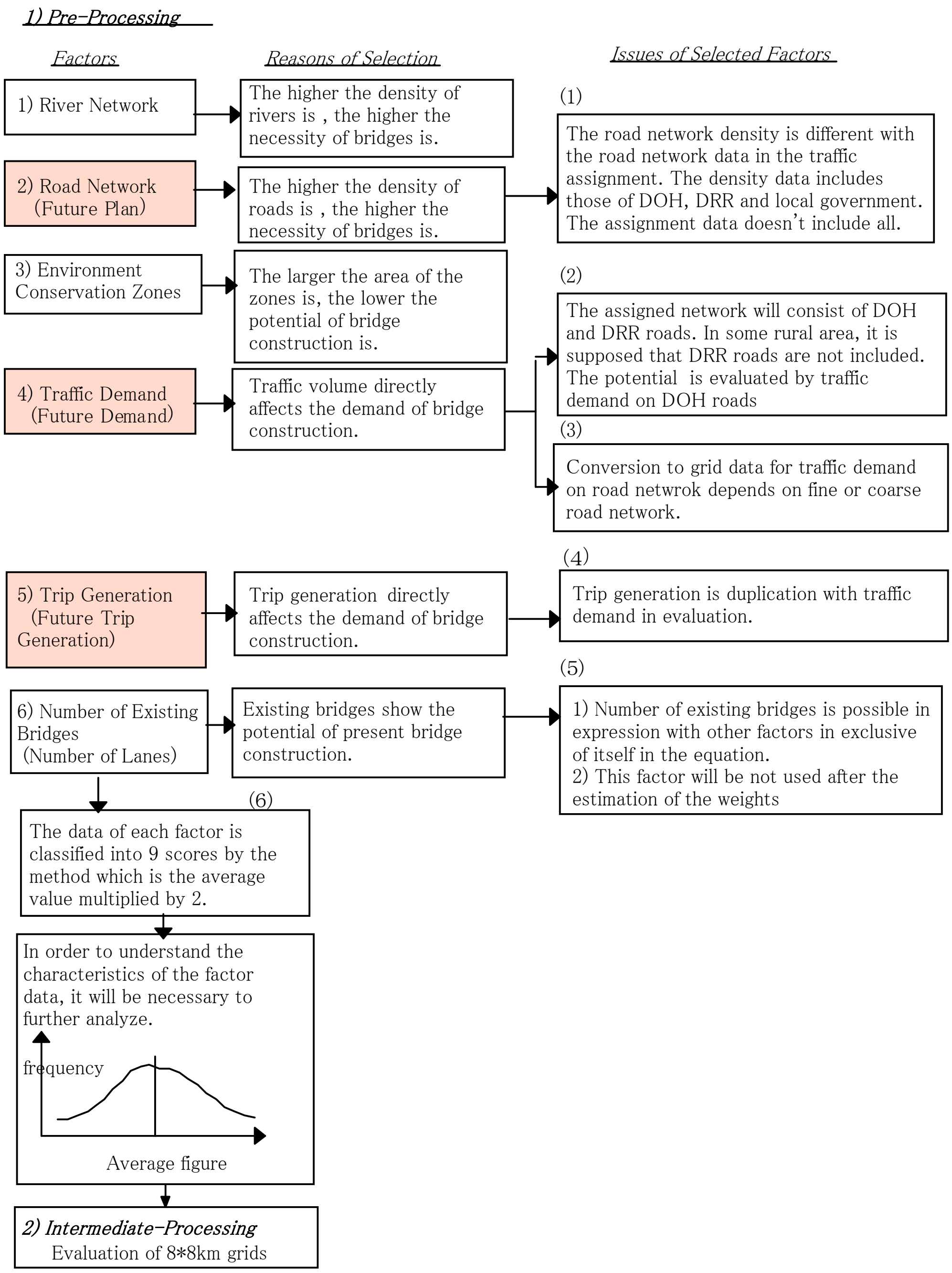


Figure 9.2-1 Issues in the Pre-Processing Step

1) Road Network Data

Road network consists of national roads, rural roads, and local roads by DOH, DRR and Local government, respectively. The road network in the DRR model is expressed in terms of the density of the road in area. However, the road network in the traffic assignment in the

4-step model of NAM model mainly consists of DOH roads, but the Bangkok City according to the information from the counterpart. Since the potential areas of bridge construction are evaluated in the liner equation with those variables, this is not well balanced between the road network density and road network data in the traffic assignment.

2) Traffic Demand

Traffic demand on roads which is one of the 7 factors is important in the evaluation of the potential of new bridge construction. The weighted score of traffic demand in the master plan report is 30, whose figure is the highest among the factors. The traffic demand is forecasted based on the NAM model in which the zoning size and road network in the 4-step model is well balance on the zoning size of district unit. According to the zone size, it is supposed that the roads selected in the network are mainly structured by DOH roads, but the Bangkok City according to the information from the counterpart. Especially, some zones in peripheral districts do not take the DRR roads in the network of the traffic assignment model. On the assumption of that, traffic demand on DOH roads is forecasted, not on DRR roads. After the potential area of bridge construction is identified by the Spatial Analysis in which the traffic demand in the 7 factors is evaluated by that on the DOH roads, the location of bridge is examined on the DRR roads. In this step, the new bridge location in the 1*1km grid is determined by the method which has two variables composed of the traffic demand and trip generation. Those variables are two of the 7 factors. The former relates to DOH roads. Therefore, it seems that the potential area of new bridge construction on the DRR road is evaluated by the traffic demand on DOH roads.

3) Conversion to Gird Data for Traffic Demand on Road Network

The traffic demand on road network must be converted to the 8*8km grid data as shown in Figure 9.1-5. The procedure to convert to the grid data is shown in the related Section. However, the traffic demand added on road network depends on the fine or coarse road network. In case of the fine network, summed traffic demand volume is larger than that of the coarse network. From the hearing, there was a reply that distribution is made correctly, on the other hands, since it seems the above understanding in a final report, comment is given here.

4) Trip Generation

Trip generation is one of the 7 factors. DRR defines in the master plan report in which demand of transportation within the area is that obtained by the trip rate within the area. The study team concludes as trip generation which is daily person trip, not traffic volume by some modal choice. The trip generation is assigned on roads in the traffic assignment model by used the origin/destination table and road network. That is the trip generation is included in the traffic demand on roads. Therefore, it seems that trip generation added to one of 7 factors is evaluated double.

5) Number of Existing Bridges

When the weights of variables are estimated in the liner equation used in Spatial Analysis, only the grid data with bridges among the all grid data is used for analysis. This indicates that the number of existing bridges is expressed with other factors in exclusive of itself in the equation. Since the input of the present data of the factors estimates the number of existing bridges, this factor should be not used after the estimation of the weights.

6) Score of Each Factor

Before the spatial analysis, the data of each factor is classified into 9 scores. The master plan report shows that data of each factor is covered within a range of 90% of all data in the width. The data of 90% is equally divided into 9 scores, and the rest 10% are in opened end from the distribution of the data. In order to understand the characteristics of collected data of 7 factors whether the data concentrates on some score, it will be necessary to further analyze the 7 factor data. For example, the frequency distribution of the data against the scores is analyzed shown in Figure 9.2-1. The characteristics of distribution of the data are obvious. The well distribution of the factor data is affected on the result estimated by the liner equation, i.e., distribution of grids with higher scores.

9.2.2 Issue of Intermediate-Processing and technical advice

The issues in the Intermediate-Processing step are shown in Figure 9.2-2 in which issues of the selected potential areas are mainly discussed.

1) Linear Equation used in Spatial Analysis

The liner equation used in Spatial Analysis is to project the appropriate number of lanes (ΔY) on new bridge by the 7 variables. The equation inputted the present figures for the 7 factors derive 0 values in the number of lanes (ΔY). In future, the different number of lanes between the existing lanes and future demanded lanes is evaluated by substituting the estimated future factors. Since out of 7 factors, only the road network X2, traffic demand X4 and trip generation X5 have future figures, The Spatial analysis indicates that ΔY in future is determined by future road plan and traffic demand.

From above reason, theoretically, X1:river network, X3:environmental protection area, and X6: the total number of lanes of the existing bridge will not affect to the required number of lanes in the future.

2) Selected Potential Area

The higher potential areas of bridge construction in 8*8km grid are selected in the DRR model. The potential areas with high scores are selected relatively among the 8*8km grids. in constructing area the most potential is (9 =Scores)highest scores the with The grid under some This shows that the necessity of the bridge is not decided .the bridge In the .criteria such as level of traffic service and alleviation of traffic congestion the bridge construction areas ,after selection of higher potential areas ,master plan wherethe traffic demand on bridges at the present exceeds the traffic capacity in the analysis, are decided.

the bridge master ,The DRR model only selects the grids with higher scores and then capacity ratio on existing bridge as a-plan is made taken into account the volume .criterionTherefore, it prefers that the criteria such as a volume-capacity ratio are included into the DRR model, not in the bridge master plan stage.

Figure 9.2-2 shows the suggestion of which at the beginning of the step, the volume-capacity ratio is estimated based on the traffic demand in 8*8km grid and then, the higher score grid with the higher ratio (i.e., over 0.7) is selected. The selected grid has the higher potential area under the criterion of the volume-capacity ratio.

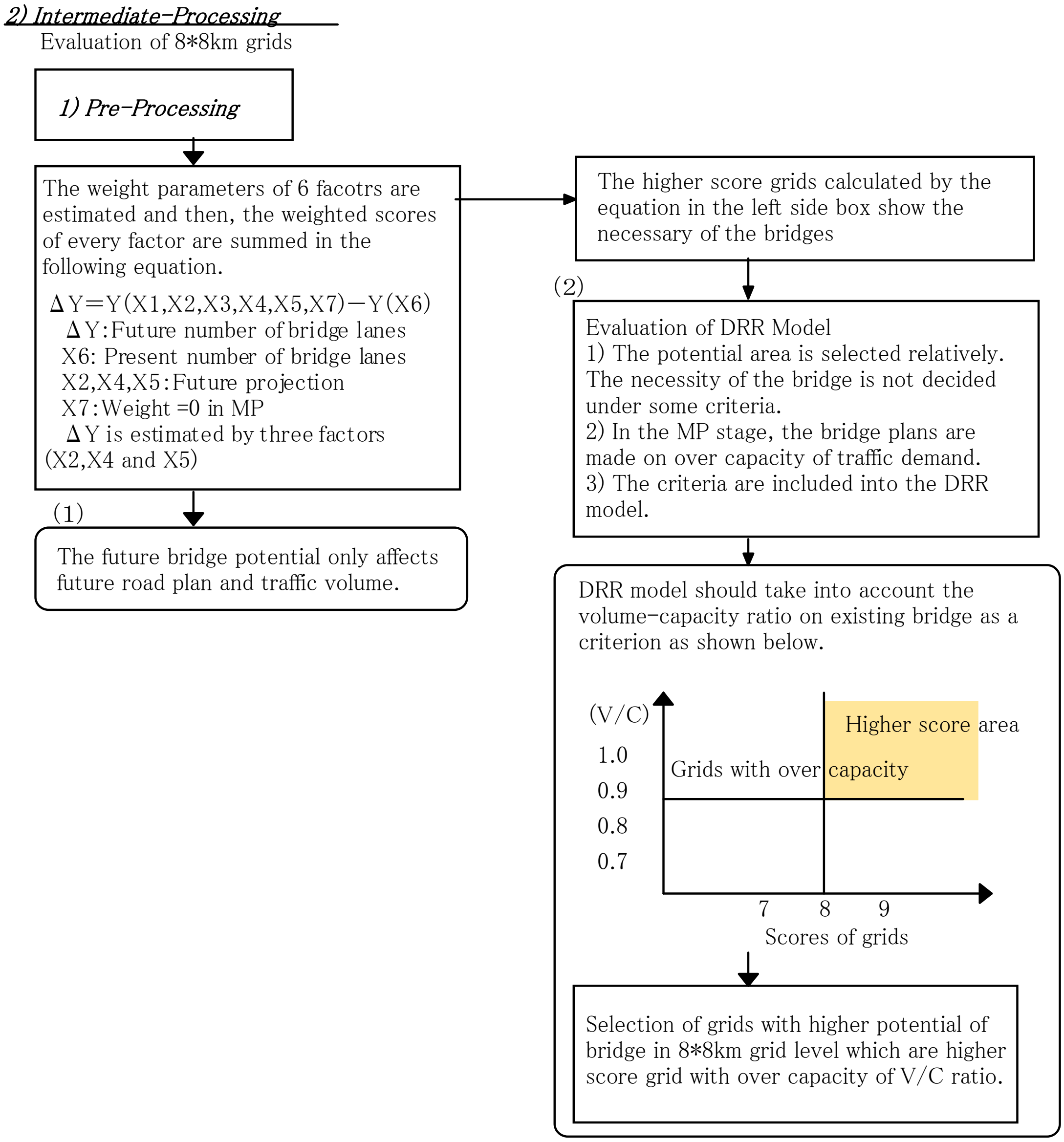


Figure 9.2-2 Issues in the Intermediate-Processing Step

9.3 Review of procedure of FS

9.3.1 Introduction

FS of a bridge is carried out after the area where potential of bridge construction is high is selected by the DRR model. As for selection of the alternative bridge location for FS, the following two methods are examined.

a) Selection of alternative bridge location in potential area using DRR model
b) Selection of the bridge alternative location by engineering judgment based on selection criteria.

A suitable bridge location is decided from 4 alternative bridge location selected above method.

In this section, at first, the outline of method of the DRR model which is a original technique of DRR (called it the post-process in DRR model) is summarized. And technical issues and advice will be provided.

9.3.2 Review of Post-Processing (Prioritization of Potential Areas)

This is the final step in the DRR model processing. After spatial analysis, the scored grids are further analyzed for determining more specific locations for bridge construction. The travel demand concept in terms of the shortest distance (or time) and travel demand is employed in this step. The 8*8km grids with higher scores are refined into 1*1km grids for determining the optimized bridge locations. The detailed is following.

(1) Determination of Specific Location for Bridge Construction in Grid 1*1km

1) Determination Method of Specific Location

The high score grids for new construction bridge in 8*8km grid level only show the necessary of the bridges, but appropriate locations. This means that the location to construct a bridge must be decided by some theoretical method in which DRR model employs evaluation factor in terms of traffic demand and distance to the nearest bridge location and selects the location in 1*1km grid level within the selected 8*8km grid. This is that the most appropriate location in 64 grids of 1*1km fine level within the 8*8km grid is selected.

The following equation is employed for evaluating the appropriated bridge location. The two variables are traffic demand in 8*8km grid and the shortest distance between areas in 1*1km grid and the nearest bridge. The traffic demand is classified into two terms, term ‘a’ for the traffic demand on roads and term ‘b’ for trip generation in 8*8km grid. The minimum value in the following equation shows the optimum location. In the master plan, a high rank of 1-20 cell grids from among 64 grids in 1*1km grid were selected as a candidate of new bridge construction.

$$Min(\sum_{i=1}^{n}(V_i L_i)_a + \sum_{i=1}^{n}(V_i L_i)_b)$$

By V_i = Traffic demand in 8*8km grid

L_i = the shortest distance between areas grid km1*1in and the nearest bridge

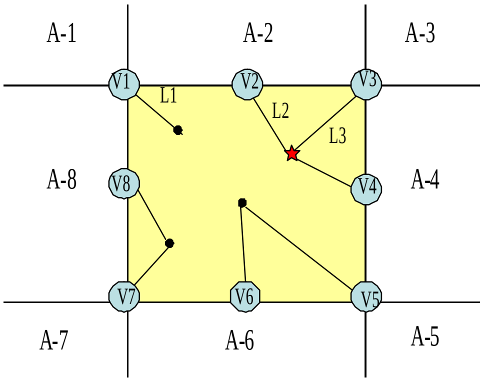
a = Traffic demand on roads in 8*8km grid

b = Trip generation in 8*8km grid

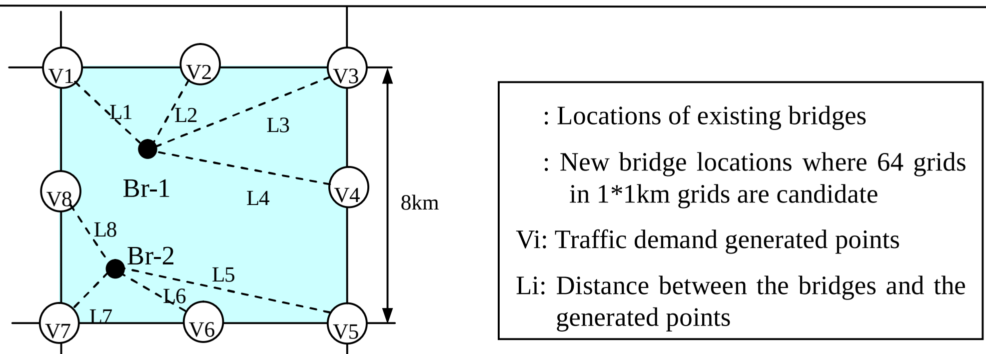
2) Evaluation Method for Traffic Demand: Term ' a'

Figure 9.3-1 shows the illustration of definition of V and L for traffic demand, term 'a'.

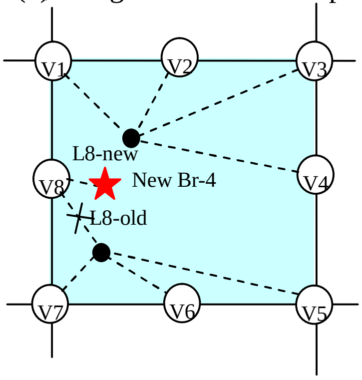
1) Traffic demands between surrounding grids such as A-1, A-2 and A-3 for selected grid A are defined as V1, V2, V3, etc., which distribute into each direction in proportion to the traffic demand in adjacent area. The traffic demands, V1-V8 on the grid boundary are calculated (see Figure 9.3-1 (1)).
2) The shortest distances L1-L8 between existing bridge locations (black point in Figure 9.3-1(2)) and the traffic generated points V1-V8 are decided, for example, the distances L1-L4 from the points V1-V4 to the nearest bridge location (Br-1) are calculated and the shortest points from Br-2 are the points V5 – V8.
3) At the present, the shortest point from V8 is Br-2. When in future new Br-4 (red star) is planned, the shortest points from points V8 change from Br-2 to New Br-4. Since the new bridge is planned, the distance from V8 is shorter than that at the present. In case of new bridge-5, this is the same procedure as that of new bridge-4. The shortest points from V3-V6 at the present will change to new bridge-5 and those distances in future from V3-V6 are shorter than that at the present. (see Figure 9.3-1(4))
4) Finally, the locations of new bridge along a river are moved within 64 grids, term 'a' in the equation is calculated. (see Figure 9.3-1(5))



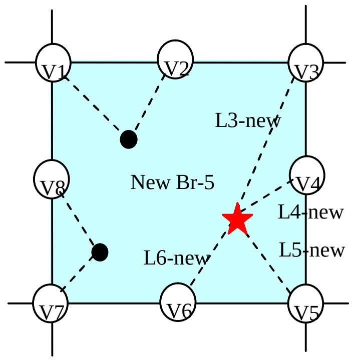
(1) Traffic demand generated points (Vi) in grid A



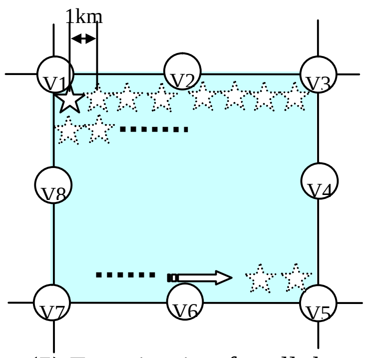
(2) Bridge locations at the present



(3) Proposed new bridge-4



(4) Proposed new bridge-5



(5) Examination for all the candidates

Figure 9.3-1 Illustration of Method for Traffic Volume: term ’ a’

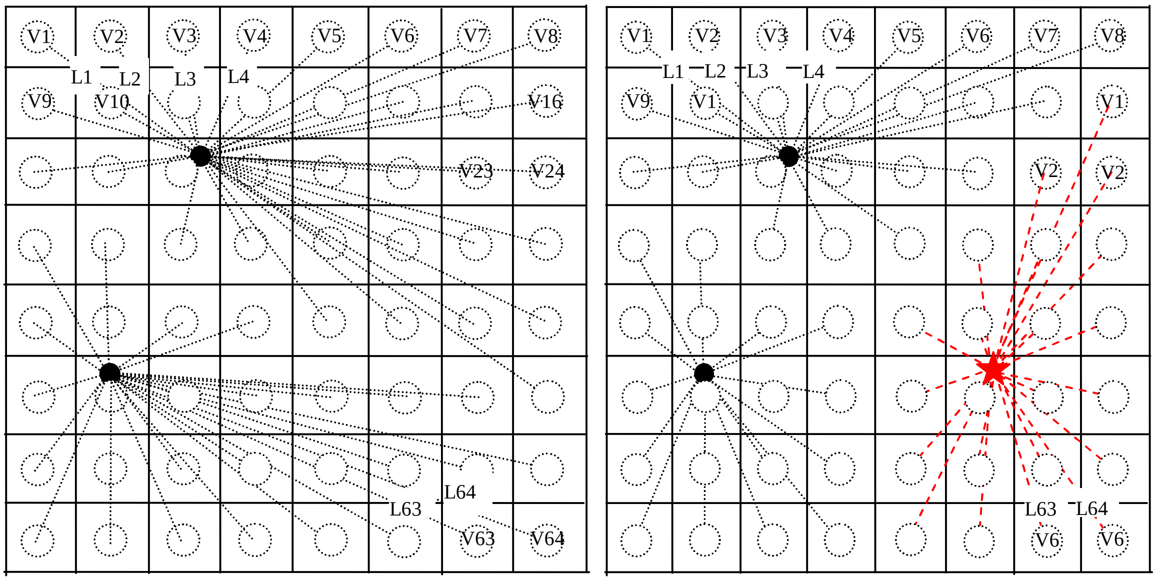
3) Evaluation Method for Trip Generation: term ’ b’

Figure 9.3-2 shows the illustration of definition of V and L for trip generation, term ‘b’.

1) Volume of trip generation is distributed in same proportion to a total grid of 64 in 1*1km grids.
2) Trip generation of V1, V2, etc., are located in each 1*1km grid. This is different in term ‘a’ which is located on the boundary of 8*8km grid.
3) The shortest bridge locations at the present from each grid are also decided on the same method as that of term ‘a’. (see Figure 9.3-2 (1))
4) Under the conditions of proposed new bridge, the shortest points from each Vi are changed based on the same method as that of term ‘a’. Then, the distance to new

bridge will be shorter than that at the present.

5) Finally, the location of new bridge along a river is moved within 64 grids, term ‘b’ in the equation is calculated.
6) The most effective location where the minimum value is shown based on the above equation is decided.



(1) At the Present Condition (2) Future Condition

Figure 9.3-2 Illustration of Method for Trip Generation: Term ’ b’

(2) Comparison of Analyzed Potential Area with Community Demand

In the master plan study, DRR model was inspected for the selected potential area of new bridge construction, which is compared to that for community demand. The areas by community demand have a score of over 6 in the DRR model. The figures are 399 bridges of total 625 bridges in Thailand, which is equivalent to 63.8%.

The DRR model is assessed based on the comparison to the community demand in the questionnaire from the responsible organization. However, since the number of collected questionnaire is not enough, DRR doesn’t conclude for the inspection result. DRR also said that it is necessary to carry out the further inspection for the analyzed scores in areas by responsible organization.

9.3.3 Review of Feasibility Study on selected 25 areas

In the Master Plan Study, the higher potential areas in 8*8km grids for new bridge construction are selected and the bridge master plan was made. In DRR, FS including concept design of bridge and economical evaluation about 25 potential areas where selected 2009’s master plan is carried out. Figure 9.3-4 are 11 provinces of the central part area selected as a candidate for FS. In this FS, the bridge position selected by a 1-km grid by the post-process of the DRR model is treated as reference, and the re-selection of the four alternative bridge positions is carried out to the every area by engineering judgment considering selection criteria.

The feasibility study is carried out on the following steps as shown in Figure 9.3-3.

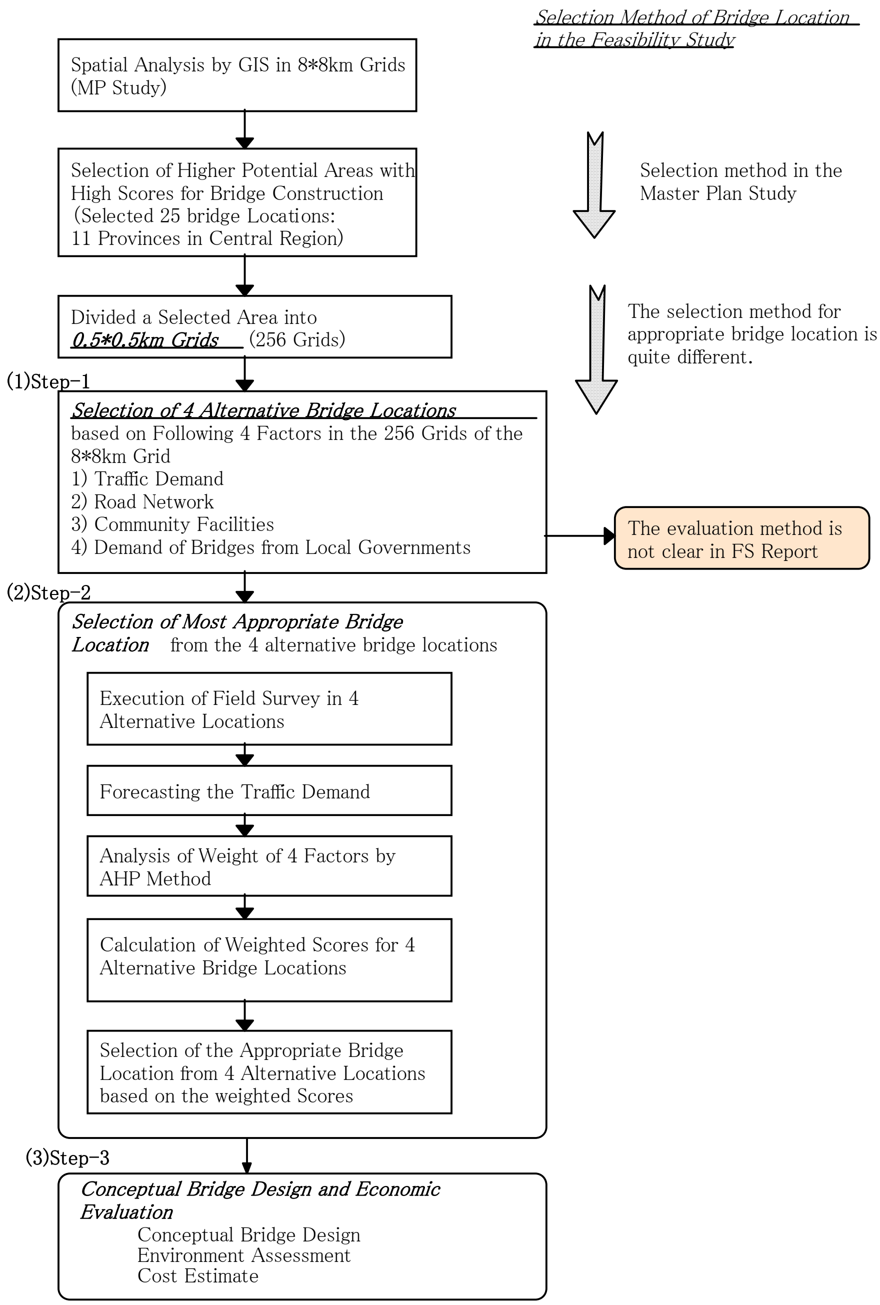


Figure 9.3-3 Study Flowchart of Feasibility Study

1) Step-1: Selection of 4 alternative locations

In FS in 2011 next to examination of the master plan in 2009, the re-selection of the potential area of new bridge construction of the 8*8-km grid of 25 was carried out. And then, the

8*8km grid in the selected areas is divided again to 0.5*0.5km grid instead of 1*1km grid in the master plan. The four (4) bridge locations are selected from the 0.5*0.5km grids based on the engineering judge, besides the following factors. As for the factors, community means public facilities such as school, temple and hospital, and the demand of bridge is for the request from the community.

1) Traffic demand
2) Road network
3) Community (facilities)
4) Demand of bridges

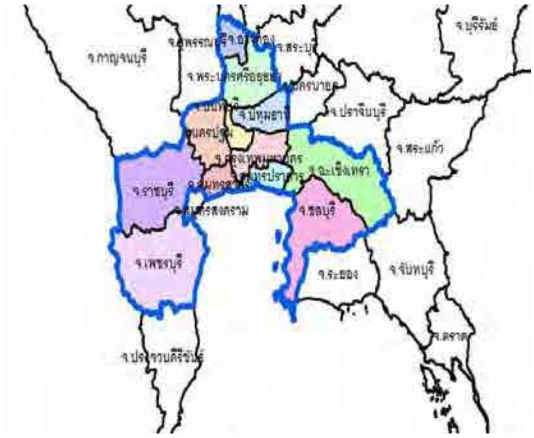


Figure 9.3-4 Selected 11 Provinces in the Central Region

2) Step-2: Selection of appropriate bridge location

The selection of appropriate bridge location is carried out on the following steps.

1) Execution of field survey
   - Topographic survey in scale of 1: 50,000
   - Soil and geological surveys (25 points)
   - Traffic count survey (10 locations)
2) Construction of traffic demand model
3) Analysis of weight of 4 factors
4) The weighted scores of 4 factors in each grid are summed on 4 alternative locations. The location with the highest score is selected as an appropriate bridge location. A total of 25 bridge locations are selected for the feasibility study.
5) Review of selected location whether the optimum location is, or not.

3) Step-3: Conceptual bride design and economic evaluation

Based on the selected 25 bridge locations, the feasibility study is carried out as shown below.

1) Conceptual bridge design
2) Environment assessment
3) Cost estimate

(2) Selection Method of Appropriate Bridge Location

When the appropriate bridge location is selected from among the 4 alternatives, the weights of 4 factors are reviewed in the feasibility study by the AHP method. The weights estimated in the master plan and feasibility studies are shown in Figure 9.3-3 in which the values in the medium table are by the AHP method with 8 factors included community requests (social factors) in the feasibility study report. The values in the right side table are that of 4 factors by the AHP method in the feasibility study report. As can be seen in Figure 9.1-10, the higher weight score is traffic demand. The appropriate bridge locations selected from the 4 alternatives have the highest value of the traffic demand among the 4 alternatives. The 18 bridge locations of 24 locations show the highest value of the traffic demand among the 4 alternatives, which is equivalent to 75% of the total.

	MP to prioritize 8km cell grid				Reexamination in FS to prioritize 8km cell grid			FS Selection of bridge location	
Infrastructure	X1	River network (km/m2)	20	=	River network (km/m2)	10	⇘		
								Width of river (m)	5
	X2	Road network (km/m2)	10	=	Road network (km/m2)	10			
							⇘	Road connection to the bridge (0,1,2 side)	9
								Major road network (0,1,2 side)	9
	X6	Number of existing bridge (lanes)	5	=	Number of existing bridge (lanes)	5	⇨	Distance from excisting bridge (km)	5
Environment	X3	Environment conservation zone (km2)	20	=	Environment conservation zone (km2)	20	⇨	Environment conservation zone (Yes, No)	16
Traffic demand	X4	Traffic demand on Roads (Daily traffic)	30	=	Traffic demand on Roads (Daily traffic)	20			
	X5	Trip generation (Daily person trip)	15	=	Trip generation (Daily person trip)	15	⇘		
								Travel demand (PCU/day)	36
Social factor	X7	Community request	0						
					Density of population	5	⇘		
								community along the side of river (0,1,2 side)	10
					Request of construction of bridge	4	⇨	Request of construction of bridge (Yes, No)	5
					Preliminary survey of the area	3	⇨	Preliminary survey of the area (Yes, No)	5
					Detailed model	5			
					Government policy	3			

Figure 9.3-5 Weights estimated in the Master Plan and Feasibility Studies

(3) Conceptual Bride Design and Economic Evaluation

1) Environment Assessment

The environment assessment is carried out on the 25 bridge locations in the feasibility study. The environmental and social consideration scoping is carried out as the initial environmental examination (IEE). The information of present natural and social conditions such as physical resources, biological resources, human use values and quality of life is collected and the environmental impacts on project construction and implementation stages respectively are studied in the 25 bridge construction areas. Those analyzed information is summarized in the environmental check list composed of current conditions and environmental impacts of the project area. As can be seen in the check list, the major negative impacts over the 25 project locations in the project implementation stage are on topography, air quality, traffic volume and shipping.

2) Economic Evaluation

1) Conditions of economic evaluation

The economic evaluation is made on the following conditions.

- Project life is 20 years.
- Discount rate is 12% commonly used in Thailand.

2) Economic Evaluation

The economic evaluation is made in the followings.

- NPV (Net Present Value)
- B/C ratio (Cost Benefit ratio)
- EIRR (Economic internal rate of return)

In the feasibility study of 25 bridges, only one bridge in which EIRR is less than 12%, B/C is less than 1.0 and NPV is minus, is identified.

9.4 Technical issues and advice for procedure of DRR FS

(1) Technical assistance for Post-Processing

The issues in the Post-Processing step are shown in Figure 9.4-1 in which issues of the bridge location selected in 1*1km grid are mainly discussed.

1) Bridge Locations by Higher Potential Areas

The high score grids for new construction bridge in 8*8km grid level only show the necessary of the bridges, but appropriate locations. In the high score grid, the location to construct a bridge must be decided by some theoretical method in 1*1km grids mentioned above. The bridge is classified into 3 categories, existing bridge, planned bridge on future planned road and bridge associated with higher potential area. The first and second categorized bridges already have been identified for the location of construction. The bridge location of third one is not identified. The identification of bridge location is only for third one. The most appropriate location of the associated bridge is selected in 64 grids divided into 1*1km fine level within the high score 8*8km grid.

2) Selection Method of New Bridge Location in 1*1km grid

The equation employed for evaluating the appropriated bridge location in 1*1km grid has two terms of ‘a’ and ‘b’ inside. The term ‘a’ is the traffic demand on roads and term ‘b’ for trip generation in 8*8km grid. The former is traffic volume on roads (the average daily traffic) and the latter is for trip generation (daily person trips). Since the bridge master plan report by DRR is not shown for modal split analysis of trip generation, it seems that the unit of trip generation is daily person trips. Under this understanding, the addition of the term ‘a’ and ‘b’ is difficult because both types of units are different. This issue is discussed again with the counter part.

3) Determination Method of Specific Location for Bridge Construction in Grid 1*1km

The location to construct a bridge is decided by some theoretical method in which DRR model employs evaluation factor in terms of traffic demand and distance to the nearest bridge location and selects the location in 1*1km grid level within the selected 8*8km grid. It is difficult to identify the bridge location based on two evaluation factors. In higher potential area of bridge construction, selection of bridge location needs many factors such as road and river network configuration, residential area, and public facilities. In the Feasibility Study, other determination method is proposed shown in Section 9.7. Since many engineering judgment is needed for selection of an actual bridge location, as the selection method of the bridge position after extracting the potential area of 8 km, the method of FS report is considered to be a realistic method.

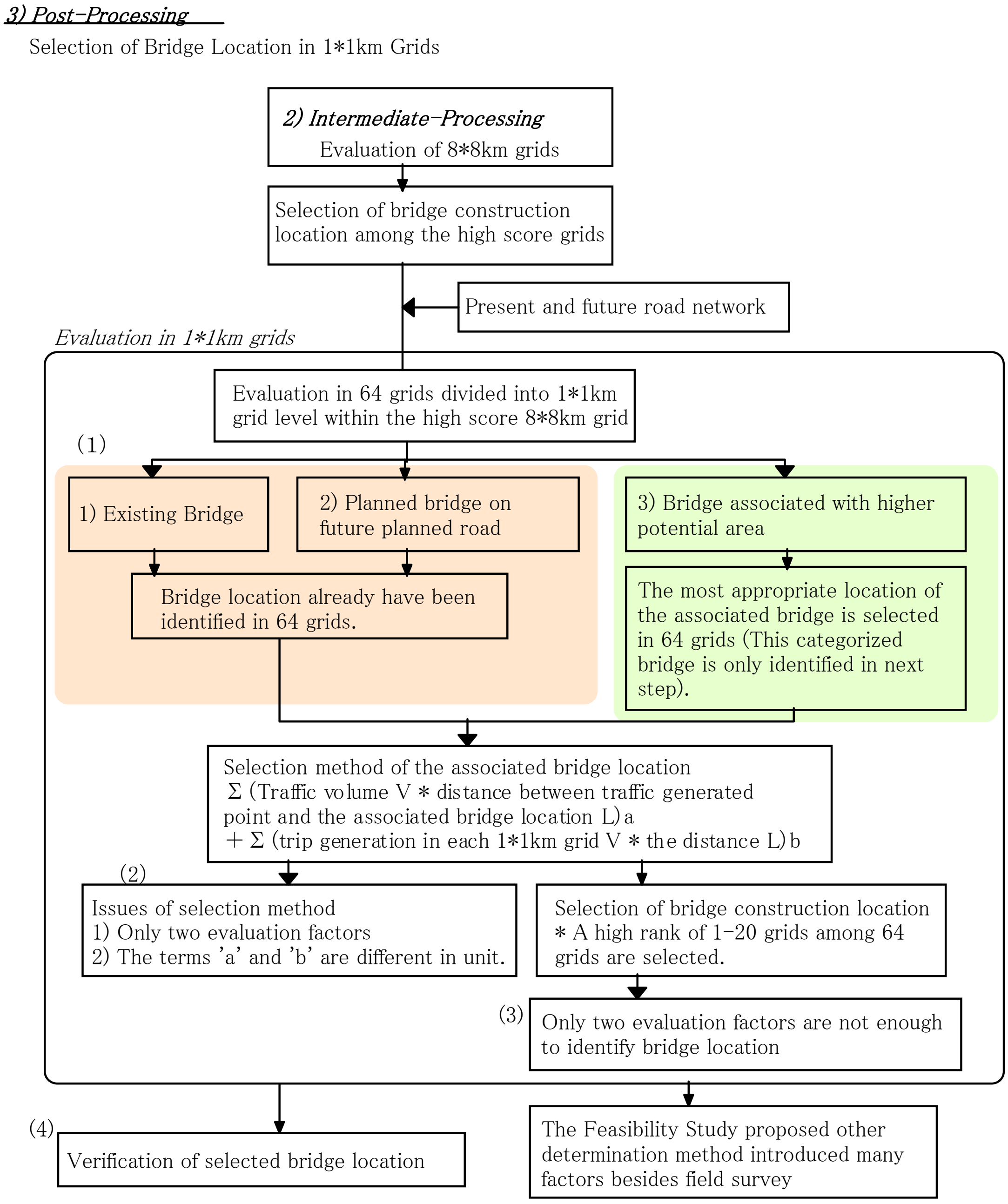


Figure 9.4-1 Issues in the Post-Processing Step

4) *Verification of Selected Bridge Location*

In the master plan study, DRR compared analyzed potential areas to community demand for new bridge construction. The areas with a score of over 6 analyzed in the DRR model are verified. The three hundred and ninety nine (399) bridges of total 625 bridges in Thailand, equivalent to 63.8%, are in those areas.

In order to employ the DRR model in local offices in DRR instead of request from the local community, the DRR model should be verified to accuracy for necessity of new bridge construction.

Figure 9.4-2 shows verification procedure of selected bridge location. In Step 1, the bridges selected by the DRR model are classified into two groups, one is with community demand, and other is for no demand. Step 2 makes frequency distribution against the score of grids each group. The each group is divided into 2 sub-groups by some criterion such as score 6. The sub-group A is categorized to areas or bridges with both community demand and high scores. The sub-group A is consistent in the potential. The sub-group B is low scores, though the areas have the community demand. On the other hand, the sub-group C with no demand has high scores. The sub-groups B and C should be further analyzed for the conditions of the areas or bridges and the results of analyses should be reflected on the DRR model. Through the analysis, the DRR model will be considerably advanced.

(4) Verification of selected bridge location

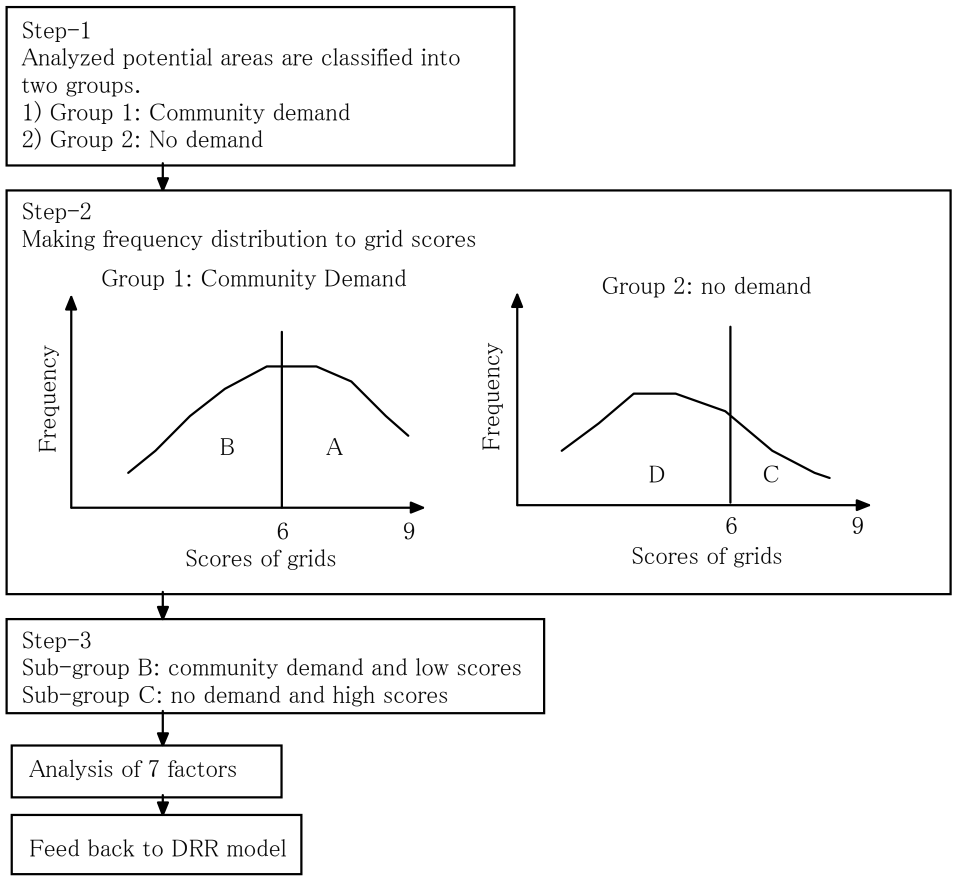


Figure 9.4-2 Verification Procedure of Selected Bridge Location

9.4.2 Technical advice for FS of selected 25 area

(1) Selection Method of Bridge Location in the Feasibility Study

The method to select optimum location of new bridge construction in the Feasibility Study on 2011 is quite different between that in the Master Plan Study after selection of the higher potential areas in 8*8km grids. The Master Plan Study employed the travel demand concept in terms of the shortest distance (or time) and travel demand to select appropriate location under the fine 1*1km grid. On the other hand, the Feasibility Study employed two step procedures. The step-1 is to select 4 alternative locations from among 256 grids divided into 0.5*0.5km grids in selected 8*8km grid. The step-2 is to select the most optimum location from the 4 alternative bridge locations.

The issues in the Feasibility Study are shown in Figure 9.1-12 in which issues of the bridge location in the Step-1 are mainly discussed. The four (4) bridge locations are selected from the 0.5*0.5km grids based on the engineering judge, besides the 4 factors mentioned in Section 9.7. As for the factors, community means public facilities such as school, temple and hospital, and the demand of bridge is for the request from the community. The employment of these factors is more reasonable in the selection of 4 alternatives. However, the selection method of the 4 alternatives is not clear in the feasibility study report as shown in orange colored box in Figure 9.3-3.

9.4.3 Technical advice for conceptual design of bridge

The conceptual design is carried out on the following assumption.

1) Conceptual design

- Abutment is on the ground.
- Vertical clearance is 6.0m.
- Gradient of vertical is less 4%.
- Width of bridge is 13.8m included 3.5*2 lanes, sidewalk and guard
- Central span is over 40m.

2) Cost estimate

- The bridge cost is estimated on the existing bridge cost of DRR.
- Unit costs of bridges which are classified into 3 scales in length, 40-55m, 55-75m, 75-100m, is used.
- Land acquisition cost is not accounted due to specific land to be donated from inhabitants.
- Maintenance cost is assumed on 25,000Baht/bridge/year.
- Environment cost is not mentioned in the feasibility study report.
- Design cost is assumed on 1.75% of the construction cost according to the Regulations of the Office of the Prime Minister on Procurement B.E. 1992 (2535) and administration cost is on 1.75% of the construction cost.

A general bridge type is selected in the conceptual design, and there is no particular problem as method of presuming an outline budget. However there is suspension bridge (center span 700m) over the Chao Phraya is in 25 selected bridges. It seemed that experience of the bridge type is insufficient in Thailand as long as a master plan figure is seen.

Technical advice is given and made it reflected in the structure plan of FS currently carried out.

I attach the advice carried out for FS of long span suspension bridge in Appendix 10-1.

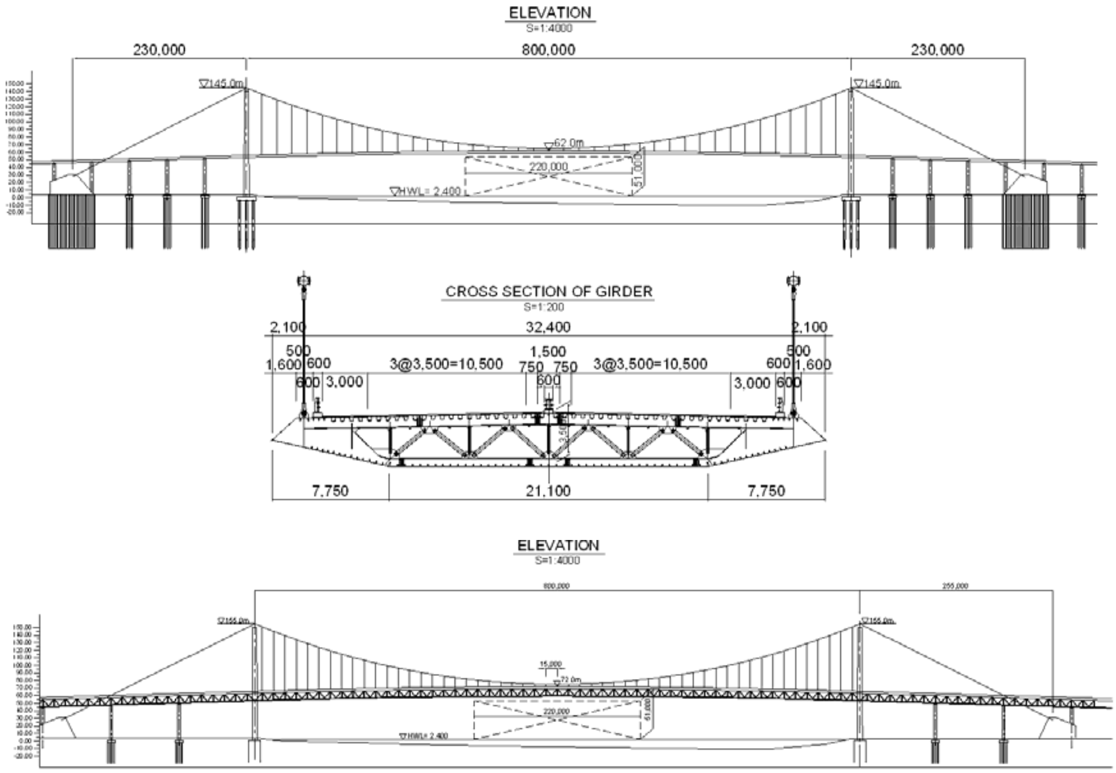


Figure 9.4-3Structure plan of suspension bridge in Samut Prakan district

Single-deck type and Double-deck type

9.4.4 Technical advice for economic evaluation method in FS

In the project evaluation of feasibility of new bridge construction, cost-benefit analysis is important in order to evaluate project validity and effectiveness. In FS of DRR, B/C is used as one of the economical evaluation indices. DRR do not have a guideline for calculation of B/C, DRR ask to provide reference of the systematized calculation procedure of B/C. In the FS report, calculation method of Benefit and reference data were not shown, and there was information from the person in charge that the method is left to the consultant normally.

In this study, study team explained the technique of the cost-benefit analysis in consideration of social and economical aspect based on "MLIT, City bureau, Manual for cost benefit analysis, and Octorver.2008" as reference. It is inapplicable without modification since unit value of a run cost and traffic accident loss in Japan is difference from Thailand, when standardizing the method in DRR in the future. However the calculation procedure will be a good reference by examining the statistical data in Thailand.

The summarized cost-benefit analysis technique procedure is shown in Appendix10-2.

Chapter 10 Conclusion

The purpose of the project was to enhance the capacity and ability of DRR officials in performing the maintenance and management on many rural bridges in Thailand. There have been many bridges left for a long time as they are even severely damaged without getting any treatment or retrofitting because the budget from the government is lacking and DRR officials are less conscious of bridge maintenance and management activities. In this project the first thing should be done was to enlighten and educate DRR officials about why and what they should do for bridge maintenance and management. Many of seminars and OJT programs, held during the project period, might contribute to educating DRR officials to learn well about the importance of bridge maintenance and management. Besides, a technical transfer was carried out faithfully for officials in both headquarter and local offices, and then they responded positively, which the project team was appreciating. At the same time, they had demanded many things from the team so the team actually made much effort at handling all requests in the appropriate manner as much as possible. Many of what they requested affected somewhat the way the team proceeds, in order to develop and transfer technology to engineers in local offices, and finally the results are summarized herein.

10.1 Bridge maintenance and management

- Bridge inspection and damage assessment

Some of goals planned to be achieved in this project have been including: bridge inspection and assessment manual development; bridge properties record ledger creation; tablet-use input system development; and OJT program implementation. What was the most focused on importantly by the team was utilization than development, so opinions and comments have been collected as many as possible, and discussion with the relevant participants has been made for many times to consider the way of inspection, data record, judgment criteria, and engineers' abilities as well during development process. More specific to note, choosing and narrowing the list of inspection items, and preparing many pictures relating to damage made it easier for providing the qualified judgment or assessment of damage. Also, table-use input system helped inputting and recording data on site shortly and more efficiently, which subsequently brought good reputation from all users. This system, of course, still needs to be upgraded further in service, but it would become very powerful when it comes to assisting bridge maintenance and management.

- Long-term bridge maintenance and management

In developing the long-term bridge maintenance and management plan, a budget simulation program was first created in order to optimize the budget necessary for carrying out bridge maintenance and management on the long term basis, taking account of a bridge life cycle. For a technical transfer, it seemed to take much time to make engineers in local offices to understand or be familiar with the content of the budget simulation program, so some of key engineers or members of a partner company have been finally chosen and educated ahead. Actually, it is expected to take years for most engineers to be able to handle it properly in their works, and there is only one way to try to practice PDCA activity repeatedly. The present system has been developed including many cases assumed at the early stage of development, because it was hard to find the exact data or history relating to backing up the system content quality, and it was found that there was few record of repair or retrofitting works and lack of budget for local bridges maintenance and management as well. After this, however, the budget would be balanced by using this system and further the system would evolve more accurate along with the increase of work record.

10.2 Bridge master plan

The bridge master plan is being developed and driven by DRR. This plan is likely to be very close to a theoretical idea, so it may need years or effort for improvement based on the experience toward its practical application. In this project, once an opinion about the need of improvement came out, the follow up has been seen. For example, one time the standard design for pier seemed to be hard to change, but now the pier that would be resistant enough against scouring phenomenon just get started being designed. Consciousness of the need must lead the change in the end, in spite of taking much time.

10.3 Flood damage rehabilitation

This was mainly to develop a flood damage rehabilitation manual and to give guidance to a trial construction as the OJT program. Since the damage due to flood that hit the last time was actually significant, many participants looked very interested in a technical program from the beginning regarding how to recover and prevent, and they even tried to make an extra budget for this program. The flood damage rehabilitation manual has been developed more practically by adding comments or opinions from engineers working in headquarter or local offices, and adopting the field-oriented method as possible, so it would be quite useful for many engineers working around all regions.

10.4 Capacity development

Many of seminars and OJT programs contributed to developing the capacity of engineers. As a result, DRR officials became highly qualified in doing their work of bridge maintenance and management.