Ministry of Transportation Department of Rural Roads
The Kingdom of Thailand

A SURVEY FOR THE BRIDGE MAINTENANCE PLANNING (THE CHAO PHRAYA RIVER CROSSING BRIDGES) IN THE KINGDOM OF THAILAND

REPORT 3

"MANUAL FOR LONG-TERM MAINTENANCE PLAN"

March 2011

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CHODAI CO., LTD.
METROPOLITAN EXPRESSWAY CO., LTD.

Ministry of Transportation Department of Rural Roads
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FORWORD

Department of rural roads(DRR) has maintenance office for each 12 bridges over Chao Phraya river and each maintenance office is performing maintenance work for the damages which were detected in the daily bridge inspection. This kind of responsive maintenance method may increase the LCC(Life Cycle Cost) and may reduce the bridge safety and reliability.

It is important to draft a long-term maintenance plan based on the principle of preventive maintenance so that we can reduce the maintenance cost and can have efficient maintenance management. Preventive maintenance means early detection of damage to reduce LCC. To put into practice, it requires establishing long-term maintenance plan and continuous action. The following are 2 manuals [(1) and (2)] for the 12 bridges over Chao Phraya river. This report is a volume of Manual for Long Term Maintenance Plan.

(1) Inspection/Evaluation Manual

[Main contents]
- Required fundamental knowledge for bridge inspection
- Contents of inspection, damage evaluation method and recording method

(2) Manual for Long Term Maintenance Plan
[Main contents]
- Determination method of countermeasure according to the damage level
- Estimation of the current and future repair cost to put preventive maintenance into practice
- Provision method for long-term maintenance plan with using LCC

We wish these manuals would contribute the maintenance works of 12 bridges over Chao Phraya river and DRR would continuously collect inspection data to improve these manuals.

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" MANUAL FOR LONG-TERM MAINTENANCE PLAN"

TABLE OF CONTENTS

1. Objective and scope of application

1.1 Objective

This manual is prepared for the formulation of a long-term maintenance plan so that efficient maintenance according to plan is carried out based on the principle of preventive maintenance.

1.2 Scope of application

Table/Figure 1.1.1 shows the bridge list which is the scope of application.

Table 1.1.1: The list of 12 Chao Phraya bridges

No.	Bridge name	Bridge type	Bridge length(m)	Open year	Years in service
1	Rama IV (Pakret)	PC box girder	416.00	2006	4
2	Rama V (Wat nakhonin)	PC box girder	320.00	2002	8
3	Rama VI (New Rama 6th)	PC box girder	290.00	1992	18
4	Krung Thon	Truss	352.00	1958	52
5	Phra Pinklao (Bangkok-Thonburil,Tha Chang Bridge)	PC box girder (with hinge)	280.00	1973	37
6	Memorial (Prapoddayodopha)	Truss (Bascule、Fixed bridge since 1984)	234.00	1932	78
7	Phra Pokklao (New Memorial)	PC box girder	212.00	1984	26
8	Taksin (Bangkok-Thonburi2, Sathorn)	PC box girder	224.00	1982	28
9	Rama III (New Krungthep)	PC box girder	476.00	2000	10
10	Krung Thep	Truss (Bascule)	350.00	1959	51
11	Industrial Ring Road Bridge North (Bhumibol 1 Bridge)	Cable stayed	582.00	2006	4
12	Industrial Ring Road Bridge South (Bhumibol 2 Bridge)	Cable stayed	702.00	2006	4

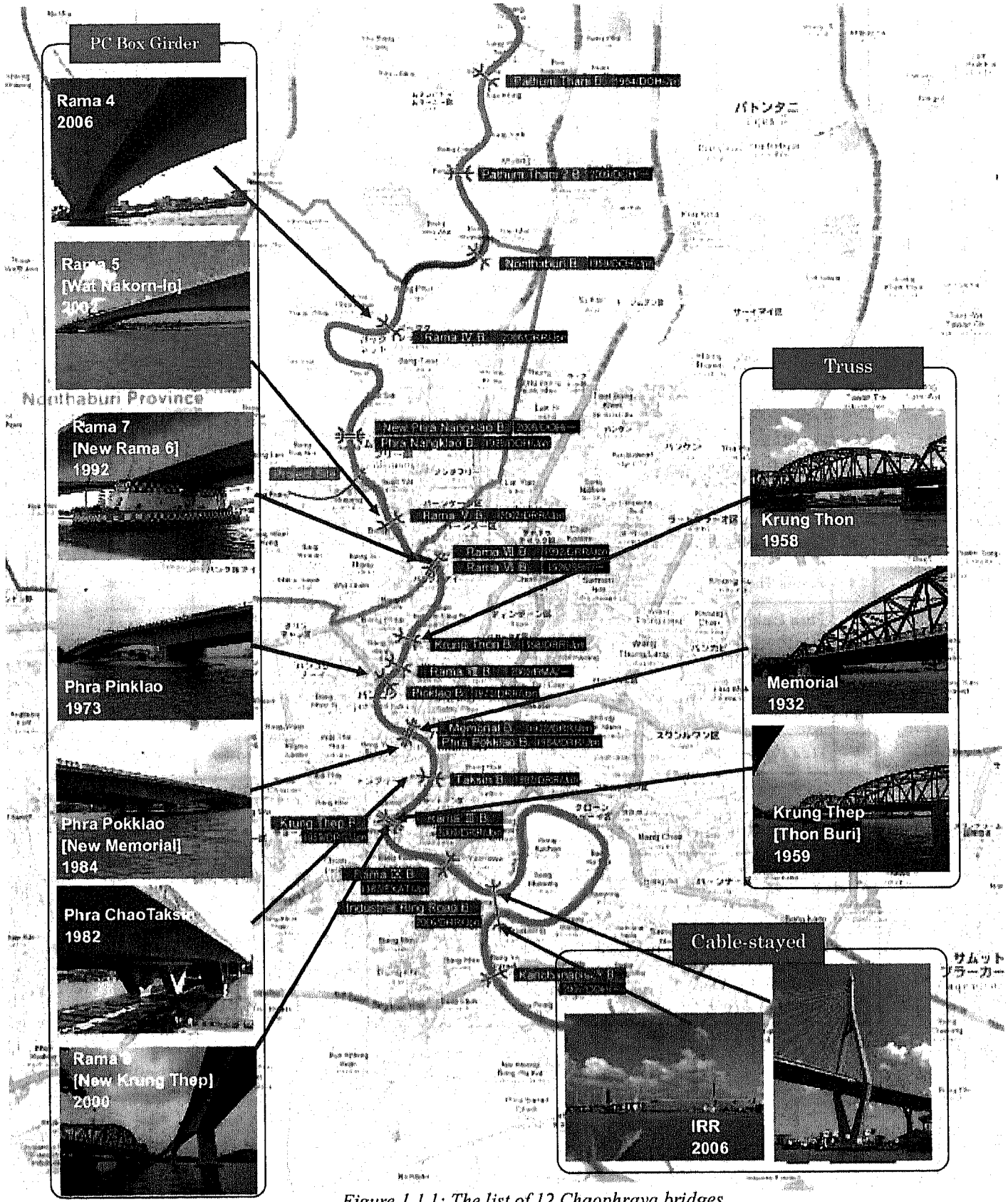


Figure 1.1.1: The list of 12 Chaophraya bridges

2. Determination of maintenance level

The concept of maintenance level is introduced as an efficient and effective maintenance method for the 12 Chao Phraya bridges. Using the maintenance level allows management of a bridge by the level related to the importance of the bridge and the purpose. In other words, it will involve writing of a maintenance scenario for each bridge.

Considering the bridge characteristics (including importance and environmental characteristics), the status of maintenance, and inspection results for the 12 Chao Phraya bridges, it is decided that the "countermeasure classification 3 (CC 3)" or more as shown in Table 2.1.1 is the target for the maintenance level to be fulfilled (specific countermeasure should be taken as soon as the condition reaches the "countermeasure classification 2 (CC 2)").
Compliance with this maintenance level will enable planned maintenance of safety and serviceability of bridges.

Table 2.1.1: Maintenance level for the 12 Chao Phraya bridges

Countermeasure Classification (CC) [Condition level]	Description	Reference	
		AASHTO	JAPAN
5	No damage	VERY GOOD	5
4	Almost no damage	GOOD	4
3	Repair is necessary depending on the situation	FAIR	3
2	Repair is swiftly necessary.	POOR	2
1	Repair is urgently necessary to ensure structural safety of bridge or to prevent damage to third parties.	CRITICAL	1

3. Long-term maintenance plan

3.1 Basic concept

Long Term Maintenance Plan of the Chao Phraya 12 bridges would be indicated as calculating the LCC (Life Cycle Cost) of next 100 years. This LCC would be based on the repair method according to countermeasure classification, repair timing and repair cost after countermeasure classification was judged by periodical inspection.

The example of estimation for LCC for next 100 years since establishing long-term maintenance is shown in Figure 3.1.1 and Table 3.1.1.

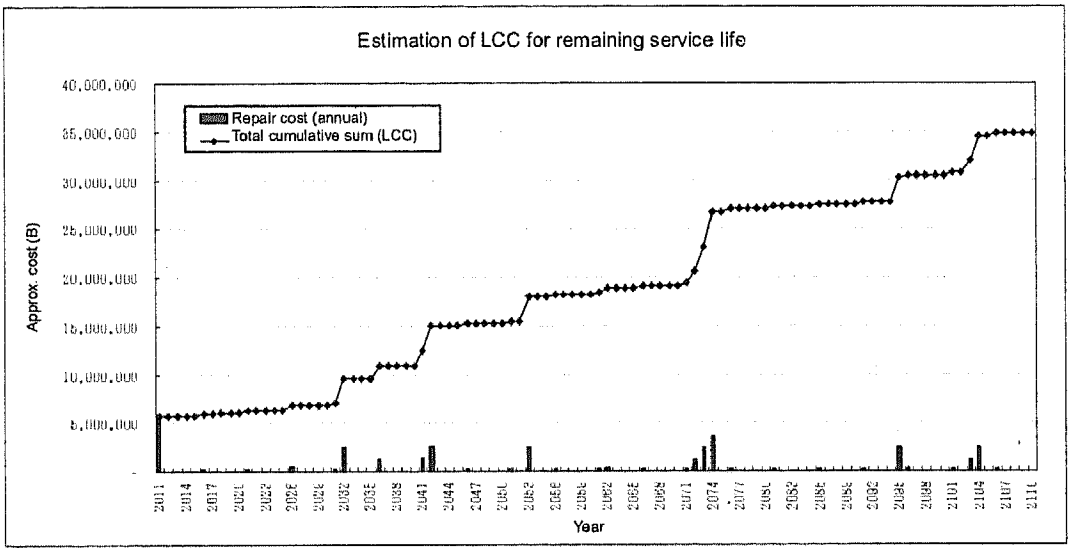


Figure 3.1.1: Estimation of example of LCC for remaining service life

Table 3.1.1: Planned maintenance repair and implementation year (example)

Member	No.	Type of damage	2011		2012		2013		2014		--	2109		2110	
			CC	Repair cost (B)	CC	Repair cost (B)	CC	Repair cost (B)	CC	Repair cost (B)		CC	Repair cost (B)	CC	Repair cost (B)
Girder	01	Crack, etc.	4		3.9	-	3.7	-	3.6	-		-	-		-
		Rebar exposure	5		4.9	-	4.8	-	4.7	-		4.5	-	4.4	-
		Damage at the anchorage of prestressing tendons	5		5.0	-	4.9	-	4.9	-		2.1	-	2.0	-
Deck	01	Rebar exposure	4		3.9	-	3.7	-	3.6	-		-	-	-	-
		Pop-outs	5		5.0	-	4.9	-	4.9	-		2.1	-	2.0	-
		Cracks in the deck	4		3.9	-	3.8	-	3.8	-		2.3	-	2.2	-
		Damage at the anchorage of prestressing tendons	5		5.0	-	4.9	-	4.9	-		2.1	-	2.0	-
	02	Rebar exposure	2	35,000	-	-	-	-	-	-		-	-	-	-
		Pop-outs	5	-	5.0	-	4.9	-	4.9	-		2.1	-	2.0	-
		Cracks in the deck	2	450,000	5.0	-	4.9	-	4.9	-		2.2	-	2.2	-
		Damage at the anchorage of prestressing tendons	5	-	5.0	-	4.9	-	4.9	-		2.1	-	2.0	-
Bearing	101	Functional damage at the bearings	2	120,000	5.0	-	4.9	-	4.8	-		4.6	-	4.5	-
	102	Functional damage at the bearings	2	120,000	5.0	-	4.9	-	4.8	-		4.6	-	4.5	-
	201	Functional damage at the bearings	5	-	5.0	-	4.8	-	4.7	-		4.5	-	4.4	-
	202	Functional damage at the bearings	5	-	4.9	-	4.8	-	4.7	-		4.5	-	4.4	-
Road surface	01	Unevenness of road surface	5	-	4.9	-	4.9	-	4.7	-		3.1	-	2.9	-
		Damage in pavement	2	2,500,000	5.0	-	4.9	-	4.7	-		3.1	-	2.9	-
Barrier	01	Damage in barriers	2	400,000	5.0	-	4.9	-	4.8	-		4.6	-	4.5	-
Expansion joint	01	Damage in expansion joints	2	1,467,400	5.0	-	4.9	-	4.8	-		4.6	-	4.5	-
Periodic inspection + reserve			2	233,400	5.0	-	2.0		5.0	-		-		5.0	-
Total				5,822,800		-				-		-			-

3.2 Management system for bridge maintenance

The bridge maintenance is managed by circulating the cycle of Plan (long-term maintenance Plan) → Do (repair countermeasure) → Check (bridge inspection) → Action (plan/Improve/Revise) to ensure continuous improvement resulting from the accumulation of basic data, findings, knowledge and experience.

The basic flow of bridge maintenance management is indicated as Figure 3.2.1.

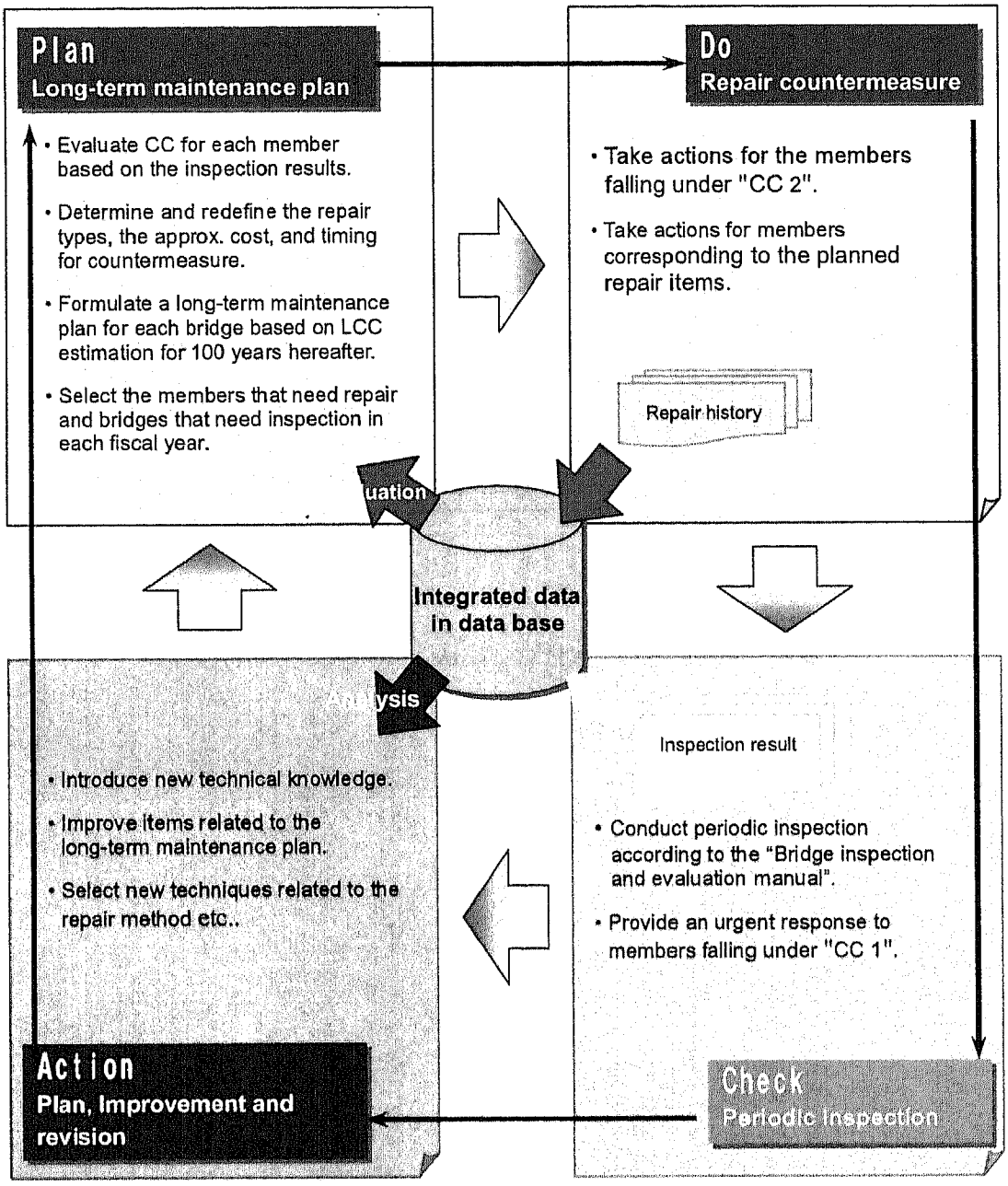


Figure 3.2.1: Management system for bridge maintenance

1) Plan (drafting a long-term maintenance plan)

The purpose is to formulate a long-term maintenance plan to ensure preventive maintenance for reduction of LCC and elongation of the service life of the structure by early detection of damage and early action, thereby realizing efficient and effective implementation of maintenance.

2) Do (implementation of repair and reinforcement countermeasure)

The purpose is to conduct advanced inspection (laboratory test, field non-destructive test, etc.) and review of repair method (estimation of damage factors, selection of best methods for the damage factors) and make repair designs based on the results of those and then conduct repair and reinforcement measures.

3) Check (periodic inspection of bridge)

The purpose is to conduct periodic inspection based on "Inspection and evaluation manual" to grasp the bridge condition and obtain the basic data necessary for developing a long-term maintenance plan. Accumulate the knowledge on the validity of the repair method and service life by monitoring the deterioration over time of the repaired and reinforced bridges thereby to improve the prediction accuracy of the long-term maintenance plan.

4) Action (sustainable plan, improvement and review)

The purpose is to ensure further improvement of the efficiency and quality of maintenance by implementing repair and reinforcement measures, analyzing periodic inspection results and introducing new knowledge, thereby revising the management level in the long-term maintenance plan or improving the accuracy of the deterioration prediction method.

3.3 Long-term maintenance plan

3.3.1 Contents and flow of long-term maintenance plan

A long-term maintenance plan for each bridge should be described using the total sum of LCC in 100 years hereafter.

In a long-term maintenance plan, countermeasure will be taken that corresponds to the countermeasure classification for the damage detected in the initial periodic inspection. After the appropriate countermeasure is taken to restore the sound condition of the bridge, periodic repair and member exchange appropriate for the service life of the bridge will be properly conducted from the viewpoint of preventive maintenance, thereby ensuring efficient maintenance of bridge soundness. The flow chart for LCC estimation is shown in Fig. 3.3.1.
LCC occurring from maintenance work should be estimated for the following items:

LCC = total sum of the maintenance cost in 100 years hereafter

[STEP-1: Maintenance cost for the damage detected by periodic inspection]

= Repair cost for the damage detected in the periodic inspection (1)

[STEP 2: Estimation of the planned maintenance cost to occur after the repair]

+ Cost for periodically conducted inspection work ..... (2)
+ Cost of repair for damage due to deterioration over time ..... (3)
+ Cost for renewal of members whose periodic exchange is necessary ..... (4)

• Cost (1) is the repair cost of damaged members identified as "CC 2" in the initial inspection.

• Cost (2) is the reserve cost related to periodic inspection, daily maintenance work and unexpected countermeasure.

• Cost (3) is the repair cost for the members identified as "CC 2" due to the deterioration over time which was originally identified as "CC 5" to "CC 3" in the initial inspection. In addition, the repair cost after the service life of the member repaired by planned repair.

• Cost (4) is the repair cost after the service life of the common members to be planned renewal.

• The timing of posting the repair cost varies depending on the service life of members or the countermeasure classification. Figure 3.3.2 is the conceptual diagram showing the countermeasure classification changes due to deterioration over time.

• For the "CC 1", it triggers implementation of emergency response measures, and therefore it is ruled out of LCC.

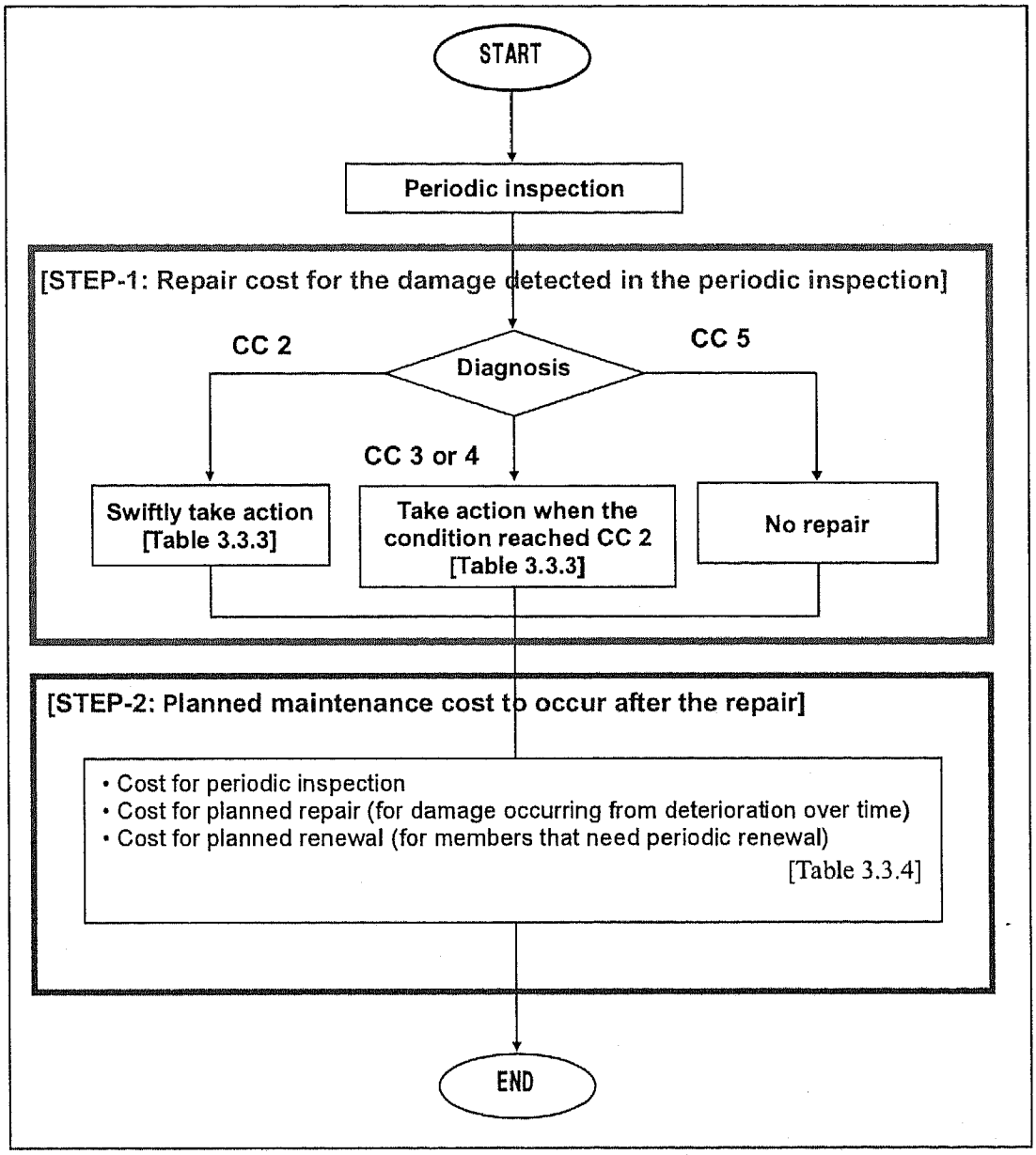


Figure 3.3.1: Flow chart for LCC estimation

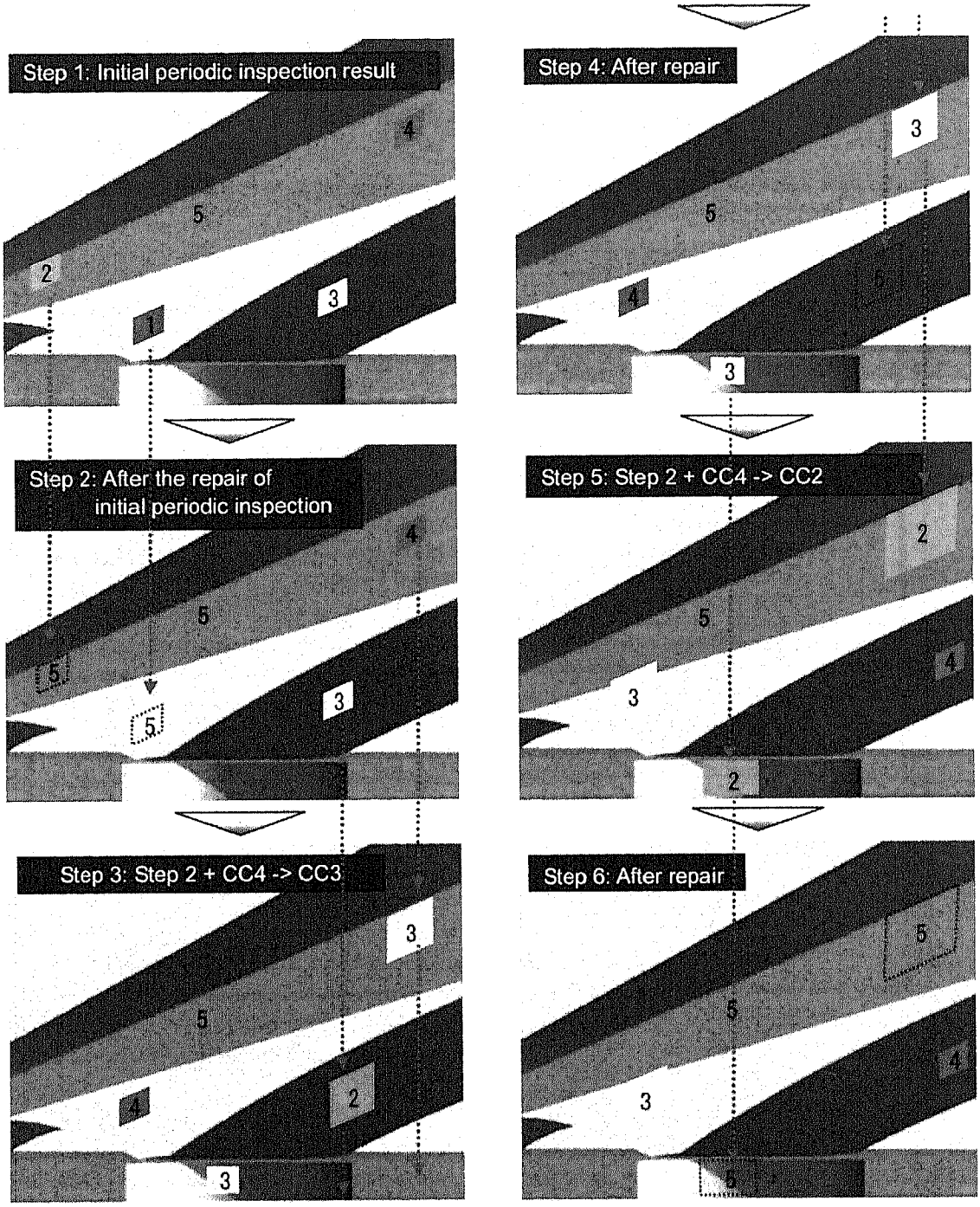


Figure 3.3.2: Schematic diagram of repair for damage occurring from deterioration over time

Table 3.3.1: Countermeasure classification (CC)

Countermeasure classification	Judgment
5	No damage is seen. Or repair has been completed.
4	Minor damage that does not need repair
3	Repair is necessary depending on the condition.
2	Swift repair is necessary
1	Urgent repair is necessary to ensure structural safety or prevent damage to third parties

3.3.2 Judgment of countermeasure classification

(1) Fundamentals in judgment of countermeasure classification

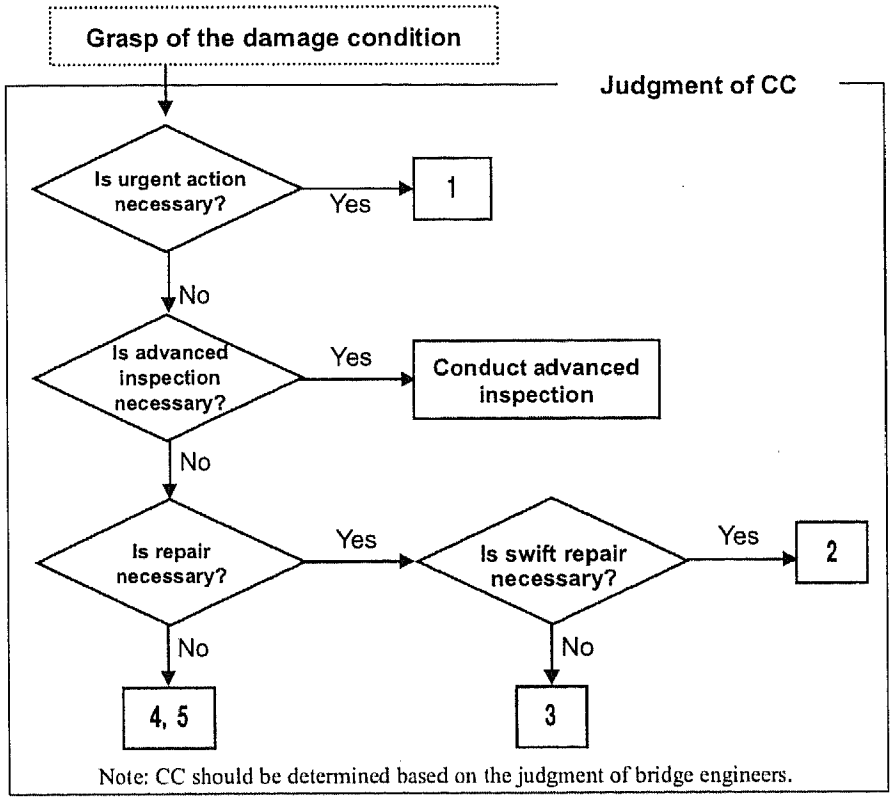
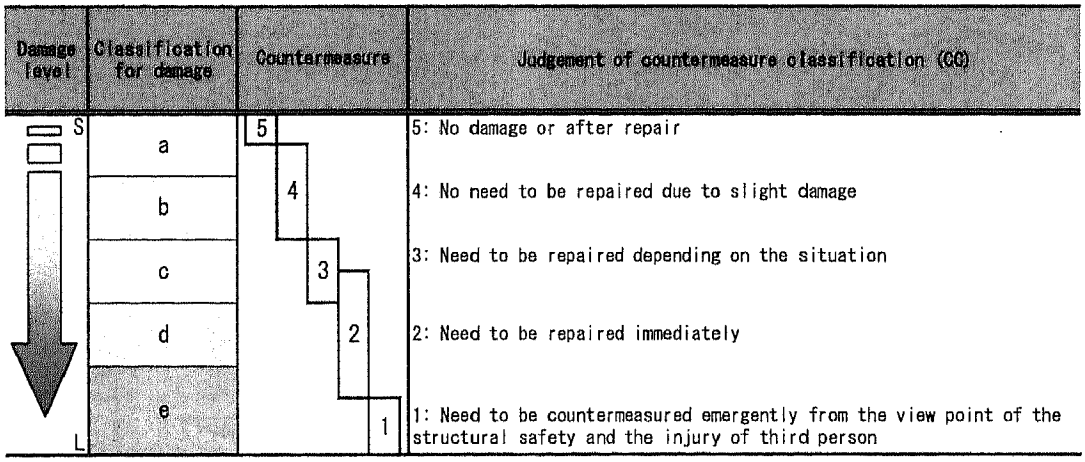


Figure 3.3.3: Flow chart for the determination of countermeasure classification

Judgment of countermeasure classification should be based on the synthetic evaluation of different damage factors including the importance of a members, the progress of damage, or environmental conditions according to the flow chart shown in Figure 3.3.3. In principle judgment should be made for each damage level by the member or the part.

The basic criteria of the determination of countermeasure based on the damage level obtained from inspection results are shown in Table 3.3.2.

Table 3.3.2: Countermeasure classification related to the damage level



Explanation of CC

[CC 5]

This level applies to the condition where no damage is detected by periodic inspection.

[CC 4]

This level applies to the condition where minor damage is detected by periodic inspection but it need not to be repaired.

[CC 3]

This level applies to the condition where damage is detected by periodic inspection and it need to be repaired. It may also apply to the condition where the cause and extent of the damage is clear, there is no great urgency suggested, and it is judged no serious damage to the safety of the structure will occur until the next periodic inspection even if the identified damage is left unrepaired.

[CC 2]

This level applies to the condition where the damage detected by periodic inspection is a seriously advanced one, the functionality or safety of the damaged part or member is remarkably degraded, and it is judged some action such as repair is necessary until at least the next periodic inspection.

[CC 1]

This level applies to the condition where the structural safety of the bridge is seriously degraded and urgent action is judged necessary.

"Manual for the long-term maintenance plan" provides for the flow chart for CC judgment for 17 types of damage listed by "Bridge inspection and evaluation manual" to estimate LCC.

An example case on "cracking, water leakage and free lime (superstructure)" is shown in the next page.

(2) Judgment of countermeasure classification related to damage level

1) Corrosion

(a) Inspection area

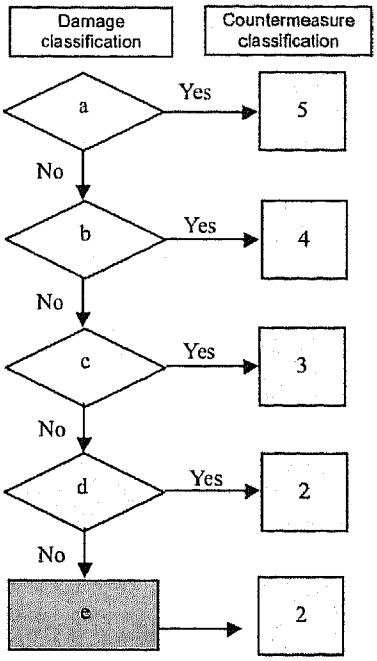
The condition of corrosion in the main members (girder, lateral bracing, end diaphragm, etc.) within visually perceptible area shall be inspected approaching close to the girder end area. Here the end diaphragm area may be considered as one panel (divided area with next diaphragm, etc. from the girder end) of a girder or the area of 5m from the girder end.

(b) Classification of damages

The inspected results shall be evaluated with the following classification:

Evaluation criteria			Classification (damage level)
Existence of rust	Depth of rust	Extent of rust	
Yes	-	-	a
No	Surface only	Local	b
		Global	c
	Reduction in thickness, Remarkable expansion of steel surface	Local	d
		Global	e

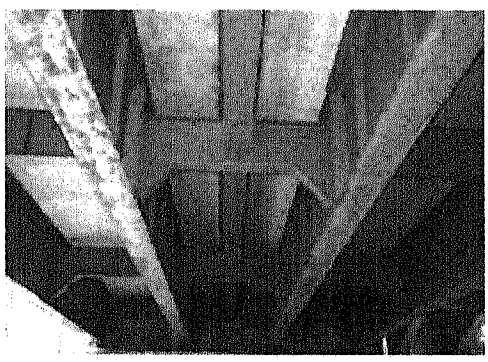
(c) Judgment of CC



Damage level b -> [CC 4]

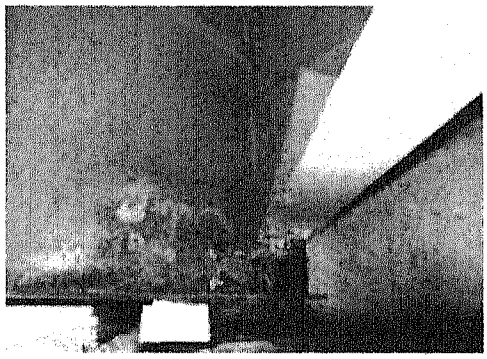
Local rust on the girder surface

Damage level c -> [CC 2]



Global rust on the lower flange surface

Damage level d -> [CC 2]



Local rust with thickness reduction at the girder end

Damage level e -> [CC 2]

Global remarkable rust with thickness reduction on the whole girder