Road Development Authority

Japan International Cooperation Agency

Bridge Management Guidelines

October 2017

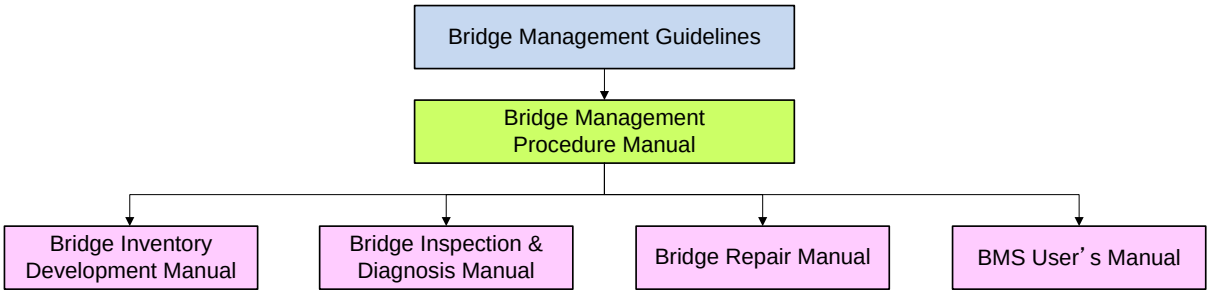
The Project for Capacity Development on Bridge Management In The Democratic Socialist Republic of Sri Lanka

Preface

In order that the entire project outputs can be sustainably used in the future, it is quite essential to document the basic ideas as well as principles of actions for the bridge management cycle, from bridge inspection to diagnosis, development of management plan and ex-post evaluation, including the details, sequence of getting outputs and the results of the study.

For this purpose, documentation called “the Guideline” is hereby developed.

This Guideline is the upper level standard for developing the bridge management plan, and there-under various manuals are developed as lower standards, documenting the specific procedures based on this Guideline.



Use of Terms and Its Concept

In this Guideline, the terms given below are used with the following definition.

(1) Indicator and Level

Both words “indicator” and “level” are used to determine the target objectives.

For examples, the target bridge management level should be set up by using the indicator of “Health Index (HI)” as “HI is 60 or greater”.

(2) Damage, Defects and Deformation

“Damage” is the general term which expresses the phenomenon that bridge member loses its function.

Whereas, deformed state of the bridge member is called “deformation”. Deformation is not always considered as “damage”.

It is called “defect” when the bridge member is deficient in its required functions from its intended state.

(3) Deterioration and Performance Degradation

Deterioration is the phenomenon that material properties are being impaired with time.

Performance degradation is the phenomenon that performance of a bridge member is being impaired with time due to deterioration as well as other factors such as fatigue by cyclic loads and vehicle collision.

(4) Repair and Strengthening

All the measures to remove the damage occurred on a bridge member, to restrict the progress of damage for keeping its performance, or to recover up to its damage free state are called “repair”.

Contrary, all the measures to be taken to improve the performance of a bridge member up to a level higher than its as constructed one are called “strengthening”.

(5) Reconstruction

Bridge reconstruction is to demolish the existing bridge and construct a new bridge.

Replacement of a bridge member is a part of the bridge repair.

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Abbreviations

Organizations	
GOSL	Government of Sri Lanka
MHEH	Ministry of Higher Education and Highways
JICA	Japan International Cooperation Agency
RDA	Road Development Authority
Division in RDA	
CD	Construction Division
ES	Engineering Services
M&M	Maintenance and Management
BD	Bridge Designs
P	Planning
PMU	Project Management Unit
RBCU	Rural Bridges Construction Unit
R&D	Research and Development
BM&AU	Bridge Management and Assessment Unit
BAU	Bridge Assessment Unit (1990s)
Position	
DG	Director General
ADG	Additional Director General
DD	Deputy Director
C/P	Counterpart
PD	Provincial Director
CE	Chief Engineer
EE	Executive Engineer
TO	Technical Officer
Manual	
BMM1997	Bridge Maintenance Manual /1997 RDA
RMM1989	Road Maintenance Manual /1989.2 RDA
VRCSG	Visual Road Condition Surveys Guidelines / 2012.6 RDA Planning Division
Others	
BMS	Bridge Management System
OJT	On-the-Job Training
BOQ	Bill of Quantity
RMTF	Road Maintenance Trust Fund
BIV	Bridge Inspection Vehicle
PPE	Personal Protective Equipment
DP	Damage Point
HI	Health Index
II	Importance Index
FOI	Functionally Obsolete Index
LHS	Left Hand Side
RHS	Right Hand Side
BDS	Bridge Database System
BRMS	Bridge Repair and maintenance System
BISS	Bridge Inspection Support System

1. Structure of Bridge Management

Bridge management should be implemented in accordance with the work flow given in Figure 1-1.

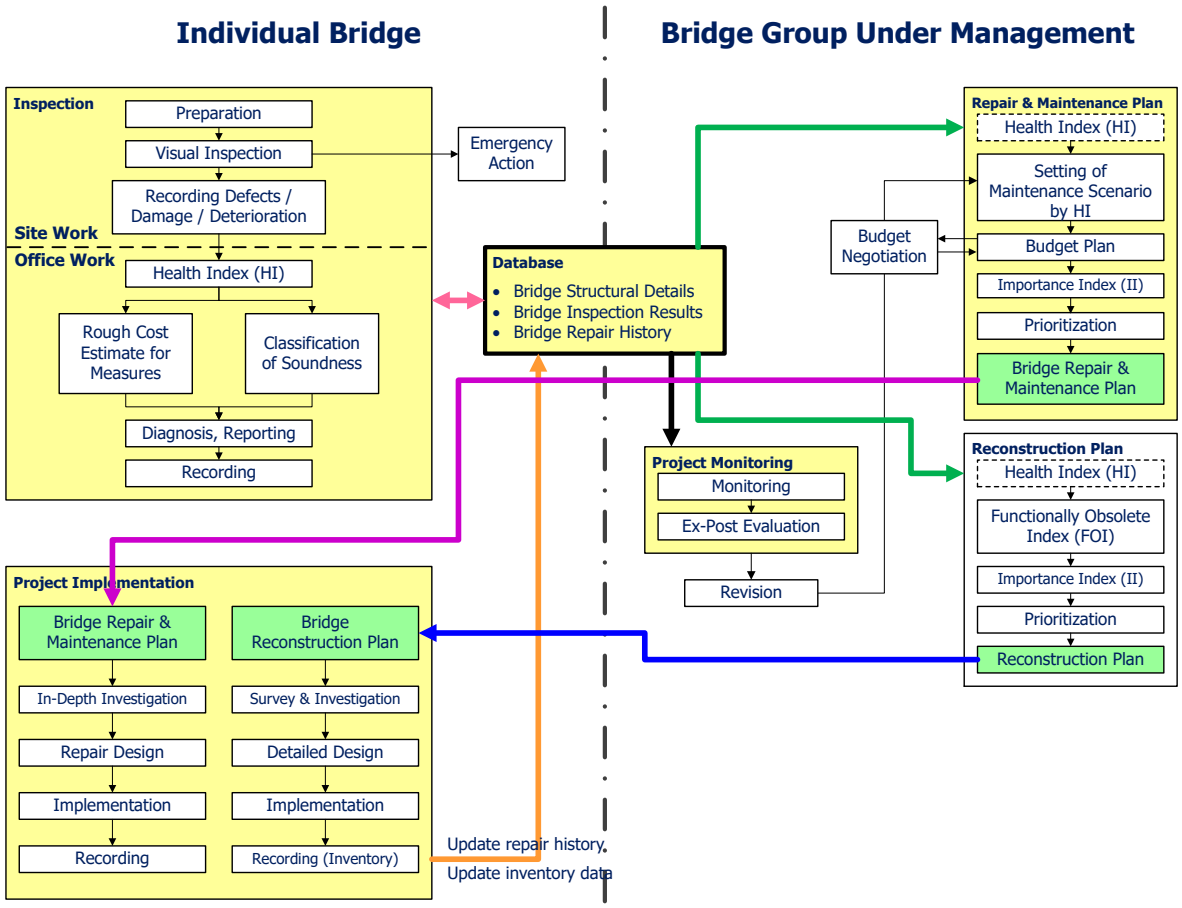

Figure 1-1 Work Flow of Bridge Management

The general work flow of bridge management is as described below.

1) Bridge inspection will be carried out to understand the present condition of individual bridge and digitize its results.

2) Based on the obtained information by bridge inspection, the condition of the bridge will be evaluated.

   Evaluation of bridge conditions is to quantify the soundness of various bridge members and scale of repair works (costs).

3) With the use of information and data obtained from evaluation of conditions, “Bridge Repair & Maintenance Plan” will be developed.

Bridge Repair & Maintenance Plan is, for a certain period of time, to efficiently repair the bridge members which are below the target management level at present.

※ *Target bridge management level is not uniquely determined; but should be determined in consideration of availability of budget to achieve such target management level.*

Therefore, it is noted that necessary budget options for several bridge management scenarios (target management levels) should be prepared for comparison and decision-making.

4) Based on the evaluation of conditions and degree of functional obsolescence of the bridge, "Bridge Reconstruction Plan" will be developed.

Bridge Reconstruction Plan is the list of bridges in the order of priority of reconstruction.

5) Ex-post evaluation should be made based on the changes with time of data and information, which can be obtained from the evaluation of conditions, bridge repair and maintenance plan, and bridge reconstruction plan.

2. Target Bridge Management Level

2-1. Bridge Management Indicator

For the bridge management, “Health Index (HI)” will be used as the bridge management indicator. HI is the quantified value of evaluation result of conditions of a bridge member from the perspective of “soundness”, incorporating all the effects of various types of damage occurred thereon.

Evaluation value is basically calculated for each bridge member; however, it can be calculated for each component, a span and a bridge.

Soundness classification of the bridge member (to be determined subjectively) generally can be made exactly only by highly experienced inspectors and/or evaluators. Therefore, in order to prevent variations among inspectors / evaluators, it is considered that such soundness classification is not preferred to be used as a bridge management indicator.

Therefore, it is decided to use “Health Index (HI)” as an indicator, which objectively quantifies the types of damage occurred on bridge member, degree of damage thereof, extent of damage to entire bridge member and seriousness of such damage to the soundness.

Health Index for each component, a span and a bridge will be calculated based on the health indices of bridge members and importance of each bridge member to a component, a span or a bridge.

2-2. Target Management Level

Target management level shall be set up with the use of Health Index (HI), as a bridge management indicator. It is noted, however, that such target management level is not uniquely determined from the health index; but shall be determined in consideration of availability of budget to achieve such level.

In general, when the target management level is set up as high, necessary costs of repair of the current damages on bridges will be increased.

Therefore, target management shall be determined in consideration of the available budget.

3. Understanding and Evaluation of Present Conditions

3-1. Investigation and Inspection

3-1-1. Bridge Inspection

Inspection of the bridge is generally categorized into routine inspection (patrol on roads), periodic inspection and emergency inspection as in Figure 3-1. It is decided that all the necessary data for bridge management should be collected from the periodic inspection.

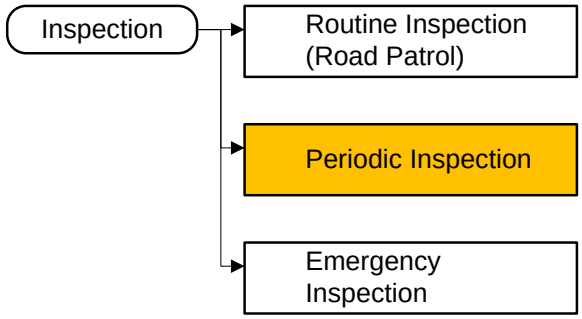

Figure 3-1 Types of Bridge Inspection

(1) Types of Bridge Inspection

It is needless to say that daily inspection (routine inspection by patrolling the road) is very important to detect the damage at an early stage, from the perspective of extending the service life of the bridge. However, it is decided that periodic inspection is utilized to collect the necessary data for bridge management.

Periodic inspection is to be implemented periodically so as to maintain the bridges in sound conditions, and should be carried out visually as close to the bridge structure as possible. As needed, it should be supplemented by non-destructive investigation such as palpation and hammering test.

(2) Frequency of Bridge Inspection

Periodic inspection should be conducted for all the bridges under RDA's management with the frequency given in Table 3-1.

Table 3-1 Frequency of Bridge Periodic Inspection

Target Bridges	Frequency
All the bridges	Initial inspection within 1 year after completion
All the bridges	Periodic inspection every 5 years

3-1-2. Details of Bridge Inspection

Details of bridge inspection are according to the "Bridge Inspection and Diagnosis Manual".

(1) Flow of Bridge Inspection

Bridge inspection is classified into site work and office work as in Figure 3-2.

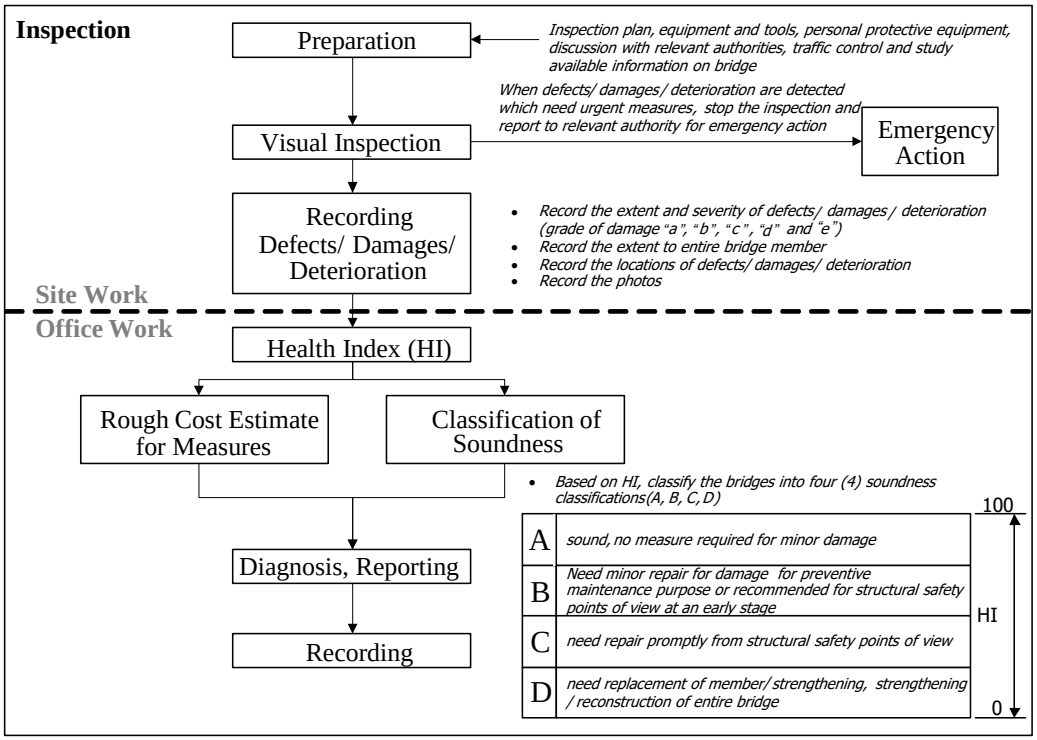

Figure 3-2 Flow of Bridge Inspection

Site Work

Bridge inspection will commence from the preparation work, such as bridge inspection plan development, arrangement of equipment, tools and personal protective equipment (PPE), discussion with relevant authorities and traffic control arrangement if needed. Studying ealier reports / inspections / built drawings / design drawings and any other information relevent to the Inspection.

Thereafter, bridge inspection will be carried out to detect the defects, damage and deterioration (hereinafter called "damage") of bridge structures. When the damage in need of emergency actions is detected, it is imperative that inspection work be interrupted and the necessary actions be requested to and be taken by the relevant authorities.

Inspection results should be recorded in the designated forms, including the degree of each type of damage (grade of damage: "a", "b", "c", "d" and "e"), extent of damage to the entire bridge member, location of each type of damage, and the photographs.

Office Work

Bridge inspection results will be evaluated with quantified value of Health Index (HI), which is to be logically calculated.

With the use of HI, bridge soundness classification as well as estimate of costs of bridge repair and strengthening will be made.

For the soundness classification, it should be reviewed by the experienced expert / engineer (called “diagnosis”). HI is the quantified evaluation value of bridge member conditions, in consideration of degree of damage and extent to the entire bridge member. However, HI does not consider the effects of the locations and state of progress of damage to the soundness. Therefore, experienced experts / engineers will need to review the soundness classification determined based on HI and to change the same as a final decision.

All the results will be recorded in the designated forms.

(2) Grading of Damage

Each type of damage should be evaluated based on its degree only. Such results should be categorized into 5 grades as in Table 3-2.

When it is difficult to evaluate the damage by 5 grades, such damage will be evaluated by 3 grades or 2 grades.

Table 3-2 Evaluation of Damage

Grade of Damage	General Conditions	
a	Sound	There is no damage on bridge member.
b	Almost sound	Damage on bridge member is small.
c	Slight	There is a certain degree of damage on bridge member.
d	High	Damage on bridge member is high.
e	Serious	Damage on bridge member is serious.

(3) Record of Damage on Bridges

Damage shall be recorded in such a manner that damage can be clarified as locally occurred or spread to its entirety, and the progress of damage to the entire bridge member can be understood.

Therefore, it is proposed that for classifying the damage locally occurred or spread to its entirety by using simple record forms with records being made by element, (which is one unit of the bridge member divided by at least 9 or 10) depending on the type of bridge member. For the bridge member with damage fully spread, number of all the elements thereof and number of elements with damage by each grade are to be recorded.

For instance, a bridge member has 9 elements, of which 8 elements classified as ”almost sound” and 1 element classified as “high” for a certain type of damage, it should be recorded as “damage grade “b” : 8/9” and “damage grade “d” : 1/9”.

For further details reference shall be made to “Bridge Inspection and Diagnosis Manual”.

3-2. Evaluation of Bridge Conditions

Condition of the bridge shall be evaluated by the Health Index (HI), which is calculated for each bridge member, span (bridge).

Health Index (HI) of the bridge member shall be calculated for various types of damage and is the quantitative value in consideration of the degree of damage, extent of damage to the entire bridge member and seriousness of damage to the soundness of bridge member.

Health Index (HI) of a span (an entire bridge) shall be the quantitative value, calculated in consideration of the health index of each bridge member and its importance to a span / an entire bridge (weighing factor / correlation factor).

(1) Evaluation of Conditions

Condition of the bridge is to be evaluated with the use of health index (HI), which is calculated for each bridge member, span and bridge based on the inspection results.

It is noted that health index (HI) is not the value of expressing the load carrying capacity directly, but is just the quantitative value of expressing the need of taking measures and its scale (repair cost).

(2) Health Index of Bridge Member

1) Damage Point (DP)

Damage Point (DP) shall be set for the grade of each damage. Damage point (DP) by grade of damage is given in Table 3-3.

Table 3-3 Damage Point (DP) by Grade of Damage

Grade of Damage	General Conditions		Damage Point (DP)
a	Sound	There is no damage on bridge member.	0
b	Almost sound	Damage on bridge member is small.	25
c	Slight	A certain degree of damage on bridge member.	50
d	High	Damage on bridge member is high.	75
e	Serious	Damage on bridge member is serious.	100

2) Weighing Factor (Correlation Factor)

Damage Point (DP) of each type of damage shall be multiplied by the weighing factor (correlation factor), evaluating the seriousness of the said damage to the soundness of target bridge member.

Weighing factors (correlation factors) were determined based on the awareness survey and its analysis using Analytical Hierarchical Process (AHP) technique.

3) Calculation of Health Index

Damage Point (DP) of a bridge member will be the sum of the products of damage point of each type of damage and its weighing factor (correlation factor). Damage point of each type of damage shall be evaluated considering the extent of the said damage to the entire bridge member.

DP of a bridge member = ∑ (ratio of damage grade “b” x 25 + ratio of damage grade “c” x 50 + ratio of damage grade “d” x 75 + ratio of damage grade “e” x 100) x correlation factor

Health Index is set as 100 for bridge member that is in sound condition without any damage, and will be calculated by deducting the Damage Point (DP) of the said bridge member from 100.

(3) Health Index of Component, Span and Bridge

Health Index (HI) of the level of component, span or bridge will be calculated with the use of demerit mark system at each level.

Damage point of the component will be the sum of the products of damage point of each bridge member comprised thereof and value of evaluating the importance of the bridge member to the component (correlation factor).

Damage point of the span will be the sum of the products of damage point of each component comprised thereof and value of evaluating the importance of the component to the span (correlation factor).

Health Index (HI) of each component and span will be calculated respectively by deducting the damage point thereof from 100.

Table 3-4 provides the image of calculating the damage point at each level of component and span by demerit mark system.

Table 3-4 Image of Demerit Mark System for Damage Point Calculation

			Evaluation of Span	Evaluation of Component		Evaluation of Member	
			Damage Point	Correlation Factor	Damage Point	Correlation Factor	Damage Point
Span	Superstructure	Main Beam	58.3	0.70	28.0	0.5	19.0
		Deck Slab				0.30	18.8
		Diaphragm				0.20	16.7
	Bridge Bearing	None		0.30	29.0	1.00	29.0
	Substructure	None		1.00	30.0	1.00	30.0

When a bridge has several spans, health index of the target bridge will be the minimum one among those of all the spans.

Detail of calculation of health index is given in the Attachment-2: “Calculation and Recording of Health Index (HI)” attached to the Bridge Inspection and Diagnosis Manual.

(4) Evaluation of Health Index

Generally, evaluation of health index will be by either the demerit mark system or weighted mean method.

Demerit mark system is to deduct the damage points of all types of damage for a bridge member, of all the bridge members for a component, and of all the components for a span / bridge, from 100 (sound condition). Damage point of a member corresponds to the degree of damage occurred on the said bridge member. This system enables the evaluator to know the effect of damage point of specific bridge member obtained from the damage thereon at each level of component, span and bridge.

For example, for the calculation of health index of a bridge, it can instinctively be seen what are the damage points of all the members composed thereof and which member(s) affects to the soundness of the said bridge.

Whereas, weighted mean method is to deduct the weighted mean of damage points of all types of damage for a bridge member, of all the bridge members for a component, and of all the components for a span / bridge, from 100 (sound condition). It will reduce the effect of seriously damaged bridge member with big damage point, if any.

It is decided that “demerit mark system” is used for evaluating the health index in this guideline.

3-3. Classification of Soundness

Soundness is classified in accordance with Table 3-5, with reference to the value of Health Index (HI).

Table 3-5 Classification of Soundness

Classification		Conditions
A	Sound	Structures are well functioning.
B	Preventive Maintenance Stage	Structures are well functioning. However, it is desirable to take necessary measures from the perspective of preventive maintenance.
C	Reactive Maintenance Stage	Functions of the structure will be possibly impaired. Necessary measures should be taken at an early stage (within 5 years).
D	Immediate Action Stage	Functions of the structure are impaired or the possibility of impairment of functions is extremely high. Necessary measures should be taken immediately (within 2 years).

When a serious damage in need of emergency action is detected, necessity of emergency actions of such bridges should be judged at site immediately. Such judgement does not depend on the Health Index.

Reference values of Health Index (HI) for soundness classification are given in Table 3-6.

It is noted, however, that values of health index are just for reference in order to minimize the variations in determining the soundness classification by different persons, and that soundness should not be classified only by the value of health index.

Table 3-6 Reference Value of HI for Soundness Classification

Classification		Health Index (HI)
A	Sound	75 – 100
B	Preventive Maintenance Stage	50 – 75
C	Reactive Maintenance Stage	25 – 50
D	Immediate Action Stage	0 – 25

Soundness classification is set up in addition to the health index. It is because it can be used for the road administrator to generally understand the condition of bridges under its management or to utilize as a convenient indicator for releasing the bridge conditions to the public.

4. Development of Bridge Repair and Maintenance Plan

4-1. Estimate of Bridge Repair Costs

The standard repair cost shall be for the purpose of understanding the repair and maintenance budget of bridges under management and be determined based on the rates of bridge repair corresponding to the health index.

For developing the bridge repair and maintenance plan, it is one of the critical issues to understand how the necessary bridge repair and maintenance budget varies for different bridge management levels.

As one of the ways of estimating the repair and maintenance costs, it has to multiply the damage area or quantity by rate of repair for each type of damage. However, it is not practical to set up the damage quantities and rates of repair corresponding to the different management level (health index).

Therefore, in this Guideline, it has to develop the standard rate of repair corresponding to the health index for each bridge member, and estimate the standard repair and maintenance costs. Standard rates of repair are developed based on the repair and maintenance costs obtained with the assumption of damage conditions or quantities corresponding to the health index

Standard repair costs can be calculated as the product of rate of repair developed per bridge surface area, width or span, and bridge surface area, width or span.

Standard rate of repair shall vary depending on the health index. As is given in Figure 4-1, standard rate at intermediate value of health index can be obtained by linear interpolation.

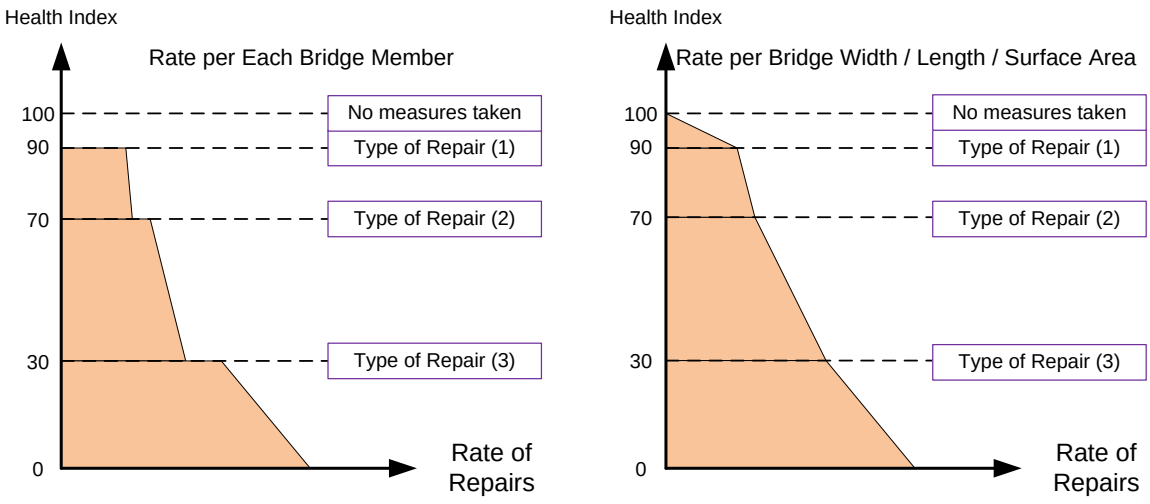

Figure 4-1 Setting of Standard Rate of Repair by Health Index

4-2. Setting of Bridge Management Scenarios

In order to develop the possible bridge repair and maintenance plan within the available budget, bridge management scenarios (several target bridge management level options) shall be developed.

Bridge management levels will be set up with the use of Health Index of a bridge. Bridges below the target management level should be repaired within the proposed bridge repair period.

However, only the bridge members below the target management level set up for each type of bridge member shall be considered for repair of the said bridge and cost estimate.

Bridge management scenarios will be developed with the use of health index of an entire bridge in such a manner that “Bridges shall be managed so that health index of the entire bridge can be 60 or above”.

For the bridge members, some of them are economically effective when managed under preventive maintenance scenario and others under scrap and bulid scenario. Therefore, additional arrangement was introduced so that separate management levels can be set up for each bridge member apart from that of an entire bridge.

Table 4-1 provides the example of setting up the target management levels for the pre-tensioned beam bridge.

Table 4-1 Example of Target Management Level (Pre-tensioned Beam Bridge)

Target Member	Target Management Level (Health Index)	Remarks
Entire Bridge	60	“Scenario 60” Option HI shall be 60 or above
Main Beam	60	HI shall be 60 or above
Bridge Bearing	10	HI shall be 10 or above
Substructure	60	HI shall be 60 or above
Pavement	60	HI shall be 60 or above
Bridge Expansion Joint	10	HI shall be 10 or above
Accessories	60	HI shall be 60 or above
Approach Road / Riverbank	60	HI shall be 60 or above

Image of the bridge members targeted for repair and budget calculation is given in Figure 4-2.

Bridge / Span	Calculated HI		Target HI	Bridge Member	Calculated HI		Target HI
Z-Bridge	58	≤	60	Beam	58	≤	60
				Bridge Bearing	55	>	10
				Substructure	80	>	60
				Pavement	40	≤	60
				Bridge Expansion Joint	70	>	10
				Accessory	35	≤	60
				Approach	75	>	60

Figure 4-2 Example of Bridge Members Targeted for Repair and Cost Estimates

4-3. Development of Bridge Repair & Maintenance Budget Plan

Budget plan for the systematic repair and maintenance of bridges below target management level shall comprise the average annual budget and proposed target repair period.

Budget plan shall be developed for all the management scenarios developed to seek for the possible target management level.

Requirements to be given for developing the plan will be an annual budget limit or a proposed target bridge repair period. When the proposed target repair period is given, annual average budget will be calculated by dividing the total repair cost necessary for repairing the bridges below the target management level by a proposed target repair period. Given with the annual budget limit, bridge repair period will be calculated by dividing the total repair cost by an annual budget limit.

Possible target bridge management level will be determined whether all the necessary bridge repair and maintenance can be implemented within the given budget or not. Therefore, it is to develop the rough budget before selecting the specific bridges and determining the order of priority of such bridges.

Budget will be calculated for all the bridge management scenarios in order to determine the possible target management level. From the perspective of budget amount, possible management scenario will be selected and used as a target bridge management level.

Budget will be an annual budget limit, or an average annual budget calculated by dividing the total repair and maintenance cost necessary for repairing the bridges below the target management level by a proposed target repair period.

4-4. Degree of Relative Priority of Repair and Maintenance

Priority for implementing the repair and maintenance work shall be evaluated comprehensively in consideration of both health index (HI), representing the conditions of damage, and importance index (II) representing the features of route, geographical conditions as well as degree of effects to road users and surrounding residents. Degree of relative priority (Priority Point) of bridge repair is given as follows:

Degree of Relative Priority (Priority Point) = α x (100 – Health Index) + β x Importance Index

Whereas, $\alpha + \beta = 1.00$

For the selected target bridge management level and annual budget, all the bridges will be prioritized for selecting the target bridges which are to be repaired for each fiscal year.

In this Guideline, it has to comprehensively evaluate the degree of relative priority (prioritization) of bridges for implementing the repair and maintenance in consideration of both health index (HI) and importance index (II).

Weighing factors of α and β used for composing the health index and importance index were set at α=0.7 and β=0.3 respectively from the awareness survey, as health index is regarded more important than importance index.

(1) Evaluation Criteria and Weighing Factors of Importance Index

Evaluation criteria and weighing factors for evaluating the degree of relative priority of bridges was determined with the use of AHP (Analytic Hierarchy Process) technique so that ideas of road administrator can be objectively incorporated into the evaluation through the awareness survey.

From the awareness survey result, evaluation criteria for importance index are systematically given in Figure 4-3.

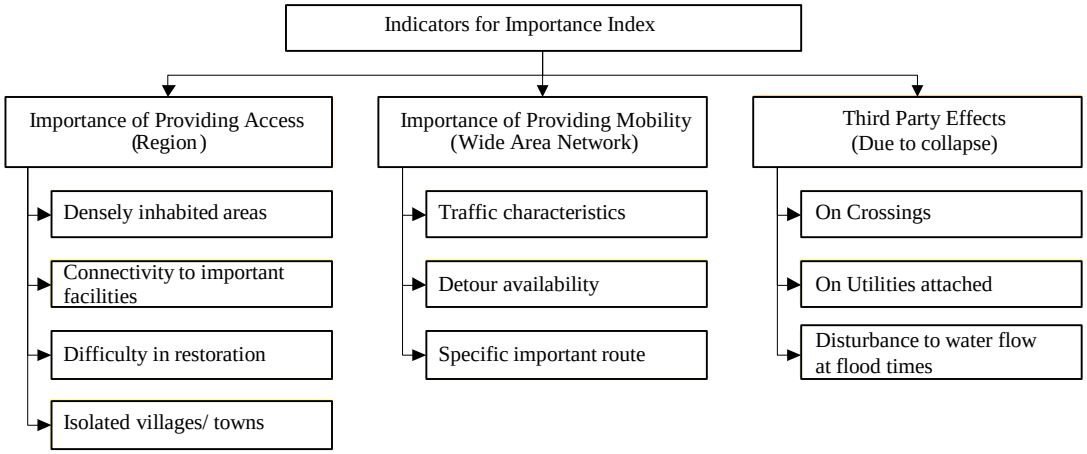

Figure 4-3 Systematized Evaluation Criteria for Importance Index

Viewpoints of evaluation and weighing factor for each criterion are summarized in Table 4-2.

Table 4-2 Evaluation Criteria & Weighing Factor for Importance Index (1)

Evaluation Criterion		Viewpoint of Evaluation
Hierarchical Level 1	Hierarchical Level 2	
Importance of Providing Access (0.32)	Densely inhabited areas (DID) (0.19)	● In order to secure the access to the areas largely affected by disaster, such as DIDs, bridges in such areas should be repaired as priority.
	Connectivity to important facilities (0.26)	● In order to secure the access to the important facilities for daily activities in the regions, such as Airports, ports, major bus and train station, main government hospital, National school, bus and train station, tourist attraction place, industrial attraction, special religious place, bridges on such routes should be repaired as priority.
	Difficulty in restoration (0.30)	● When a temporary bridge cannot be constructed within ROW or can only be constructed outside ROW with land lease, such bridges should be repaired as priority.
		● Bridges with a span of 25 meters or longer should be repaired as priority, since it will take a longer time to design and fabricate beams (standard beam cannot be used.)
		● Bridges with pier(s) in deep water should be repaired as priority, since it will need a longer period of time and high costs to reconstruct such bridges with cofferdam.
		● Bridges with a long length should be repaired as priority, since it will need a longer period of time and high costs to reconstruct such bridges.
	Isolated villages / towns (0.25)	● Bridges on the route to the isolated villages / towns should be repaired as priority to prevent isolation.

Table 4-2 Evaluation Criteria & Weighing Factor for Importance Index (2)

Evaluation Criterion		Viewpoint of Evaluation
Hierarchical Level 1	Hierarchical Level 2	
Importance of Providing Mobility (0.27)	Traffic characteristics (0.28)	● Bridges on heavily trafficked roads should be repaired as priority, since closure of such bridges will affect the social and economic activities.
	Detour (0.33)	● Bridges on the road, without any detour or with a detour taking long period of time, should be repaired as priority, since closure of such bridges will affect to the social and economic activities.
	Specific important routes (0.39)	● Bridges on all road sections within 25-kilometer radius from the strategically important facilities should be repaired as priority, since closure of such bridges will affect to the national development. (Bandaranaike International Airport, Mattala Airport, Colombo Harbor, Hambantota Harbor)
Third Party Effects (0.41)	Crossings (0.50)	● Influence of damage to railway under the bridge, such as daily passenger and freight transport, loss of life.
		● Influence of damage to expressway under the bridge, such as daily passenger and freight transport, loss of life.
		● Influence of damage to road under the bridge, such as daily passenger and freight transport, loss of life.
	Utilities attached (0.28)	● Influence of damage to the residents by collapse of attached utilities.
	Disturbance to water flow at flood times (0.22)	● At flood times, water level in upstream will increase and overflow, or erosion at abutment will occur, due to small water way opening at a bridge.

Note: The value in parenthesis is a weighing factor for each evaluation criterion.

(2) Evaluation Point of Each Criterion for Importance Index

Evaluation points are set up as in Table 4-3 for each criterion given in Table 4-2.

Table 4-3 Evaluation Point of Each Criterion for Importance Index (1)

Hierarchical Level 1		Hierarchical Level 2		Setting of Evaluation Point		
Evaluation Criterion	Weighing Factor	Evaluation Criterion	Weighing Factor	Classification		Evaluation Point
Importance of Providing Access	0.32	Densely inhabited areas (DID)	0.19	Inside DIDs		100
				Outside DIDs		0
		Connectivity to important facilities	0.26	Extremely important facilities: Airports, ports, major bus and train station, main government hospital,		100
				Important facilities: National school, bus and train station, tourist attraction place, industrial attraction, special religious place		50
				No important connectivity		0
		Difficulty in restoration	0.30	Space for temporary bridge	No space	100
					Yes, outside ROW	50
					Yes, inside ROW	0
				Span	More than 25 meters	100
					25 meters or less	0
				Bridge piers in water	Yes, in need of cofferdam	100
					No cofferdam needed, not in water	0
				Bridge length	More than 50 meters	100
					50 meters or less	0
				Not applicable		0
		Isolated villages / towns	0.25	Yes		100
				No		0
Importance of Providing Mobility	0.27	Traffic characteristics	0.28	Traffic volume	50,000 or more	100
					20,000 – 49,999	75
					5,000 – 19,000	50
					500 – 4,999	25
					0 – 499	0
		Detour	0.33	Additional time needed	60 minutes or more	100
					30 – 59 minutes	50
					0 – 29 minutes	0
		Strategically important routes	0.39	Yes: road sections within 25-kilometer radius from Bandaranaike International Airport, Mattala Airport, Colombo Harbor, Hambantota Harbor		100
				No		0

Table 4-3 Evaluation Point of Each Criterion for Importance Index (2)

Hierarchical Level 1		Hierarchical Level 2		Setting of Evaluation Point			
Evaluation Criterion	Weighing Factor	Evaluation Criterion	Weighing Factor	Classification			Evaluation Point
Third Party Effects	0.41	Crossings	0.50	Railway	Yes		100
					No		0
				Expressway	Yes		100
					No		0
				Road by traffic volume	20,000-		100
					500-19,999		50
					0-499		0
				River	Yes		0
					No		0
				No crossing			0
		Utilities attached	0.28	Telecommunication (Optic)		Yes	33
						No	0
				Telecommunication (Metal)		Yes	33
						No	0
				Power Cable		Yes	33
						No	0
				Water supply / sewage pipes		Yes	33
						No	0
				Oil pipeline		Yes	33
						No	0
				None			0
		Disturbance to water flow at flood times	0.22	Single span			100
				2 spans			50
				3 spans or more, no crossing the river			0

Note1: For “Difficulty in restoration”, there are 5 sub-criteria: space for temporary bridge, span, bridge piers in water, bridge length, and not applicable. Maximum value among those for these criteria should be the representative value.

Note2: For “crossings”, there are sub-criteria: railway, expressway, road, river, and not applicable. Maximum value among those for these criteria should be the representative value.

Note 3: For “Utilities attached”, when several utilities are attached to the bridge, evaluation point should be the sum of all points given to each utility; however, such total point should not exceed 100.

4-5. Development of Bridge Repair & Maintenance Plan

Based on the latest inspection results, Bridge Repair & Maintenance Plan is to provide the specific times and work descriptions of repair and maintenance for a proposed target repair period. The Plan should be reviewed every year based on the latest inspection results and repair histories.

The Bridge Repair & Maintenance Plan will be developed in the following procedure.

(1) Target Bridge Management Level

From the bridge management scenarios and required budget thereof, possible scenario will be selected as a target bridge management level.

(2) Selection of Target Bridges

Bridges below the target management level will be selected.

(3) Priority of Implementation of Bridge Repair and Maintenance

Priority of implementing the repair and maintenance works should be determined in the following procedure and image of the same is given as in Figure 4-4.

First Priority Group: Bridges categorized as Soundness Classification "D" (Immediate Action Stage)

↓

Second Priority Group: Bridges categorized as Soundness Classification "C" (Reactive Maintenance Stage)

↓

Third Priority Group: Bridges categorized as Soundness Classification "B" (Preventive Maintenance Stage)

Degree of the relative priority of each group can be determined by the health index and importance index as follows:

$$\text{Degree of Relative Priority} = \alpha \times (100 - \text{Health Index}) + \beta \times \text{Importance Index}$$

Whereas, $\alpha + \beta = 1.00$

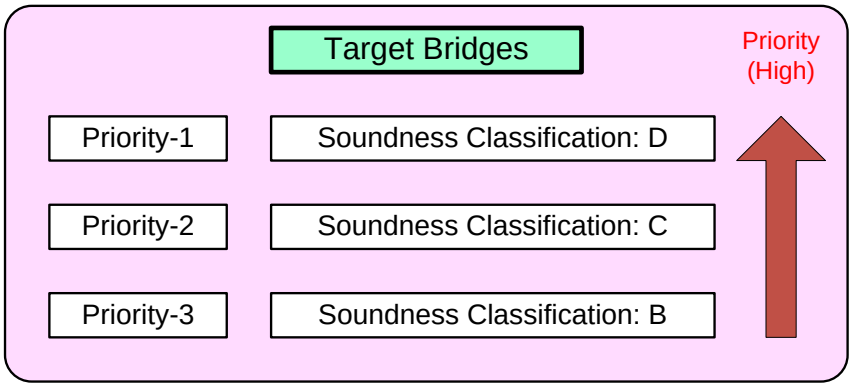

Figure 4-4 Image of Prioritization of Bridge Repair

(4) Period of Review of the Plan

Bridge Repair & Maintenance Plan needs to incorporate the latest inspection results and repair histories at all the times. Therefore, the plan should be reviewed and updated every year.

5. Bridge Reconstruction Indicator

"Functionally Obsolete Index (FOI)" will be used as the bridge reconstruction indicator. FOI is the quantified value of expressing the extent of obstruction to the surrounding environments due to functional obsolescence of the bridge.

The value of FOI is calculated for a bridge by condition of the bridge.

In general, it is well known that life cycle cost (LCC) of the bridge repair option is less than that of reconstruction option, as in Figure 5-1, when the bridge inspection is periodically carried out to detect the damage, and appropriate repair and maintenance are implemented while such damage is small.

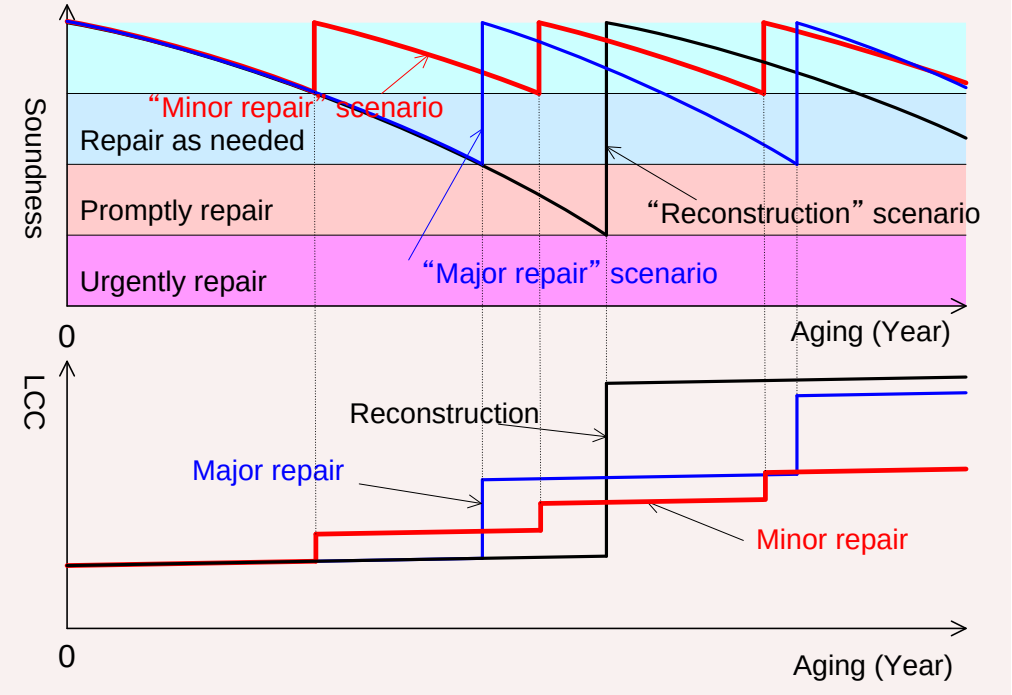

Figure 5-1 Comparison of Life Cycle Costs for Bridge Repair & Reconstruction

Therefore, the need of bridge reconstruction can be determined, not by the economic efficiency, but by other factors. In this Guideline, the need of the bridge reconstruction is determined by the obsolescence of the functions required from a bridge.

Functions provided at the construction become obsolete due to the advanced requirements from the changes of social needs and environments. Extent of obstruction to the surrounding environments due to such functional obsolescence is quantified as an indicator called "Functionally Obsolete Index (FOI)". FOI will be used for evaluating the need for bridge reconstruction.

6. Development of Bridge Reconstruction Plan

6-1. Estimate of Reconstruction Cost

Bridge reconstruction cost should involve demolition of existing bridge, temporary work, construction and removal of detour with temporary bridge included, as well as construction of a new bridge.

The bridge reconstruction cost should be the product of standard rate of bridge reconstruction per bridge surface area.

Construction cost of a new bridge is calculated based on the general type of a bridge commonly constructed in Sri Lanka.

Costs of demolition of existing bridge, temporary work as well as construction and removal of the detour, needed prior to the construction of a new bridge, are calculated based on the practices of bridge reconstruction that RDA has previously implemented.

6-2. Evaluation of Needs of Bridge Reconstruction

The need of bridge reconstruction shall be evaluated by using the Functionally Obsolete Index (FOI), which is calculated bridge by bridge. FOI is the quantified value of evaluating the extent of obstruction to the surrounding environments due to the functional obsolescence of the bridge.

(1) Evaluation of Need of Bridge Reconstruction

Evaluation of the need of bridge reconstruction should be made by quantitatively evaluating the extent of obstruction to the surrounding environments due to functional obsolescence of the bridge.

(2) Calculation of Functionally Obsolete Index (FOI)

1) Evaluation Criteria and Weighing Factors of Functionally Obsolete Index

Evaluation criteria and weighing factors for evaluating the functional obsolescence of the bridge should be determined with the use of AHP (Analytic Hierarchy Process) technique so that ideas of road administrator can be objectively incorporated into the evaluation through the awareness survey.

From the awareness survey result, evaluation criteria of functionally obsolete index are systematically given in Figure 6-1.

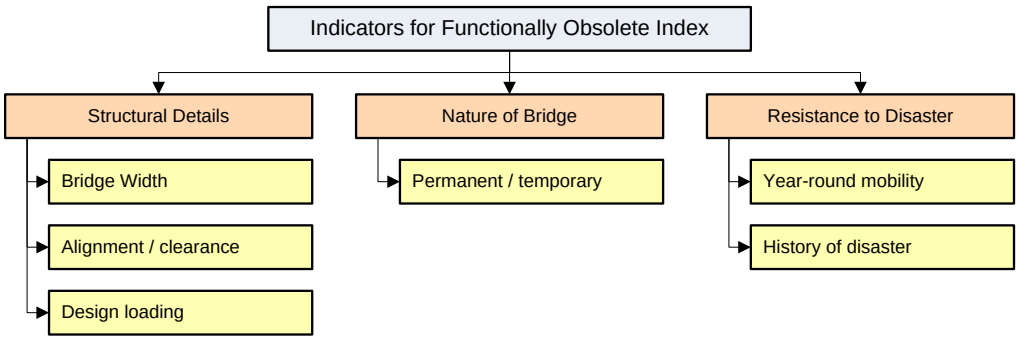

Figure 6-1 Evaluation Criteria for Functionally Obsolete Index

Viewpoints of evaluation and weighing factor for each criterion are summarized in Table 6-1.

Table 6-1 Evaluation Criteria & Weighing Factors for Functionally Obsolete Index

Evaluation Criterion		Viewpoint of Evaluation
Hierarchical Level 1	Hierarchical Level 2	
Structural Details (0.40)	Bridge width (0.40)	● Bridges with insufficient kerb-to-kerb width (centre median included, sidewalk excluded) should be reconstructed as priority.
	Alignment / clearance (0.40)	● Bridges with bad vertical / horizontal alignments and/or insufficient vertical / horizontal clearances should be reconstructed as priority to prevent accidents, which result in inefficient social and economic activities and loss of live.
	Design loading (0.20)	● Bridges with insufficient load carrying capacity should be reconstructed as priority.
Nature of Bridge (0.30)	Nature of bridge (1.00)	● Bridges with low fatigue durability and redundancy should be reconstructed as priority.
Resistance to Disaster (0.30)	Year-round mobility (0.40)	● Bridges, which are inundated at disaster times and hindrance to critical activities for the public, should be reconstructed as priority.
	History of disaster (0.60)	● Bridges which have records of disaster history should be reconstructed as priority to prevent closure of the said bridge due to wash away of bridge structures and approaches, large damage due to scouring, log impact and debris in the past or not.

Note: The value in parenthesis is a weighing factor for each evaluation criterion.

2) Evaluation Point of Each Criterion for Functionally Obsolete Index

Evaluation points are set up as in Table 6-2 for each criterion given in Table 6-1.

Table 6-2 Evaluation Point of Each Criterion for Functionally Obsolete Index

Hierarchical Level 1		Hierarchical Level 2		Setting of Evaluation Point	
Evaluation Criterion	Weighing Factor	Evaluation Criterion	Weighing Factor	Classification	Evaluation Point
Structural Details	0.40	Bridge width	0.40	Do not meet the required kerb-to-kerb width for category one rank lower from the traffic volume.	100
				Meet the required kerb-to-kerb width for category one rank lower from the traffic volume.	50
				Meet the required kerb-to-kerb width for category from the traffic volume.	0
		Alignment / clearance	0.40	Impaired the safe driving due to bad vertical / horizontal alignments and/or vertical / horizontal clearances, resulted in frequent accidents.	100
				Impaired the safe driving due to bad vertical / horizontal alignments and/or vertical / horizontal clearances.	50
				Alignments / clearances meet the design requirements. No accident.	0
		Design loading	0.20	Live loads used for design do not meet the design requirement.	100
				No use so far. However, in the future, when the bridges on Class-C / D roads are under the RDA's management, additional category will be added here.	50
				Live loads used for design meet the design requirement.	0
Nature of Bridge	0.30	Nature of bridge	1.00	Temporary bridge (Bailey bridge) with low fatigue durability.	100
				Modular bridge with low redundancy	50
				Others (permanent)	0
Resistance to Disaster	0.30	Year-round mobility	0.40	Inundated at disaster times, resulted in hindrance to critical activities for the public.	100
				Inundated for a short period of time only; however, no hindrance to critical activities for the public.	50
				No inundation.	0
		History of disaster (wash away, scouring, log impact / debris damage))	0.60	There are several records of disasters.	100
				There is a record of disaster.	50
				There is no record of disaster.	0

6-3. Classification of Functional Obsolescence

Functional obsolescence of the bridge is classified in accordance with Table 6-3, with reference to the value of Functional Obsolete Index (FOI).

Table 6-3 Classification of Functional Obsolescence

Classification		Conditions
A’	Satisfactorily functioning	A bridge exhibits the required functions satisfactorily.
B’	Functionally obsolete	A bridge is functionally obsolete, though no adverse effect to socioeconomic activities is identified.
C’	Functionally obsolete remarkably	A bridge is functionally obsolete to the extent that socioeconomic activities are adversely and highly affected.
D’	Functionally obsolete seriously	A bridge is functionally obsolete to the extent that socioeconomic activities are adversely and seriously affected.

Reference values of Functionally Obsolete Index (FOI) for classification of functional obsolescence of the bridge are given in Table 6-4.

Table 6-4 Reference FOI Values for Classification of Functional Obsolescence

Classification		Functional Obsolete Index (FOI)
A’	Satisfactorily functioning	0 – 25
B’	Functionally obsolete	25 – 50
C’	Functionally obsolete highly	50 – 75
D’	Functionally obsolete seriously	75 - 100

It is noted, however, that values of functionally obsolete index are just temporary for reasons of insufficient number of data. After sufficient number of data is collected, such values should be reviewed so that extent of effects to the surrounding environments due to functional obsolescence of the bridge matches the conditions given in Table 6-3.

6-4. Degree of Relative Priority of Reconstruction

Priority for reconstructing the bridges shall be evaluated comprehensively in consideration of (i) health index (HI) representing the conditions of damage, (ii) importance index (II) representing the features of route, geographical conditions as well as degree of effects to road users and surrounding residents, and (iii) functionally obsolete index (FOI) representing the extent of obstruction to the surrounding environments due to functional obsolescence of the bridge. Degree of relative priority (Priority Point) of bridge reconstruction is given as follows:

Degree of Relative Priority (Priority Point) = α' x (100 – Health Index) + β' x Importance Index + γ' x Functionally Obsolete Index

Whereas, $\alpha' + \beta' + \gamma' = 1.00$

All the bridges registered in the database will be prioritized for reconstruction so that target bridges can be selected from the plan (list of bridges in the order of priority) when the budget is available.

In this Guideline, it has to comprehensively evaluate the degree of relative priority (prioritization) of bridge reconstruction in consideration of health index (HI), importance index (II) and functionally obsolete index (FOI).

Weighing factors of α', β' and γ' used for composing the health index, importance index and functionally obsolete index were set as $\alpha'=0.7$, $\beta'=0.2$ and $\gamma' = 0.1$ respectively from the awareness survey.

6-5. Development of Bridge Reconstruction Plan

Based on the latest inspection results, Bridge Reconstruction Plan shall be developed to provide the list of all the bridges, registered in the database, in the order of priority.

The Plan should be reviewed every year based on the latest inspection results and repair histories.

The Bridge Reconstruction Plan will be developed in the following procedure.

(1) Priority of Implementation of Bridge Reconstruction

Priority of bridges for reconstruction should be determined, not to omit the functionally obsolete bridges, in the following procedure and image of the same is given in Figure 6-2.

First Priority Group: Bridges categorized as Functional Obsolescence Classification "D' "

↓

Second Priority Group: Bridges categorized as Functional Obsolescence Classification "C' "

↓

Third Priority Group: Bridges categorized as Functional Obsolescence Classification "B' "

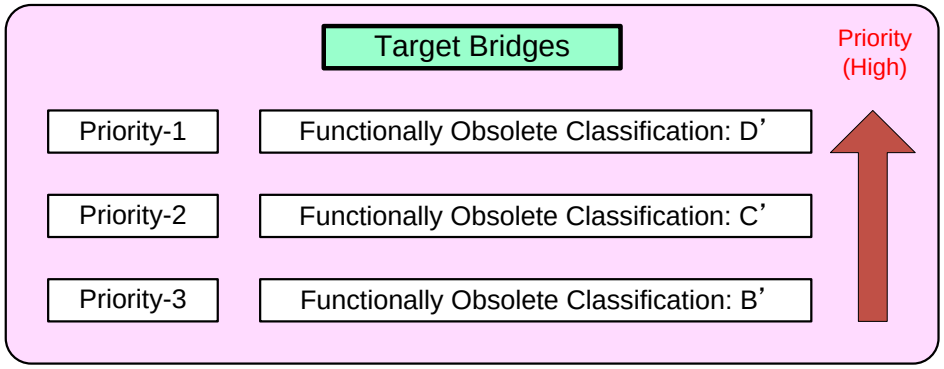

Figure 6-2 Image of Prioritization of Bridge Reconstruction

Degree of the relative priority of each group can be determined by the health index, importance index and functionally obsolete index as follows:

Degree of Relative Priority = α' x (100 – Health Index) + β' x Importance Index γ' x functionally obsolete index

Whereas, α' + β' + γ' = 1.00

(2) Period of Review of Bridge Reconstruction Plan

Bridge Reconstruction Plan needs to be incorporated the latest inspection results and repair histories so that target bridges can be selected properly. Therefore, the plan should be reviewed and updated every year.

7. Monitoring and Ex-Post Evaluation

7-1. Monitoring

Monitoring is to upload the inspection results and repair histories into the database periodically and understand the condition of bridges (defects, damage and deterioration) at all times.

Monitoring should be implemented to understand the condition of the individual bridge at all the time. Therefore, when the bridge inspection, repair, maintenance and reconstruction are carried out, such records should immediately be uploaded for update.

Bridge repair records can be entered into the system in the screen given in Figure 7-1. It enables to delete the present damage and update the health index and soundness classification of the target bridge. In order to minimize the burden for entering a large number of bridge repair records, such mechanism as selecting all the bridge members below the target health index was introduced. Bridge repair record can also be entered into the system one by one.

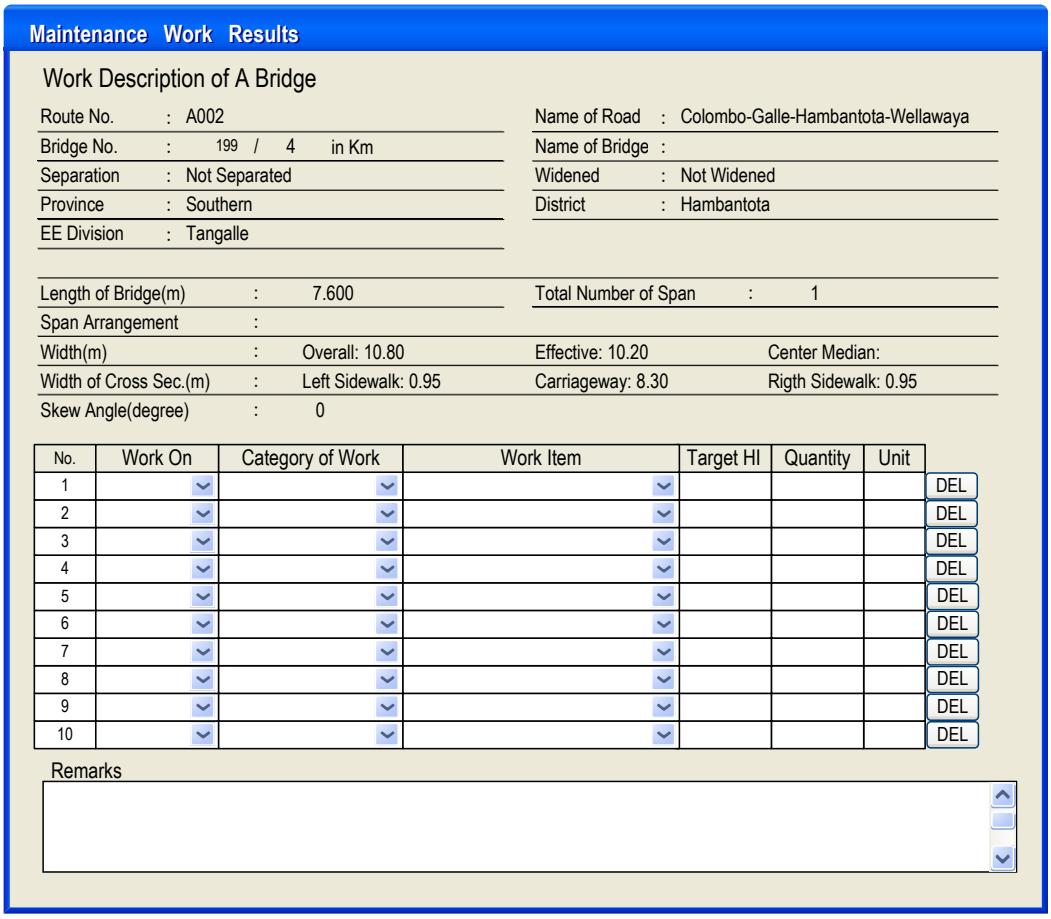

Figure 7-1 Image of Monitoring

7-2. Ex-Post Evaluation

Periodically, distribution of health indices or soundness classifications of all bridges under management should be summarized by route or bridge members based on the latest inspection results. Effect of implementation of bridge repairs should be verified with the change of trend of such distribution.

Ex-post evaluation should be implemented targeted for all the bridges under the management of RDA.

Evaluation will be made to confirm whether the improvement of conditions of bridges can be seen or not by checking the health indices or soundness classifications of such bridges before and after the investment. Based on the ex-post evaluation, budget increase or review of bridge management level should be made.

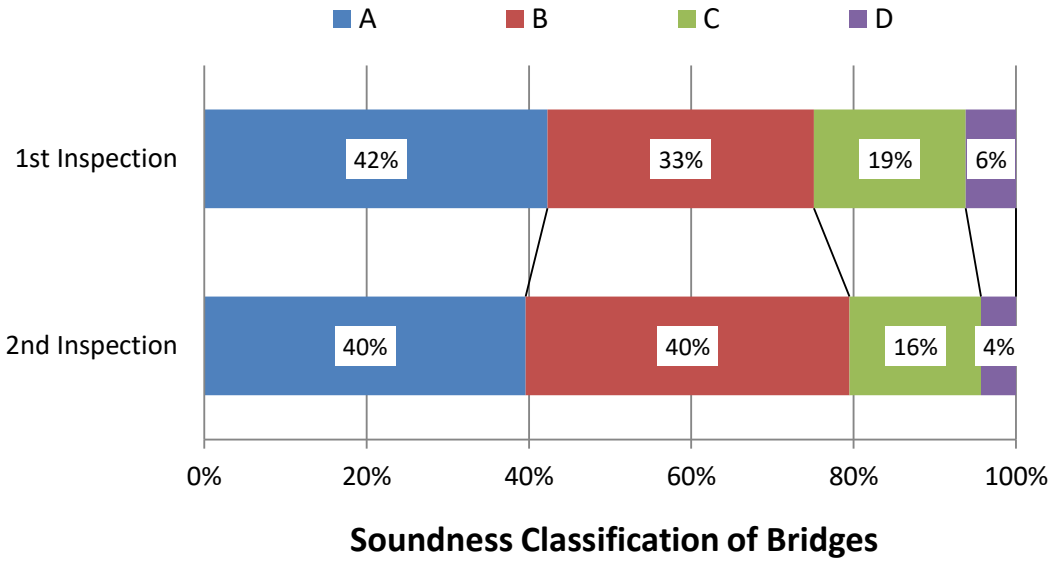

Figure 7-2 Image of Ex-Post Evaluation

Attachment 1 - Bridge Management Procedure Manual

Preface

In order to ensure the safety of the road users all the time, it is essential for RDA, as a road administrator, to appropriately maintain and manage the road structures and functions for the future.

Maintenance & Management doesn't simply mean to conduct inspection, diagnosis, repair and strengthening individually. It represents to implement and connect each of the following processes: inspection, diagnosis, emergency actions and in-depth investigation planning and implementation of necessary actions applied according to inspection results.

This Manual explains "Maintenance & Management of Bridges" and its procedure.

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1. Outline of Bridge Management

1-1. Structure of Bridge Management

In order to ensure that the users can drive safely and comfortably, it is necessary to implement the proper maintenance & management of the bridges. Therefore, each division and staff of RDA should be engaged in the operation with firm understanding of Bridge Management.

In case that Bridge Management is not implemented appropriately, it could lead to a sudden collapse of bridges or serious accidents causing death or injury. Not only the head of the division but also every staff who gets involved in Bridge Management should understand Bridge Management and conduct the daily operations.

When it comes to Bridge Management, each process does not work individually. Especially, the periodic inspection results links with emergency actions, in-depth investigation, repair & maintenance and reconstruction planning and measures. Moreover, during the procedure, it is necessary to accumulate the required information for “Bridge Management”. The accumulated data is utilized for the operation such as the future periodic inspection. Repeating the management cycle enables to grasp the damage progress and the re-evaluation of the repair methods. For the details of Bridge Management, refer to “Bridge Management Guidelines Manual”.

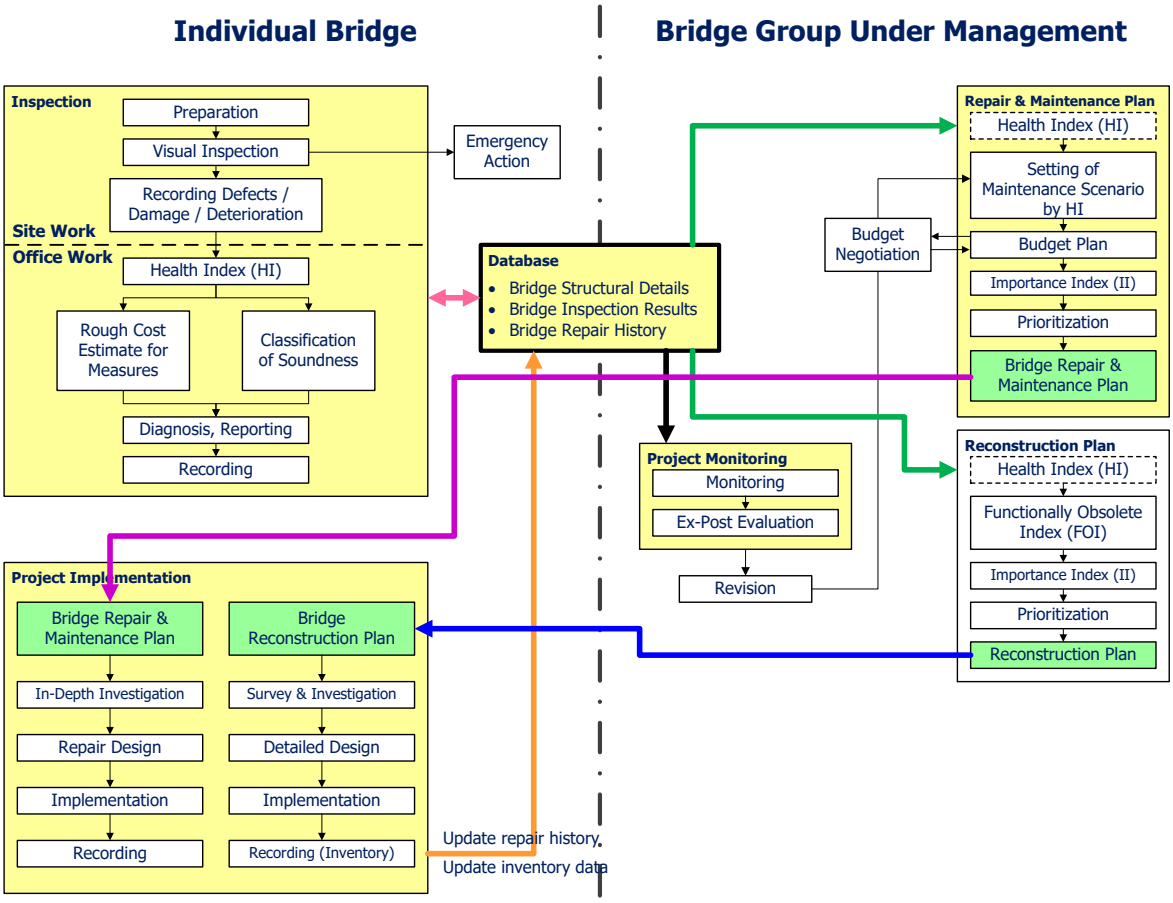

Figure 1-1 Work Flow of Bridge Management

1-2. Institutional Framework, Roles & Responsibilities

For Bridge Management, it is important for the member in divisions of RDA, who gets involved in Bridge Management, to carry out Bridge Management based on understanding each roles & responsibilities.

Institutional framework for Bridge Management is given in Figure 1-2, and roles & responsibilities of each division are given in Table 1-1. Those who have the authority for decision making and approvals must make a judgment on proposed matters responsibly.

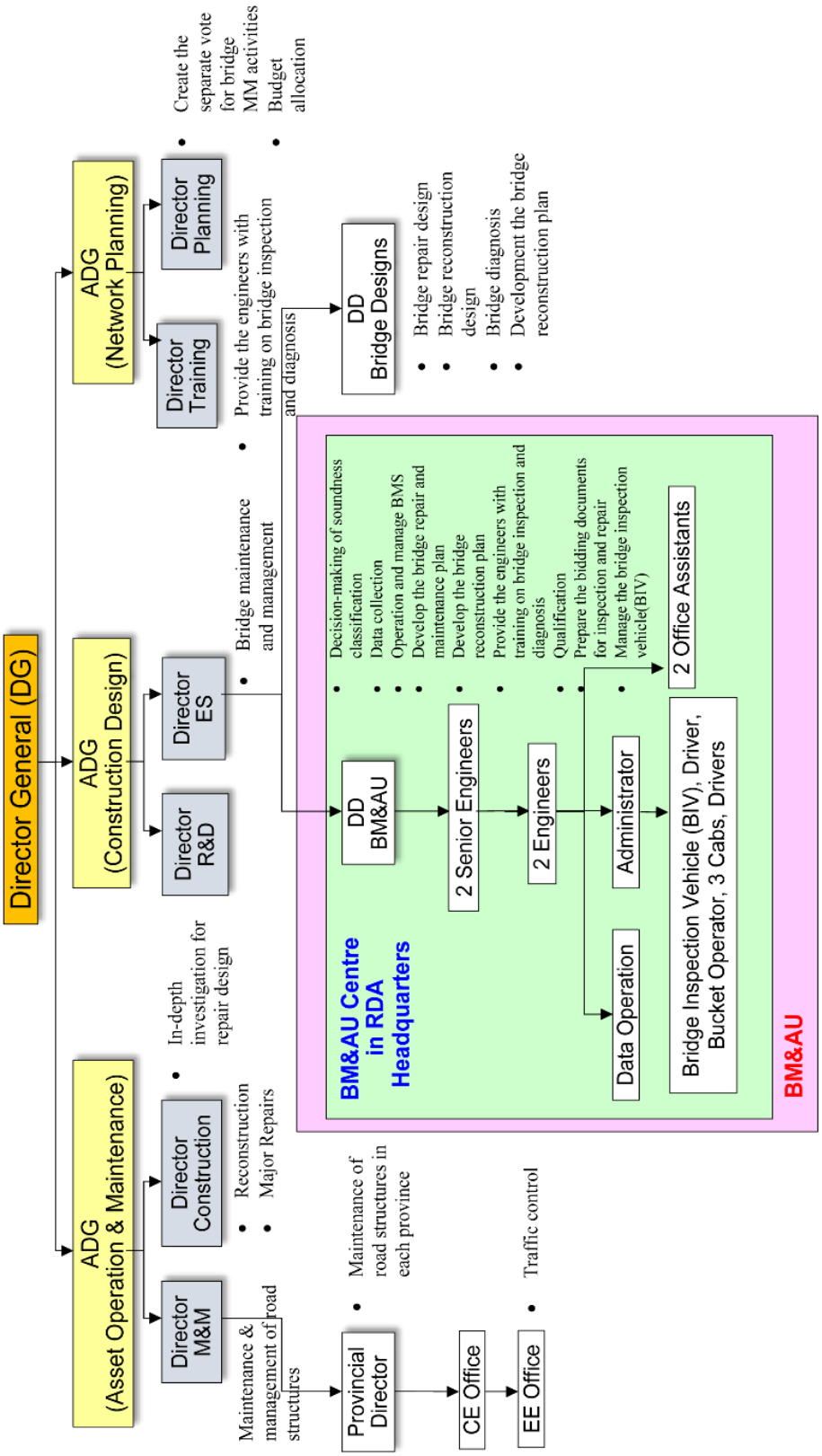

Figure 1-2 Division of Bridge Management

Table 1-1 Roles and Responsibilities

Division (Position)	Roles and Responsibilities
Ministry of Higher Education and Highways	• Budget Available from Foreign Funds
Director General	• Approval of Selection of Bridges for Reconstruction and Cost (Local Fund) • Budget Available from Foreign Funds
ADG CD	General Bridge Management • Confirmation of Periodic Inspection Plan (Nationwide) • Confirmation of Emergency Actions • Confirmation of Soundness Classification (Diagnosis Result) • Confirmation of Bridge Management Scenarios • Approval of Budget Plan for Bridge Repair & Maintenance • Budgetary Negotiation and Determination for Bridge Repair & Maintenance • Approval of Bridge Repair & Maintenance Plan • Approval of Bridge Reconstruction Plan • Confirmation of Ex-Post Evaluation
Director, Engineering Service	• Approval of Periodic Inspection Plan (Nationwide) • Approval of Emergency Actions • Approval of Soundness Classification (Diagnosis Result) • Approval of Bridge Management Scenarios • Finalization of Budget Plan for Bridge Repair & Maintenance • Confirmation of Budget Allocation for Bridge Repair & maintenance • Finalization of Bridge Repair & Maintenance Plan • Confirmation of Need of In-depth Investigation / Repair Design • Selection of Bridges for Reconstruction from Bridge Reconstruction Plan • Finalization of Bridge Reconstruction Plan • Development of Drawings and BOQ (Local Fund) • Approval of Drawings and BOQ (Foreign Funds) • Approval of Ex-Post Evaluation • Approval of rates for repair recommendation in database.
Director, R&D	• In-depth Investigation
Director, Planning	• Approval of Bridge Management Scenarios • Finalization of Budget Plan for Bridge Repair & Maintenance • Budget Negotiation for Bridge Repair & Maintenance • Confirmation of Budget Allocation for Bridge Repair & Maintenance • Approval of Selection of Bridges for Reconstruction and Cost (Local Fund) • Finalization of Bridge Reconstruction Plan
Director, Maintenance & Management	• Prepare Budget for Road Maintenance Trust Fund (RMTF) • Confirmation of RMTF Budget Allocation • Responsible for Routine Maintenance • Responsible for Implementing Bridge Minor Repairs • Responsible for Tendering of Bridge Major Repairs • Responsible for Supervising Bridge Major Repairs
Director, Construction	• Responsible for Tendering of Bridge Reconstruction • Responsible for Supervising Bridge Reconstruction
Director, Training	• Responsible for Providing Training on Bridge Basic Knowledge, Bridge Inspection, Diagnosis, Design, Repair, System Operation, Planning and Management

Deputy Director, Bridge Design	• Advise on Approval of Soundness Classification (Bridge Diagnosis) • Responsible for Bridge Repair Design • Finalization of Bridge Reconstruction Plan • Development of Drawings and BOQ (Local Fund) • Survey and Detailed Design of Bridge Reconstruction • Costing of repair / reconstruction design
BM&AU	
Head (Deputy Director)	• Arrangement of Bridge Inspection Vehicle • Development of Bridge Inspection Plan (Nationwide) • Decision of Emergency Actions • Approval of Entered Inventory and Inspection Data • Final Draft of Soundness Classification (Bridge Diagnosis) • System Operation • Development of Bridge Management Scenarios • Development of Budget Plan for Bridge Repair & Maintenance • Decision of Degree of Priority for Bridge Repair & Maintenance • Development of Bridge Repair & Maintenance Plan • Judgment of Need of In-depth Investigation / Repair Design • Approval of Entered Data for Bridge Repairs • Decision of Degree of Priority for Bridge Reconstruction • Development of Bridge Reconstruction Plan • Approval of Entered Data for Bridge Reconstruction (Inventory, Initial Inspection) • Responsible for Ex-Post Evaluation • Preparing Bridge Reconstruction Plan with priority • Updating Repair costs / Reconstruction costs in database
Senior Engineer	• Review of Periodic Inspection Plan (Nationwide) • Decision of Emergency Actions • Bridge Diagnosis • Visual Inspection (as needed) • Confirmation of Draft of Bridge Repair & Maintenance Scenario, Budget Plan, and Bridge Repair & Maintenance Plan / Reconstruction Plan • Confirmation of Ex-Post Evaluation
Engineer	• Assist DD BM&AU in the following process: ➢ Arrangement of Bridge Inspection Vehicle ➢ Development of Periodic Inspection Plan (Nationwide) ➢ Approval of Entered Inventory and Inspection Data ➢ Development of Final Draft of Soundness Classification ➢ Development of Draft of Bridge Management Scenarios, Budget Plan for Bridge Repair & Maintenance, Degree of Priority for Bridge Repair & Maintenance and Bridge Repair & Maintenance Reconstruction Plan ➢ Approval of Entered Data for Bridge Repairs ➢ Development of Draft of Degree of Priority for Bridge Reconstruction and Bridge Reconstruction Plan ➢ Development of Draft of Ex-Post Evaluation
Data Operation	• System Operation
BM&AU Engineer at PD Offices	• Judgment of Need of Emergency Actions, and Implementation of Emergency Actions • Visual Inspection of Periodic inspection and Initial Inspection • Data Entry of Periodic Inspection, Initial Inspection and Repair Record • Cross-check Soundness Classification and Bridge Condition • Development of Periodic Inspection Plan (for Each Province)
Provincial Director	• Assist BM&AU Engineer

EE Offices	• Planning and Implementation of Traffic Control during Periodic Inspection • Implementation of Emergency Actions • Visual Inspection with BM&AU Engineer at PD Offices • Development of Tender Document • Supervisor of Bridge Repair Work / Reconstruction (Local Fund) • Preparation of Data Entry • Implementation of Routine Maintenance of Bridges
International Consultants	• Development of Drawings and BOQ (Foreign Fund except World Bank, Kuwait, Saudi Funds) • Development of Tender Document of Bridge Reconstruction by Foreign Fund (as needed) • Supervisor of Bridge Reconstruction (Foreign Fund) • Preparation of Data Entry

1-3. Process Schedule

In order to implement Bridge Management efficiently with limited management resource, it is imperative to conduct the periodic inspection, planning of repair, maintenance and reconstruction; then the budgetary negotiation for securing the budget in accordance with the designated schedule.

Bridge Management is implemented in accordance with the standard schedule for bridge management in Figure 1-3.

(1) Periodic Inspection

It is imperative to conduct the periodic inspection by the end of fiscal year for the repair & maintenance / reconstruction plan and the request of the budget plan and the budget allocation. Therefore, the periodic inspection plan should be finalized in the beginning of fiscal year.

(2) Budget allocation

The repair cost can be calculated based on the results of the periodic inspection during the concerned year. Then, the repair & maintenance plan for the budget negotiation / allocation would be developed in accordance with Health Index (HI) and the repair cost.

However, if bridges already have the detailed design for the repair & maintenance work based on the previous inspection results, the accuracy of the repair cost could be improved. Therefore, it is necessary to develop the next year's budget plan with integrating both estimated costs if increase or decrease of cost is large.

In case the damage is in need of immediate and major repair is detected during the periodic / routine inspection, it is imperative to implement the countermeasure within fiscal budget. If the additional budget is needed, the budget plan from RDA for the countermeasure should be developed, and/ or contigency funding shall be used.

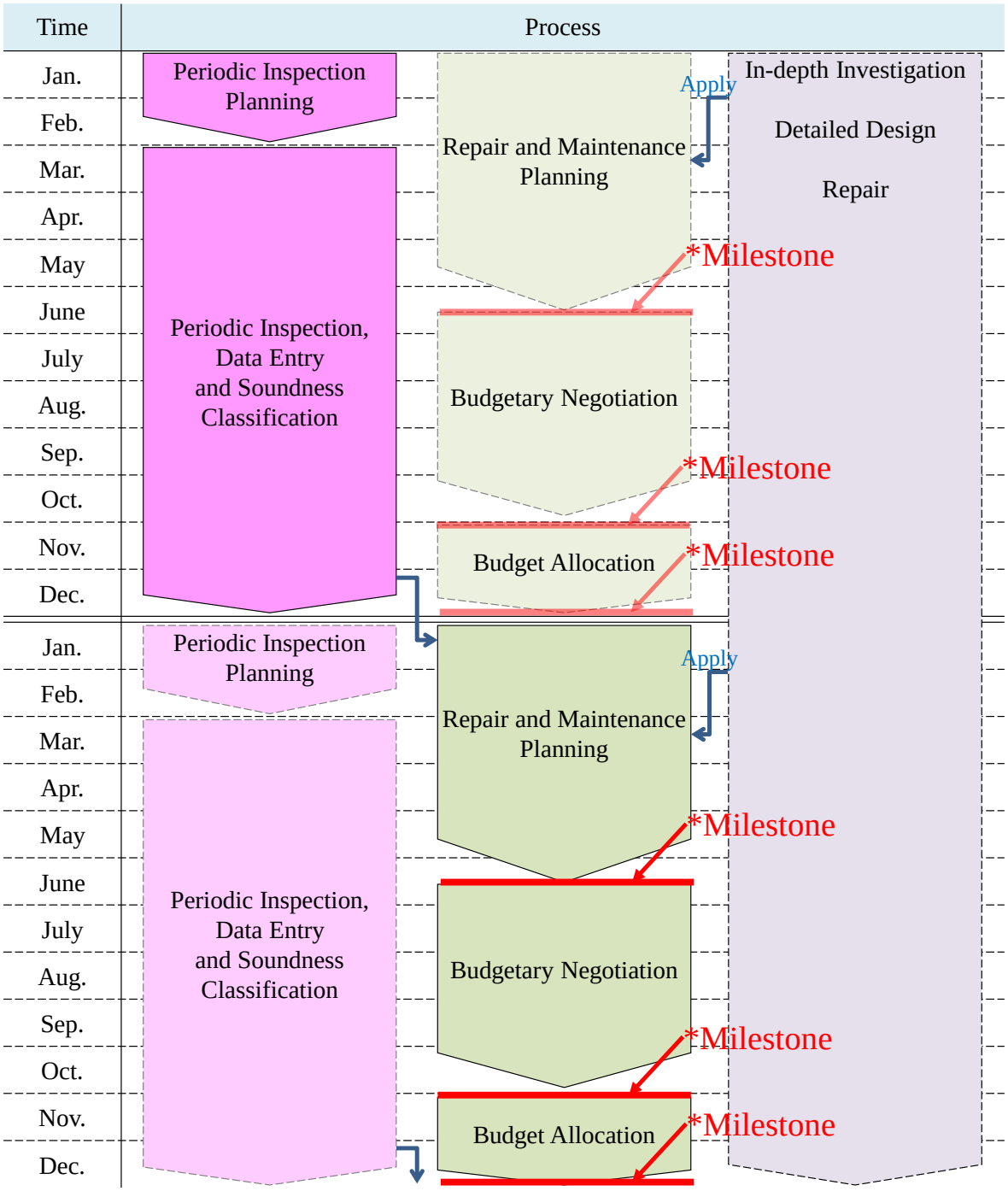

Figure 1-3 Standard Schedule for Bridge Management

1-4. Related Manuals

Bridge Management is implemented in accordance with the each manual in Figure 1-4.

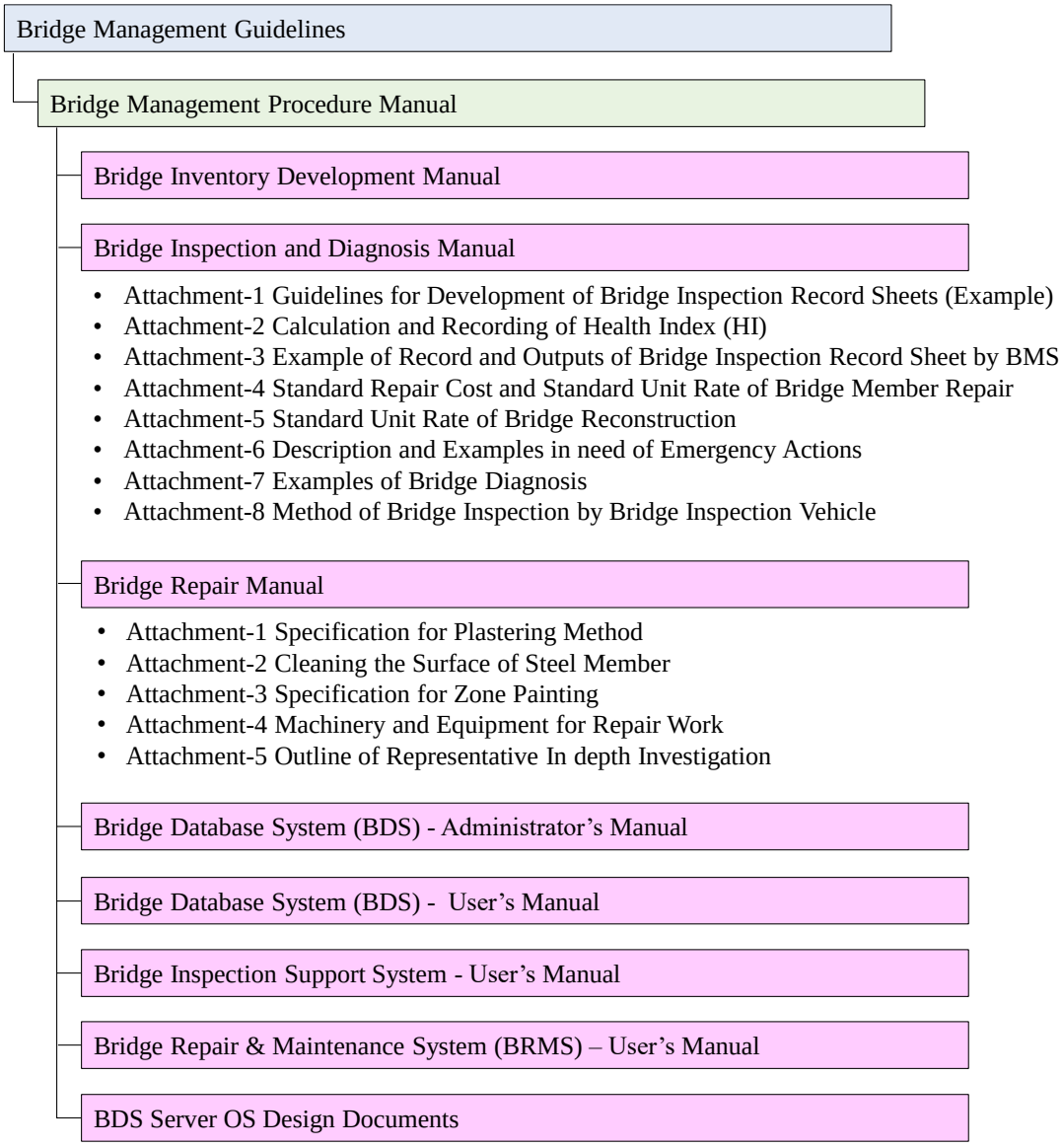

Figure 1-4 Related Manuals

2. Periodic Inspection

2-1. Preparation of Periodic Inspection Plan

Prior to Periodic Inspection, it is required to organize the periodic inspection plan. The periodic inspection must be implemented appropriately and efficiently in accordance with the periodic inspection plan.

During the periodic inspection, it is important to collect and record the correct information required for proper Bridge Management.

(1) Items to be included in Periodic Inspection Plan

The following are the standard items to be included in the periodic inspection plan

- Target Bridge List

  The periodic inspection is conducted every 5 years. It is desirable that the number of target bridges in each year should be equal. Target bridges which could not be inspected in the past years due to inconvenient reasons such as bad weather must be included in the Inspection Plan.

- Target Bridges Inventory

  The overview of the target bridges, such as the inventory, the disaster history and the repair history, must be understood by collecting the existing data or the site exploration (inventory research). In addition, the site exploration or a map should be applied for the confirmation of the inspection route and the equipment location such as Bridge Inspection Vehicle for the proper and efficient inspection.

- Implementation Structure

  The allocation of the inspectors / staff for both site work and office work should be organized.

- Inspection Process

  It is necessary to verify whether the traffic restriction or the scaffolding settings due to repair work are planned in the period of the periodic inspection or not.

  If the period of the periodic inspection and repair work conflict with each other, the possible actions to be taken are either to reschedule the inspection or to make some arrangement to conduct the inspection during the repair work period.

  For example, if the inspection is conducted at the same time with the repair & maintenance work / the construction work, it is necessary to implement some safety measures such as avoiding the construction site and appointing a safety supervisor. In this case, it could lead to the overall

efficiency of Bridge Management by reducing overlapping cost for the traffic restriction and the scaffolding.

In addition, the timing of Bridge Inspection Vehicle (BIV) is cared for in the inspection process.

- Employed Equipment such as Bridge Inspection Vehicle (BIV) and Measures for Difficult-to-Inspect Areas

The list of the required equipment (BIV, Vehicle for traffic control tools, Boat) for periodic inspection should be organized based on the conditions of the bridge site written in the references collected in advance. In addition, the alternate procedures for the inspection sites where the visual inspection cannot be conducted need to be considered. For Bridge Inspection Vehicle, refer to "Bridge Inspection and Diagnosis Manual, Attachment-8, Method of bridge Inspection by Bridge Inspection Vehicle".

Table 2-1 Examples of Difficult-to-Inspect Areas and Countermeasures

Location	Reasons	Countermeasures
Tall Bridge Pier	Unreachable with ladders	Pole Camera Bridge Inspection Vehicle
Overhang Part near Median Divider	No space under the beam (No space between the bridge bottom and the roads, railways, rivers below the bridge)	Temporary closure of the roads and railways below the bridge Pole camera Boat

- Emergency Contact System

In case of accidents such as falling from the bridge, traffic accidents during the inspection and the damage on bridge accessories, the emergency contact list, such as BM&AU Head Office, ambulance, fire department and local authorities should be organized.

- Safety Measures

The list of personal protective equipment (PPE) and the equipment in need of traffic restriction should be organized. The equipment such as binoculars and inspection hammers must be checked to see if the anti-drop safety measures are applied.

- During the visual inspection, it is necessary to protect the inspector's head (helmet), hand (gloves), foot (safety boots) and further safety belt for prevent falling from high positions and also safety vest against vehicle drivers are required.
- In case the traffic restriction is required at the site, coordination with the local police in advance is necessary for the safety of traffic control. And it is required to install signboards and other equipment that clearly inform the inspection activity or repair works to road users.

- Related Authorities

  When target bridges cross over the roads, railways and rivers that are not under the management of RDA, the advance coordination should be held as necessary. Therefore, the list of the related authorities should be prepared.

- Other Necessary Items

  When the target bridges require other items unspecified above, they should be organized as necessary.

(2) Procedure of Development of Periodic Inspection Plan

The periodic inspection plan is developed in accordance with the procedure in Figure 2-1.

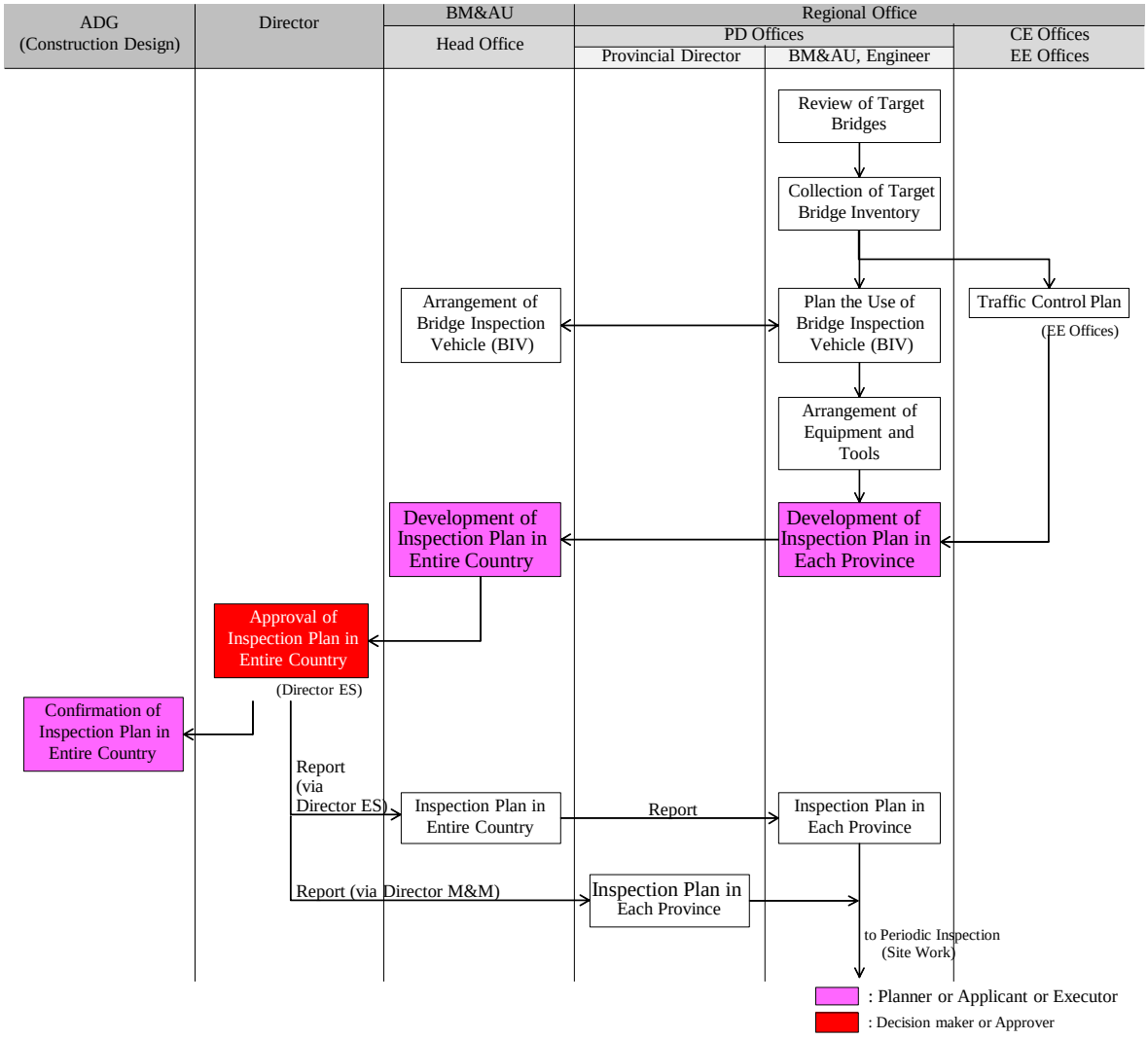

Figure 2-1 Procedure of Development of Periodic Inspection Plan

- Review of Target Bridges

  - BM&AU Engineer at PD Offices should prepare the list of target bridges for the periodic inspection. The bridges that were not inspected in the previous year should be identified and added to the list.

- Collection of Target Bridge Inventory

  - BM&AU Engineer at PD Offices is in charge of collecting the information of target bridges such as the bridge inventory by utilizing Bridge Inspection Support System and Bridge Database System. In addition, the filed surveys and maps should be utilized as needed.

- Traffic Control Plan

  - When the traffic restriction is required for the periodic inspection, the control methods should be organized. EE Office must be in charge of planning because of their experience with the surrounding roads of target bridges.

- Arrangement of Bridge Inspection Vehicle (BIV), Equipment and Tools

  - The equipment necessary for the visual inspection should be arranged. In case the required equipment is unavailable, it should be arranged prior to the visual inspection.

  - For the bridges that require BIV, BM&AU Engineer at PD Offices should coordinate with BM&AU Head Office which manages BIV. To avoid the impact on the establishment of the periodic inspection schedule, BM&AU Head Office must consider the planned use of BIV in each province in order to determine and notify the operation schedule of BIV to each province.

- Development of Periodic Inspection Plan

(3) BM&AU Engineer at PD Offices should formulate Periodic Inspection Plan in accordance with the items written in Section 2-1.(1) ; “Items to be included in Periodic Inspection Plan”, Data Collection, Traffic Control Plan and Arranging of BIV, Equipment and Tools above.

  - After receiving reports on the periodic inspection plan from each province, BM&AU Head Office should put them together as a nationwide periodic inspection plan. Thereafter, the plan should be reported to Director ES by BM&AU Head Office, and approved by Director ES.

  - After the periodic inspection plan gets approved by Director ES, it should be confirmed by ADG (CD) and reported to BM&AU Head Office via Director ES. In addition, Provincial Director should receive the plan from Director MM.

2-2. Periodic Inspection (Site Work)

The periodic inspection should be conducted appropriately in accordance with the periodic inspection plan for site work.

The periodic inspection should be conducted with the understanding of the objectives of the periodic inspection. (Refer to "Bridge Inspection and Diagnosis Manual") The improper periodic inspection makes it impossible to collect the data regarding the bridge conditions which are fundamental for Bridge Management. It leads to improper classification of bridge soundness, calculation of repair cost and the formulation of repair plan.

(1) Important Matters of Periodic Inspection (Site Work)

- Preparation for Inspection

  Items to be available on the day of the visual inspection are the following:
  - Information such as the inventory of target bridges
  - Equipment necessary for the visual inspection and personal protective equipment (PPE)
  - Designated Inspection Record Forms from Bridge Inspection Support System
  - Written permit for traffic restriction
  - Bridge Inspection Vehicle (BIV) if needed.

- Emergency Actions

  If risky condition is observed for the judgment on necessity of emergency action, it shall be decided by BM & AU Engineer and /or EE immediately during the periodic inspection based on the inspection results done by inspector.

  To avoid the third-party damages, when the measures can be promptly implemented on site, for example, traffic restriction, removing the delaminated concrete and installation of the caution signboards, they should be implemented at site.

  In case that the damage on the bridges under the management of RDA affects roads and railways under / along the bridges, RDA should immediately notify the matters to the relevant road and railway administrators. It is necessary for RDA to require them to take appropriate actions such as the roads / railways closure and installation of the caution signboards.

  For procedures concerning damage in need of Emergency Action, refer to "Bridge Inspection and Diagnosis Manual, Attachment-6 Description and Examples in need of Emergency Actions".

- Visual Inspection

The periodic inspection is conducted primarily by visual inspection. The physical inspection and the hammering inspection are conducted as needed.

Each type of damage should be evaluated based on its degree only. Such results should be categorized into five (5) grades as in Table 2-2. For the methods for recording and taking pictures, refer to "Bridge Inspection and Diagnosis Manual, Attachment-1, Guidelines for Development of Bridge Inspection Record Sheets (Example)."

Table 2-2 Evaluation of Damage

Grade of Damage	General Condition	
a	Sound	There is no damage on bridge member.
b	Almost Sound	Damage on bridge member is small.
c	Slight	There is a certain degree of damage on bridge member.
d	High	Damage on bridge member is high.
e	Serious	Damage on bridge member is serious.

(2) Procedure of Periodic Inspection (Site Work)

The periodic inspection (site work) is implemented in accordance with the procedure in Figure 2-2.

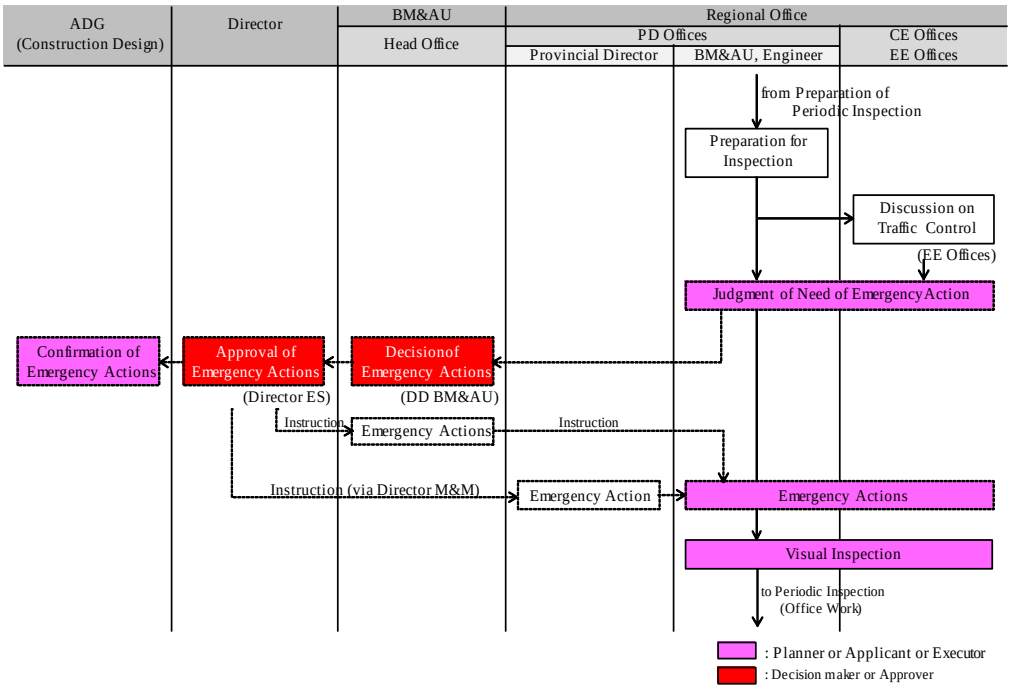

Figure 2-2 Procedure of Periodic Inspection Plan (Site Work)

- Preparation for Inspection

  - Prior to the visual inspection, the inspectors should understand the periodic inspection plan and confirm the bridge inventory, the inspection route and the emergency contact lists.

  - BM&AU Engineer at PD Offices should print out the designated forms for target bridges from Bridge Inspection Support System.

  - In case BIV is required, BM&AU Engineer at PD Offices arranges BIV from BM&AU Head Office.

- Discussion on Traffic Control

  - In case that the visual inspection requires BIV or the width of the bridge is narrow, such as narrow width of a lane and a single lane in each direction, the traffic restriction might be required during the visual inspection. Therefore, BM&AU Engineer at PD Offices (EE Office) needs to discuss with the Police Department.

- Emergency Actions

  - The inspectors should judge whether there is a damage in need of Emergency Actions or not before the visual inspection.

  - In case the damage is need of Emergency Actions, the inspectors should implement the measures if the prompt measures are available. (i.e. tentative traffic control, removing the delaminated concrete)

  - Then, the inspectors must report to BM&AU Head Office and EE Office on the site conditions.

  - In the serious case, BM&AU Engineer should report to BM&AU Head Office. After BM&AU Head Office decides Emergency Actions, it should be approved by Director ES. Thereafter, ADG (CD) should confirm Emergency Action. BM&AU Head Office should instruct Emergency Actions to BM&AU Engineer at PD Offices, as well as Director MM should instruct it to Provincial Director.

  - When the roads and railways outside the management of RDA are being affected, the RDA / PD should inform the relevant authorities and request to take countermeasures. EE Office must take over the traffic control from the inspectors and start the traffic control.

- Visual Inspection

  - The inspectors should put on PPE. (Refer to “Bridge Inspection and Diagnosis Manual”)

  - The inspectors conduct the visual inspection as a basic method and adopt the physical inspection and the hammering inspection as needed. Moreover, in order to ensure the safety of the inspectors and the drivers, the traffic restriction should be implemented as needed.

  - The inspectors record the information obtained by the inspection in the designated forms.

  - Support staff for the periodic inspection should be nominated from EE Offices. (BM&AU Engineer at PD Offices trains the engineer from EE Offices to become BM&AU Engineer in future.)

2-3. Periodic Inspection (Office Work)

The data obtained by the periodic inspection should be immediately entered into Bridge Inspection Support System. The soundness classified by BMS should be reviewed and finalized by the experienced engineers.

The data obtained by inspection is utilized for the classification of bridge soundness and calculation of the repair & maintenance / reconstruction costs. Therefore, the data recorded on site needs to be registered into Bridge Inspection Support System promptly and properly.

If severe damage is observed, it could cause a serious incident such as the collapse of the bridge, leading to death and injury. This is the reason why the diagnosis should be conducted for the entire bridge after the visual inspection.

(1) Important Matters regarding Periodic Inspection (Office Work)

- Data Entry to Bridge Inspection Support System

  After the visual inspection, the data must be entered promptly and accurately into the system. The incorrectly recorded data leads to inaccurate classification of the bridge soundness and calculation of the costs. As a result, the proper bridge management would be impossible to be implemented. For more information concerning the data entry, refer to “Bridge Inspection Support System - User Manual”.

- Calculation of Health Index

  Health Index (HI) is calculated according to the data entered into the system in order to classify the bridge soundness and calculate the costs. Health Index (HI) shall be calculated by each member, span and bridge based on the degree of damage on members.

  <Reference: The Calculation Procedure of HI>

  1) Calculate Damage Point (DP) by adding the weighing factors based on the significance of the damage to the evaluation point according to the degree and extent of the damage on the member as observed at inspection.

  2) Consider HI is 100 when the condition is absolutely sound with or without damage. Calculate HI by subtracting DP from 100.

  $$\text{Health Index (HI)} = 100 - \sum \text{Damage Point (DP)}$$

  3) Calculate HI by integrating DP of each span and structure type, based on the DP of each member and weighing factor evaluated according to the significance of types of member and structure.

4) HI of the bridge shall be the minimum HI of its spans.
Refer to "Bridge Inspection and Diagnosis Manual, Attachment-2, Calculation and Recording of Health Index (HI)" for more detailed procedure of HI calculation.

- Soundness Classification

Bridge soundness is classified in accordance with Table 2-3, with reference to the value of Health Index (HI).

Table 2-3 Classification of Bridge Soundness

Classification		Condition	Health Index
A	Sound	Structures are well functioning.	75 – 100
B	Preventive Maintenance Stage	Structures are well functioning. However, it is desirable to take necessary measures from the perspective of preventive maintenance.	50 – 75
C	Reactive Maintenance Stage	Functions of the structure will be possibly impaired. Necessary measures should be taken at an early stage (within 5 years)	25 – 50
D	Immediately Action Stage	Functions of the structure are impaired or the possibility of impairment of functions is extremely high. Necessary measures should be taken immediately (within 2 years)	0 – 25

Soundness classification is set up in addition to the health index. It is because it can be used for the road administrator to generally understand the condition of bridges under its management or to utilize as a convenient indicator for releasing the bridge conditions to the public.

- Bridge Diagnosis

Health Index (HI) is used to prevent variations of the soundness among the inspectors / evaluators. Thereafter, soundness of the bridge member, a span and an entire bridge are categorized into four (4) classifications given in table 2-3.

However, it is noted that Health Index (HI) does neither consider all types of damage on each bridge member and rate of progress of damage, nor include the influence of location of damage to the soundness of the bridge member, a span and an entire bridge.

Highly experienced experts within RDA shall review and change the bridge soundness classification of a span (not of a bridge member) determined by Health Index from the viewpoints of shortcomings of HI mentioned above at the end of bridge periodic inspection. The value of Health Index shall not be changed. In addition, all bridges must be reviewed by experienced engineers.

If the serious damage is not judged appropriately, the serious damage will not be repaired and strengthened. Therefore, there is a possibility of the collapse of a bridge suddenly without warning and serious accidents causing death and injuries. Refer to “Bridge Inspection and Diagnosis Manual, Attachment-7, Examples of Bridge Diagnosis”.

- Estimation of Bridge Repair & Maintenance cost

  The standard repair cost shall be for the purpose of understanding the repair and maintenance budget of bridges under management and be determined based on the rates of bridge repair corresponding to the health index. For the standard repair cost and standard unit rate, refer to “Bridge Inspection & Diagnosis Manual, Attachment-4, Standard Repair Cost and Standard Unit Rate of Bridge Member Repair”.

(2) Procedure of Periodic Work (Office Work)

The periodic inspection (office work) is implemented in accordance with the procedure in Figure 2-3.

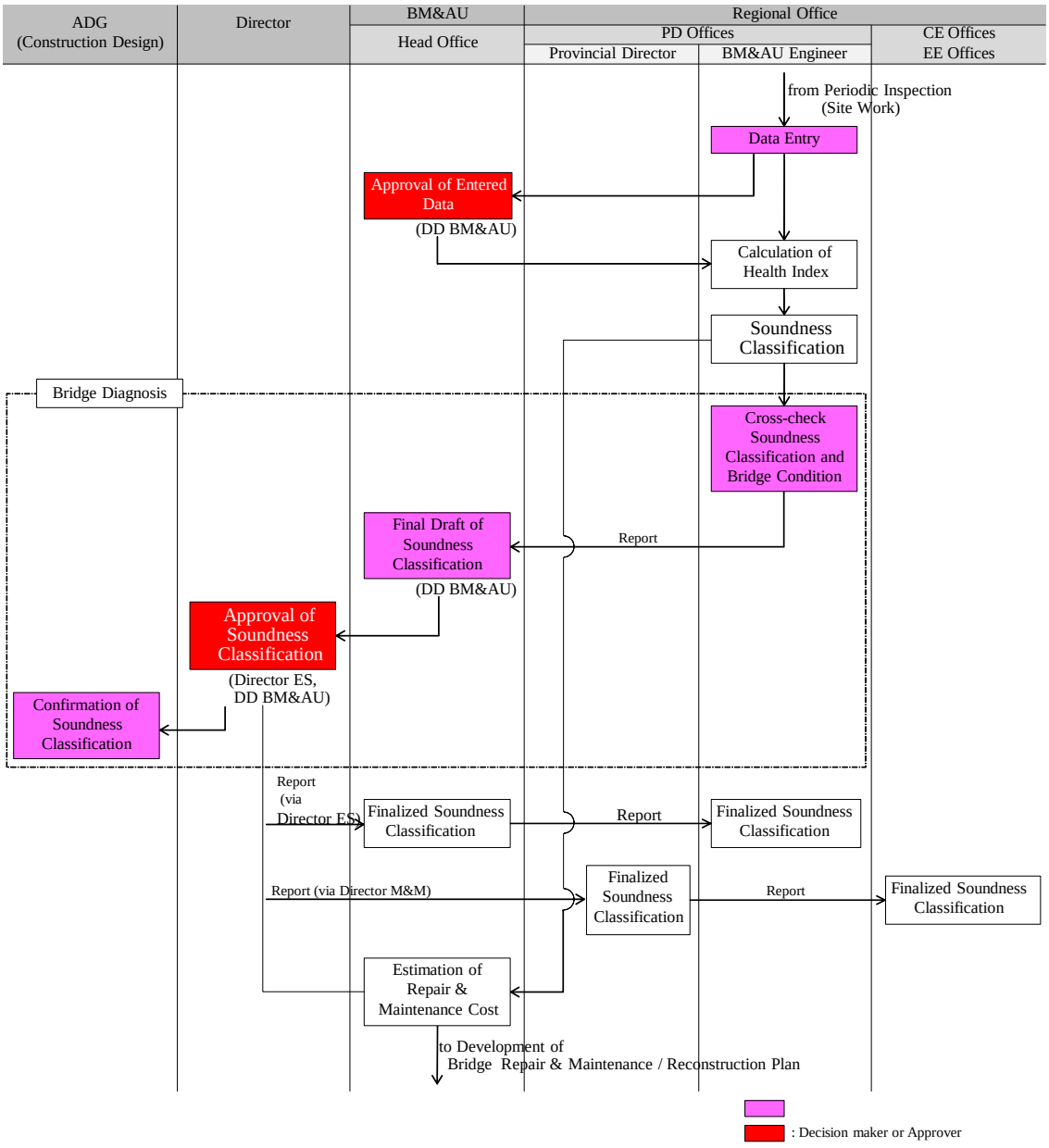

Figure 2-3 Procedure of Periodic Inspection Plan (Office Work)

- Data Entry to Bridge Inspection Support System

  - BM&AU Engineer at PD Offices should input the data of damages obtained by the visual inspection into the system. BM&AU Engineer at PD Offices can appoint a person to perform the data entry. However, BM&AU Engineer at PD Offices must be held responsible for confirming the accuracy of the entered data. Support staff for the periodic inspection should be nominated from the engineer at EE Offices. (BM&AU Engineer at PD Offices trains the engineers from EE Offices to be candidate BM&AU Engineers.)

- The entered data needs to be approved by BM&AU Head Office.

- Calculation of Health Index (HI)

  - After BM&AU Engineer at PD Offices enter the inspection data into Bridge Inspection Support System, Heath Index (HI) is automatically calculated.

- Soundness Classification

  - Bridge soundness classification is automatically determined from HI.

- Bridge Diagnosis

  - BM&AU Engineer at PD Offices must confirm the soundness classification and the bridge condition with the visual inspection results and pictures restored in the system. In addition, the additional field investigation should be implemented as needed. In case that the bridge condition is more serious than the soundness classification, it is necessary that the soundness classification is to be changed to the higher rank.

  - BM&AU Head Office should collect the confirmation results from BM&AU Engineer at PD Offices, and conduct the diagnosis. In addition, the additional field investigation should be implemented as needed. When BM&AU Head Office change the soundness classification from that automatically determined based on HI, BM&AU Head Office should describe the reasons in remarks column in Bridge Inspection Support System. The diagnosis results (the soundness classification) should be approved by Director (ES) and DD (BM&AU).

  - The finalized Soundness Classification must be confirmed by ADG (CD).

  - After the soundness classification gets approved by Director ES and DD BM&AU it should be reported to BM&AU Head Office via Director ES and to Provincial Director via Director MM.

- Estimation of Bridge Repair & Maintenance costs

  - Bridge repair & maintenance costs are automatically calculated in the system. Therefore, BM&AU Head Office must be aware of the progress of the data entry. In detail, BM&AU Head Office should notify the deadline for the data entry to BM&AU Engineer at PD Offices considering the process after data entry, such as the cost calculation based on the management scenarios, the repair & maintenance plan and the budgetary negotiation.

3. Development of Bridge Repair & Maintenance Plan

Bridge Repair & Maintenance Plan is developed in accordance with the soundness classification finalized based on the inspection results and the diagnosis.

The soundness classification and the repair cost is calculated based on Health Index (HI). According to these data and considering bridge management scenarios feasible within the limited budget, the repair & maintenance plan is created and the budget is negotiated.

(1) Important Matters regarding Development of Bridge Repair & Maintenance Plan

- Setting of Bridge Management Scenarios

  In order to formulate the repair & maintenance plan feasible within the limited budget, the bridge management scenarios are necessary. For the budgetary negotiation with Ministry of Finance and the external accountability regarding the budgetary request, the validity of the repair & maintenance plan is expected. Therefore, when formulating the repair & maintenance plan, it is important to prepare the objective bridge management scenarios. It is essential to utilize Health Index (HI) calculated objectively based on the damage grade to the bridge management scenarios. For the management scenarios, refer to “Bridge Management Guidelines” Manual.

- Development of Bridge Repair and Maintenance Budget Plan and Budgetary Negotiation

  The budget plan for the budgetary negotiation with Ministry of Finance is developed based on bridge management scenarios. It is important to include the information required for the negotiation. (i.e. Health Index (HI) of bridges, structures and members to repair, feasible budget and repair period) The bridge repair & maintenance costs for the budget plan are automatically calculated by the system based on the bridge management scenarios (based on HI) with Bridge Repair & Maintenance System.

  This year’s list might contain the bridges from the previous years’ lists but have not yet repaired. When those unrepaired bridges already have the detailed repair design for the repair & maintenance, the accurate repair cost could be accumulated. Therefore, those repair cost must be replaced if necessary. For the budgetary negotiation with Ministry of Finance, the finalized budget plan should be adopted. Refer to “Bridge Management Guidelines” manual for more information.

- Prioritization of Bridge Repairs and Development of Bridge Repair and Maintenance Plan

  As the budget is fixed after the budgetary negotiation with Ministry of Finance, the bridges on the repair list are prioritized in order to formulate bridge repair and maintenance plan. The

prioritization of the bridges for repairs should be performed based on Health Index (HI) and Importance Index (II). Importance Index (II) is determined based on the awareness survey. The systematized evaluation criteria for Importance Index (II) are given in Figure 3-1.

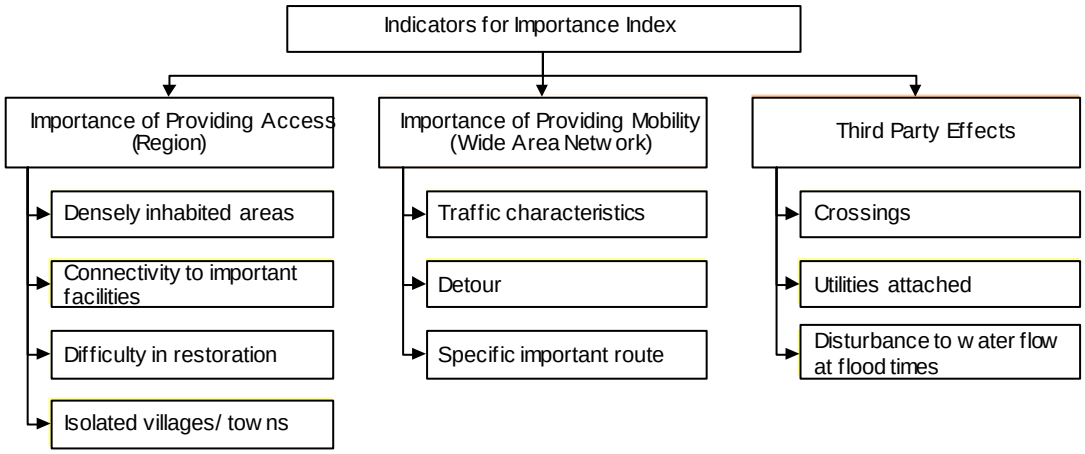

Figure 3-1 Systematized Evaluation Criteria for Importance Index

It is necessary to confirm that the bridges in the soundness classification “D” are prioritized. Moreover, the bridge list for the repair might contain those from the past years. It is required to verify that those bridges have the past inspection results and more accurate repair cost.

For Prioritization of Bridge Repairs and Development of Bridge Repair and Maintenance Plan, refer to “Bridge Management Guidelines.”

<Reference: Degree of Relative priority of Repair and Maintenance>

Priority for implementing the repair and maintenance work shall be evaluated comprehensively in consideration of both Health Index (HI) and Importance Index (II). Degree of relative priority (Priority Point) of bridge repair is given as follows:

Degree of Relative Priority (Priority Point) $=\alpha \times (100 - \text{Health Index}) + \beta \times \text{Importance Index}$

Whereas, $\alpha + \beta = 1.00$

(2) Procedure of Development of Bridge Repair & Maintenance Plan

The bridge repair & maintenance plan is developed in accordance with the procedure in Figure 3-2.

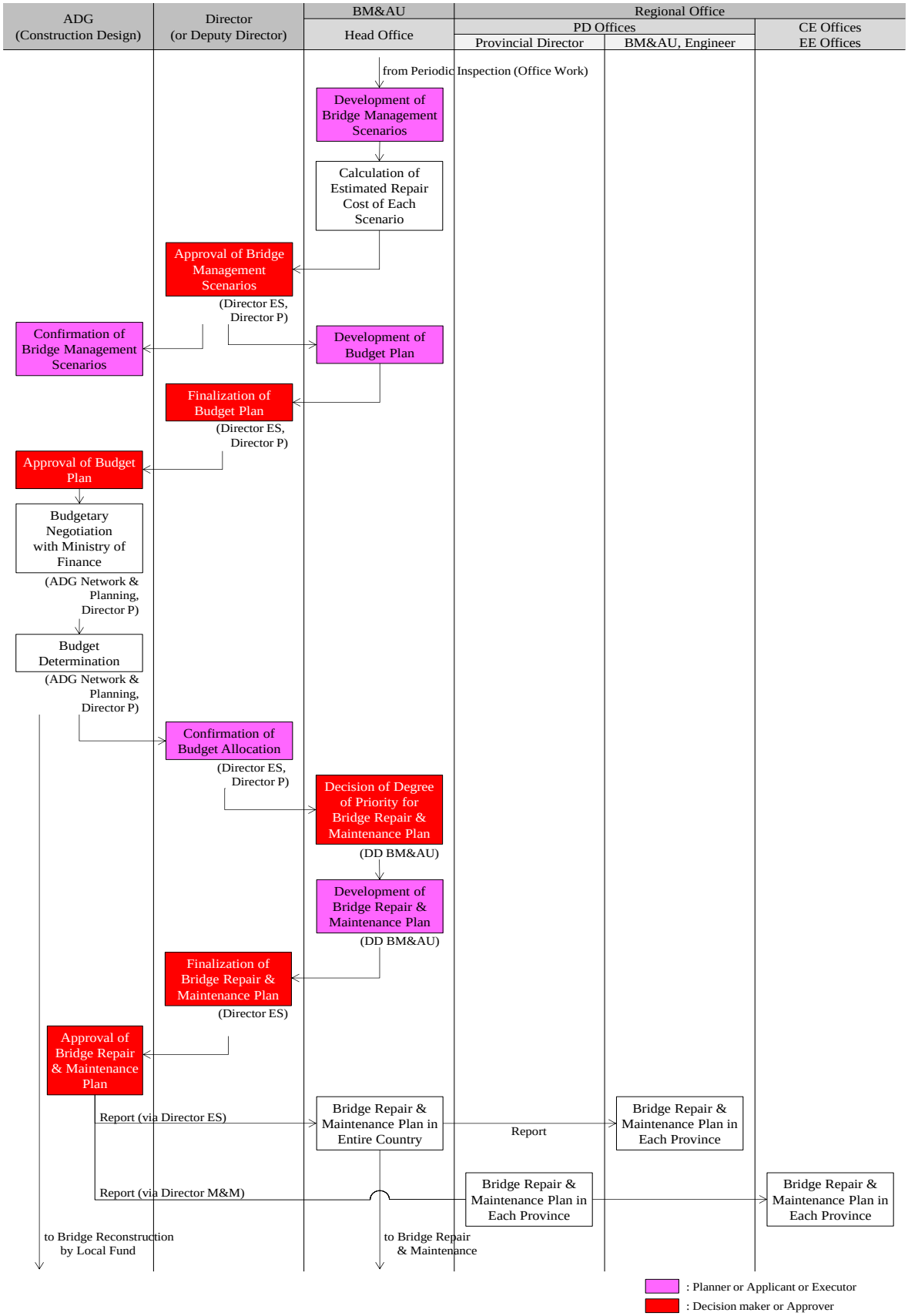

Figure 3-2 Procedure of Development of Bridge Repair & Maintenance Plan

- Setting of Bridge Management Scenarios

  - BM&AU Head Office should develop bridge management scenarios based on Health Index (HI) and calculate the bridge repair & maintenance costs based on the bridge management scenarios (based on HI) with Bridge Repair & Maintenance System.

  - The developed scenarios should be reviewed and approved by Director ES and Director P and confirmed by ADG (CD).

- Development of Bridge Repair and Maintenance Budget Plan and Budgetary Negotiation

  - BM&AU Head Office develops the budget plan to negotiate with Ministry of Finance in accordance with the approved scenarios.

  - Director ES and Director P should select one scenario from the approved scenarios, and finalize the budget plan

  - The finalized plan should be approved by ADG (CD).

  - The budgetary negotiation with Ministry of Finance should be implemented based on the approved budget plan.

- Prioritization of Bridge Repairs and Development of Bridge Repair and Maintenance Plan

  - As the budget is fixed after the budgetary negotiation with Ministry of Finance, Director ES and Director P should confirm the budget allocation.

  - BM&AU Head Office should prioritize the bridges on the repair list created based on Health Index (HI) and Importance Index (II). Thereafter, BM&AU Head Office should develop the bridge repair & maintenance plan. BM&AU Head Office should confirm the bridges from the past years' repair lists and more accurate cost as needed.

  - The formulated bridge repair & maintenance plan should be reviewed and finalized by Director ES, and approved by ADG (CD).

  - After the bridge repair & maintenance plan gets approved by ADG (CD), it should be reported to BM&AU Head Office via Director ES and to Provincial Director via Director MM. The Approved bridge repair & maintenance plan is utilized for the bridge repair & maintenance and the bridge reconstruction by local funds.

4. Development of Bridge Reconstruction Plan

When the bridge reconstruction is necessary according to the results of Periodic inspection and Bridge diagnosis, reconstruction plan must be formulated.

As a result of periodic inspection, sometimes it is detected that the bridges require not only repair and strengthening, but reconstruction. In those cases, reconstruction plan should be formulated. As well as Repair & Maintenance, it is necessary to develop the reconstruction plan feasible within the limited budget and submit the budgetary request.

(1) Important Matters regarding Development of Bridge Reconstruction Plan

- Functionally Obsolete Index (FOI)

  Prioritization of reconstruction, the basic elements of bridge reconstruction plan, is performed based on Health Index (HI), Importance Index (II) and Functionally Obsolete Index (FOI). Functionally Obsolete Index (FOI) represents the obsoleteness of the bridge functions. The evaluation criteria for FOI is given in Figure 4-1. As Table 4-1 shows, the functional obsoleteness is classified into 4 categories based on FOI. For further information, refer to “Bridge Maintenance Guidelines” manual.

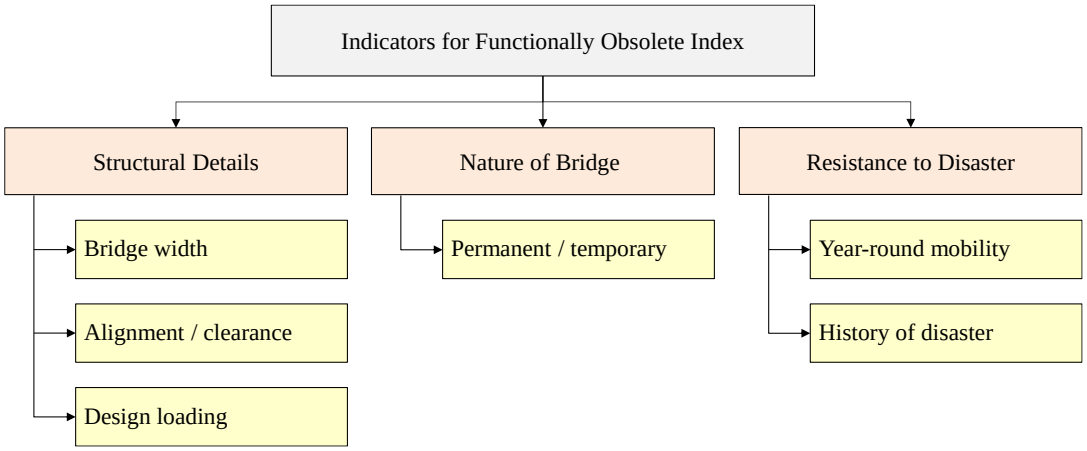

Figure 4-1 Evaluation Criteria for Functionally Obsolete Index

Table 4-1 Classification of Functional Obsolescence

Classification		Condition	FOI
A’	Satisfactorily functioning	A bridge exhibits the required functions satisfactorily.	0 - 25
B’	Functionally obsolete	A bridge is functionally obsolete. However, no adverse effect to socioeconomic activities is identified.	25 – 50
C’	Functionally obsolete remarkably	A bridge is functionally obsolete to the extent that socioeconomic activities are adversely and remarkably affected.	50 – 75
D’	Functionally obsolete seriously	A bridge is functionally obsolete to the extent that socioeconomic activities are adversely and seriously affected.	75 - 100

- Prioritization of Bridge Reconstruction and Development of Bridge Reconstruction Plan

  The bridges on the reconstruction list should be prioritized prior to the development of reconstruction plan.

  The prioritization is based on Health Index (HI), Importance Index (II) and Functionally Obsolete Index (FOI). It should be confirmed that the bridges with Classification “D” of Functionally Obsolete Index (FOI) are prioritized. For further information, refer to “Bridge Maintenance Guidelines” manual.

  Moreover, the bridges that require reconstruction are not only those inspected this year. It is important to be aware that the information includes the inspection results from the past years and the construction cost for those bridges has more accuracy.

  The reconstruction plan should be developed regardless of whether the budget for the reconstruction is secured or not.

(2) Procedure of Development of Bridge Reconstruction Plan

The bridge reconstruction plan is developed in accordance with the procedure in Figure 4-2.

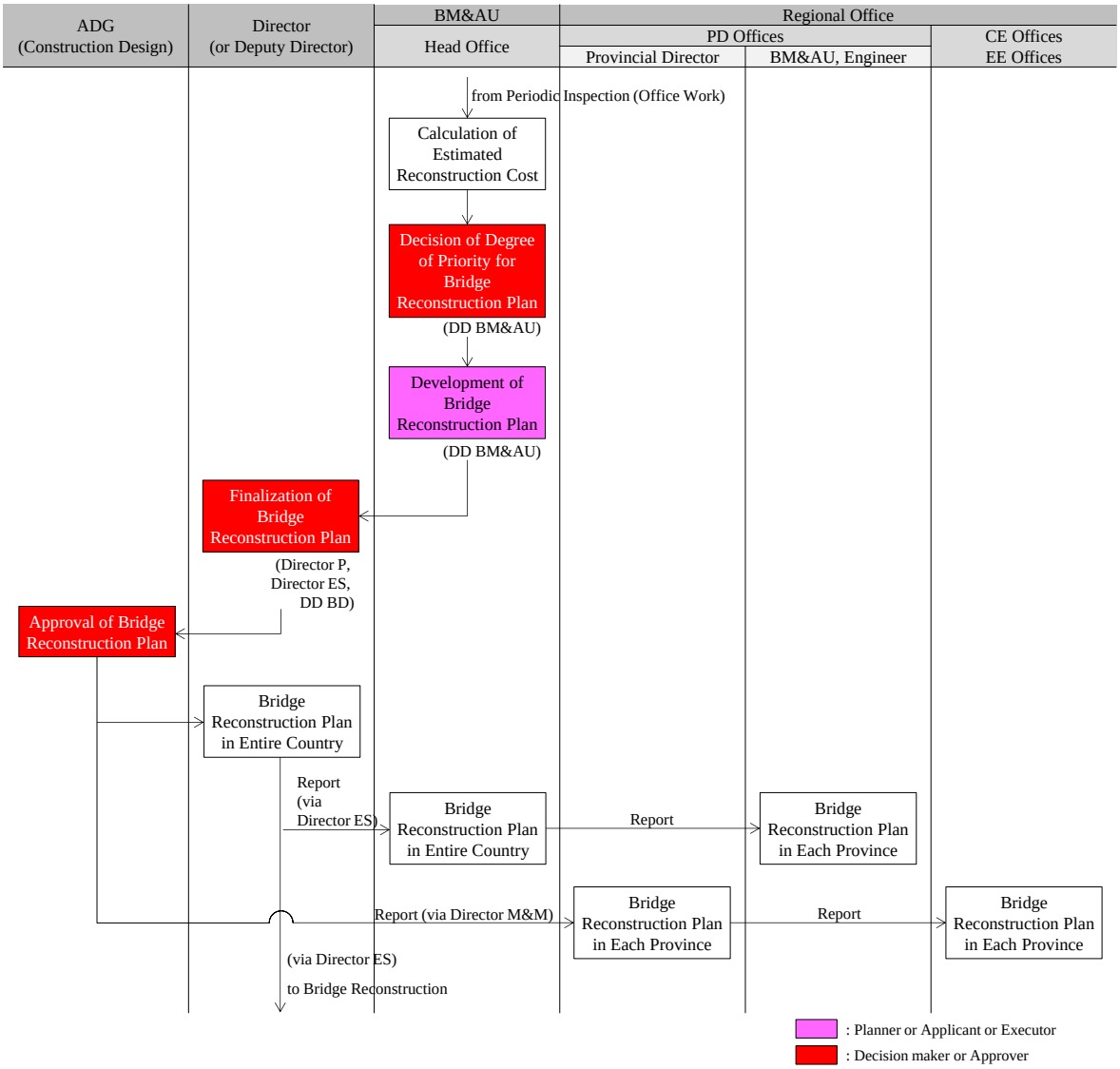

Figure 4-2 Procedure of Development of Bridge Reconstruction Plan

- Prioritization of Bridge Reconstruction and Development of Bridge Reconstruction Plan

  - BM&AU Head Office should calculate the bridge reconstruction cost with Bridge Repair & Maintenance System.

  - BM&AU Head Office should prioritize the bridges on the reconstruction list created based on Health Index (HI), Importance Index (II) and Functionally Obsolete Index (FOI) for the reconstruction plan. Thereafter, BM&AU Head Office should develop the bridge reconstruction plan.

- Thereafter, Director P, Director ES and DD BM&AU should finalize the bridge reconstruction plan. They should confirm the bridges from the past years and more accurate construction cost for the bridge reconstruction plan.
- The finalized bridge reconstruction plan should be approved by ADG (CD).
- After the bridge reconstruction plan gets approved by ADG (CD), it should be reported to BM&AU Head Office via Director ES and to Provincial Director via Director MM.

5. Bridge Repair and Maintenance

The repair and maintenance of the bridges must be properly implemented according to the approved bridge repair and maintenance plan. After the completion of repair and reinforcement, the data such as construction history should be entered into the system.

Since the proper maintenance & management is required even after the repair, the data such as construction history should be entered into the system after the completion.

(1) Important Matters regarding Bridge Repair and Maintenance

- In-depth Investigation

The following are the main objectives of in-depth investigation:

- Understanding the cause of defects, damage and deterioration
- Identification of degree and extent of damage / defects, damage and deterioration and needs of measures to rectify
- Selection of bridge repair method
- Collection of data and information necessary for detail design.

In case more bridges are added to the investigation or unnecessary frequency or range of investigations are selected, the proper damage evaluation could be difficult.
The standard procedure for in-depth investigation is given Figure 5-1.

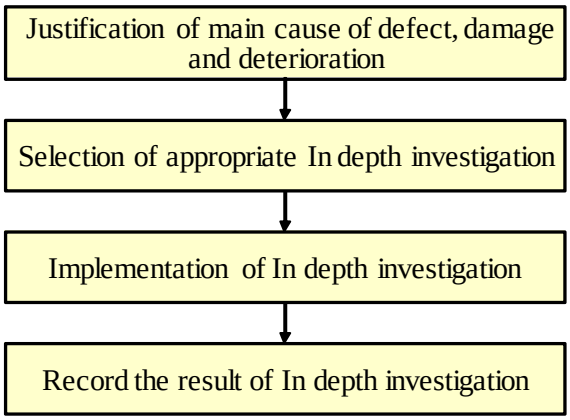

Figure 5-1 Work flow of In-depth Investigation

For more details, refer to “Bridge Repair Manual” and “Bridge Repair Manual Attachment-5 Outline of Representative In depth Investigation”.

- Repair Design

  It is important to select the appropriate repair methods based on the data and information obtained by in-depth Investigation. In case of complicate repair method or large repair scale, repair design might be necessary.

  In case the estimated repair cost is revised to be more accurate after repair design and the timing of estimated repair cost doesn't conflict with Budget Negotiation schedule, the repair cost should be replaced with more accurate one as needed.

  For repair methods, refer to "Bridge Repair Manual".

- Implementation of Bidding

  When contracting the construction, the approval and the bidding procedure should be conducted properly in accordance with the procedures and authorities prescribed by RDA.

- Implementation of Bridge Repair and Maintenance

  During the construction, the quality management should be implemented to ensure the long lifetime of the bridge. Moreover, it is the duty of RDA to pay attention to the safety control of the construction.

  In case unexpected incidents that have not been observed during the in-depth investigation and the repair design (i.e. unexpected progress of the damage and increase of form / support / scaffolding) are confirmed, the appropriate measures should be implemented. If the construction cost is increased, the discussion with relevant divisions should be held in order to secure the necessary budget.

- Ex-Post Evaluation

  In order to implement Ex-post evaluation, the data entered into the system should be uploaded for update after the completion of the repair & maintenance work. Thereafter, Health Index (HI) and the soundness classification should be automatically updated in the system. For Ex-post evaluation, refer to "Bridge Management Guidelines" manual.

  This data is going to be utilized for the future bridge management.

(2) Procedure of Bridge Repair & Maintenance

The bridge repair & maintenance is generally conducted in accordance with the procedure in Figure 5-2. However, DG-RDA may decide on any other procedure in carrying out repairs if necessary.

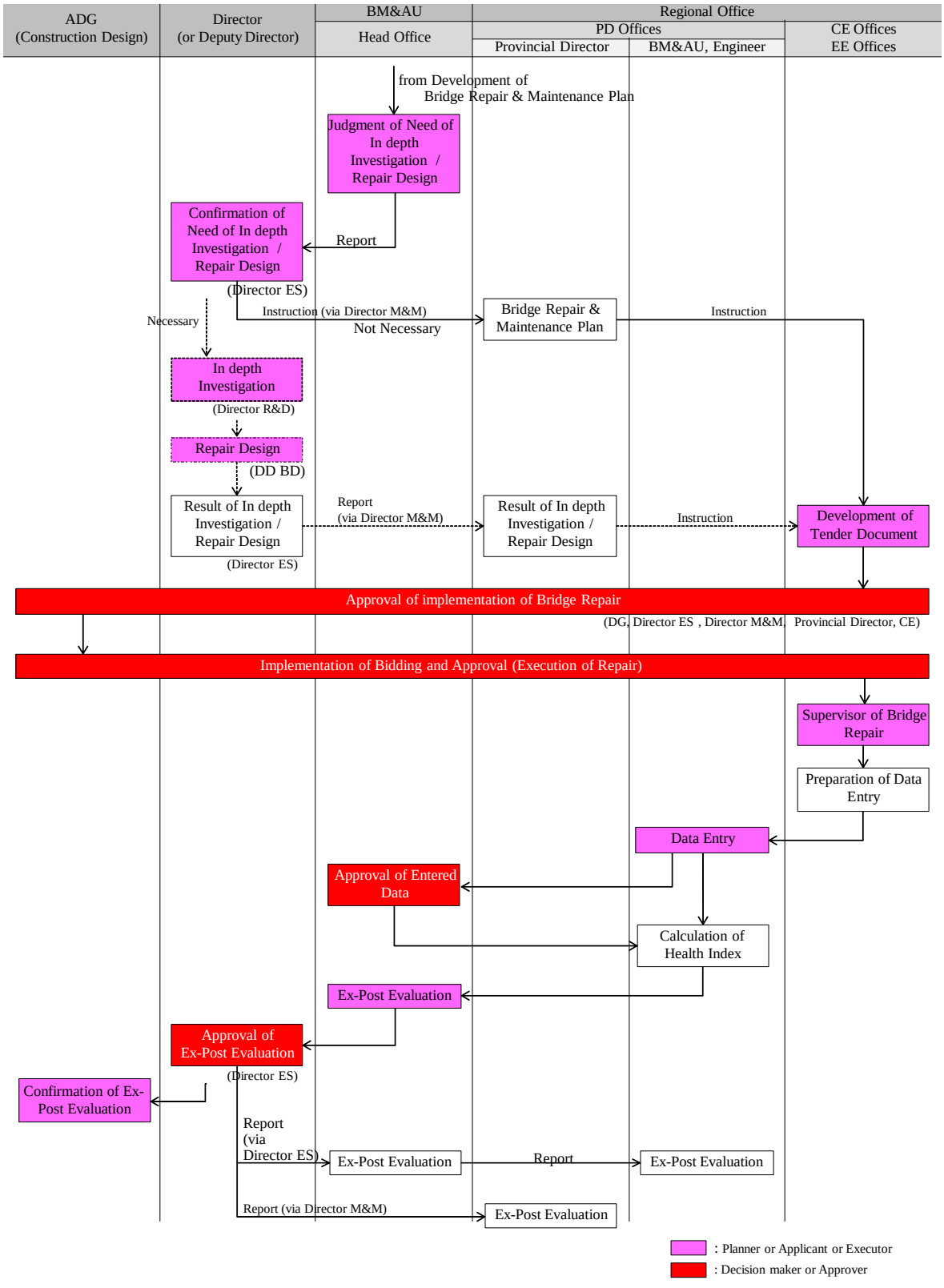

Figure 5-2 Procedure of Bridge Repair & Maintenance

- Judgment of Need of In-depth investigation / Repair Design

  - BM&AU Head Office should judge whether an in-depth investigation / the repair design is needed or not, thereafter, Director ES should confirm the judgment.

- In-depth Investigation

  - Director ES should report the bridge inventory and inspection results of the bridges that require an in-depth investigation for the repair design to Director R&D. Thereafter, Director ES should request the implementation of in-depth investigation from Director R&D.

  - In-depth investigation should be conducted under the responsibility of Director R&D.

  - The results of the investigation should be submitted to Director ES.

- Repair Design

  - Director ES should report the bridge inventory and inspection results of the bridges that require the repair design and request the implementation of the repair design to DD BD. In case in-depth investigation has been performed, the results of in-depth investigation should be submitted as well.

  - The repair design should be conducted under the responsibility of DD BD.

  - The results of repair design should be submitted to Director ES.

  - Thereafter, it should be reported to Provincial Director via Director MM, and reported to EE Office where the tender document is created. (Or to any other office where documents are formed for tendering)

  - Director MM shall decide on the office of Bid preparation.

- Implementation of Bidding

  - CE or EE Office should develop the tender document in accordance with the in-depth investigation and the repair design in order to carry out the bidding.

  - After the tender document is prepared, the procedure for approval of the construction should be started. The procedure should be implemented properly in accordance with the procedures and authorities prescribed by RDA. The list of the approvers is given in Table 5-1.

Table 5-1 Approval of Construction

Categories	Approver	Note
Direct Labor	There is no upper limit if it's within the budget. However, the limit per 1 material purchase is 1,000,000LKR.	
Construction Cost: less than Rs 1,000,000	Chief Engineer	
Construction Cost: less than Rs 5,000,000	Provincial Director	
Construction Cost: more than Rs 5,000,000	Director MM or Director General	

- The bidding and the contracting of the construction should be implemented after the approval. The procedures for the bidding and contracting should be carried out in accordance with the procedures and authorities prescribed by RDA. The bidders and approvers are listed in Table 5-2.

Table 5-2 Execution and Approval of Bidding

Categories	For Bidding and Approval	Note
Construction Cost: less than Rs 1,000,000	Bidding : EE Office Approval : CE Office	
Construction Cost: less than Rs 3,000,000	Bidding : CE Office Approval : PD Office	
Construction Cost: less than Rs 5,000,000	Bidding : PD Office Approval : Director MM	

- Implementation of Bridge Repair and Maintenance

  - The appointed division should supervise the construction. In case it is Direct Labor, EE Office should be in charge of the supervision, or as denied by PD.

- Recording of Bridge Repair and Maintenance

  - The division in charge of the construction supervision should organize and submit the information regarding the repair history to BM&AU Engineer at PD offices promptly after the completion of the repair & maintenance. This shall be a clause in construction supervision Terms of Regulations if the supervision is contracted out.

  - After receiving the information, BM&AU Engineer at PD offices should immediately enter the information into the system.

  - The entered data should to be approved by BM&AU Head Office.

- After BM&AU Engineer at PD Offices enter the inspection data into the system, Heath Index (HI) is automatically calculated.

- Ex-Post Evaluation

  - BM&AU Head Office should develop the ex-post evaluation based on the update data.

  - The developed ex-post evaluation should be approved by Director ES, and confirmed by ADG CD.

  - After the ex-post evaluation gets approved by Director ES, it should be reported to BM&AU Head Office via Director ES and to Provincial Director via Director MM.

6. Bridge Reconstruction

The bride reconstruction should be conducted properly according to the created Plan. After the completion of the bridge reconstruction, the initial inspection should be implemented and the results should be entered into the system.

Since the proper maintenance & management are required even after the reconstruction, the data such as construction history should be entered into the system after the completion. The procedure for the bridge reconstruction is different among the funds.

(1) Reconstruction by Local Fund

The bridge reconstruction by the local fund is generally conducted in accordance with the procedure in Figure 6-1. Director (Construction) may be assigned the function allotted to Director MM / C by the DG-RDA if necessary.

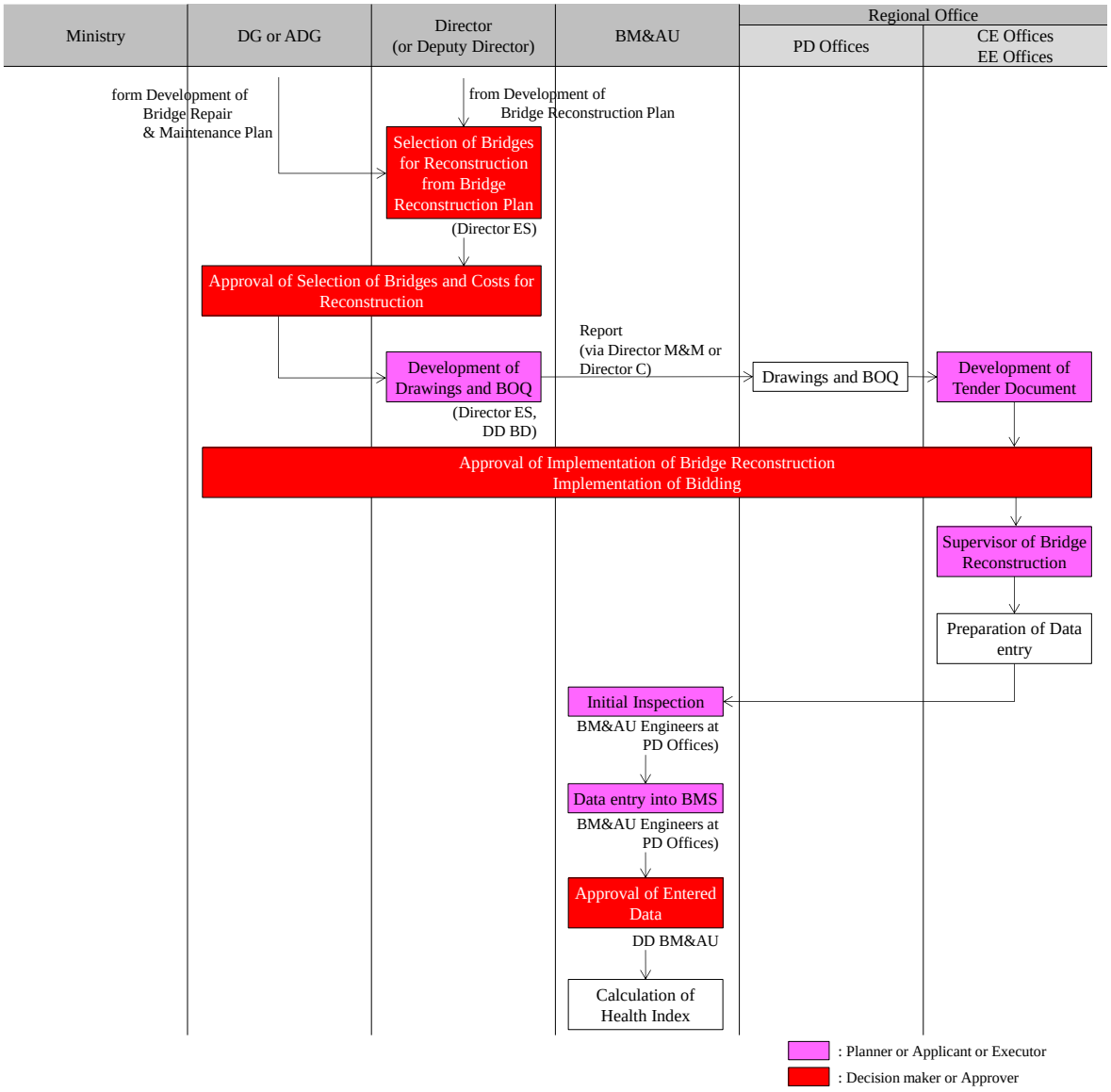

Figure 6-1 Procedure of Bridge Reconstruction by Local Fund

- Selection of Bridges for Reconstruction

  - In case of the bridge reconstruction by the local fund, it is imperative that the bridge reconstruction should be implemented in the budget for the bridge repair & maintenance plan. Therefore, Director ES should secure the budget for the reconstruction within the budget for the repair & maintenance.

  - Thereafter, Director ES should select the bridges for the bridge reconstruction from the bridge reconstruction plan.

  - The selection of the bridges and costs for the bridge reconstruction should be approved by ADG (CD).

- Development of Drawing and BOQ

  - Director ES should develop the drawing and BOQ for the bidding and report them to PD Offices and EE Offices via Director MM / C, and/ or Director (Construction) as appropriate.

- Implementation of Bidding

  - EE Office or the appointed division should develop the tender document in order to carry out the bidding.

  - After the tender document is prepared, the procedure for approval of the construction should be started. The procedure should be implemented properly in accordance with the procedures and authorities prescribed by RDA.

  - The bidding and the contracting of the construction should be implemented after the approval. The procedures for the bidding and contracting should be carried out in accordance with the procedures and authorities prescribed by RDA.

- Implementation of Bridge Reconstruction

  - The appointed divisions (CE / EE or any other) should supervise the construction.

- Initial Inspection and Entry Data Entry into BMS

  - After the completion of reconstruction, BM&AU Engineer at PD office and EE should collect the inventory data for the initial inspection.

  - BM&AU Engineer at PD Offices should input the updated data obtained by visual inspection / as built documents into the system, and may appoint a person to enter the data. BM&AU Engineer at PD Offices can appoint a person to perform the data entry. However, BM&AU Engineer at PD Offices must be held responsible for confirming the accuracy of the entered

data. Support staff for the periodic inspection should be nominated from the engineer at EE Offices. (BM&AU Engineer at PD Offices trains the engineer from EE Offices to be candidate BM&AU Engineer.)

- Inspectors should wear personal protective equipment (PPE) during the inspection. (Refer to "Bridge Inspection and Diagnosis Manual") Inspectors primarily adopt visual inspection and add physical and hammering inspection as needed. In order to ensure the safety of the inspectors and drivers, the traffic restriction should be implemented when necessary.

- The registered data should be approved by BM&AU Head Office. After BM&AU Engineer at PD Offices enter the inspection data into the System, Heath Index (HI) is automatically calculated.

(2) Reconstruction by JICA Fund

The bridge reconstruction by JICA fund is conducted in accordance with the procedure in Figure 6-2. JICA may change the procedure from time to time overriding the listed procedure.

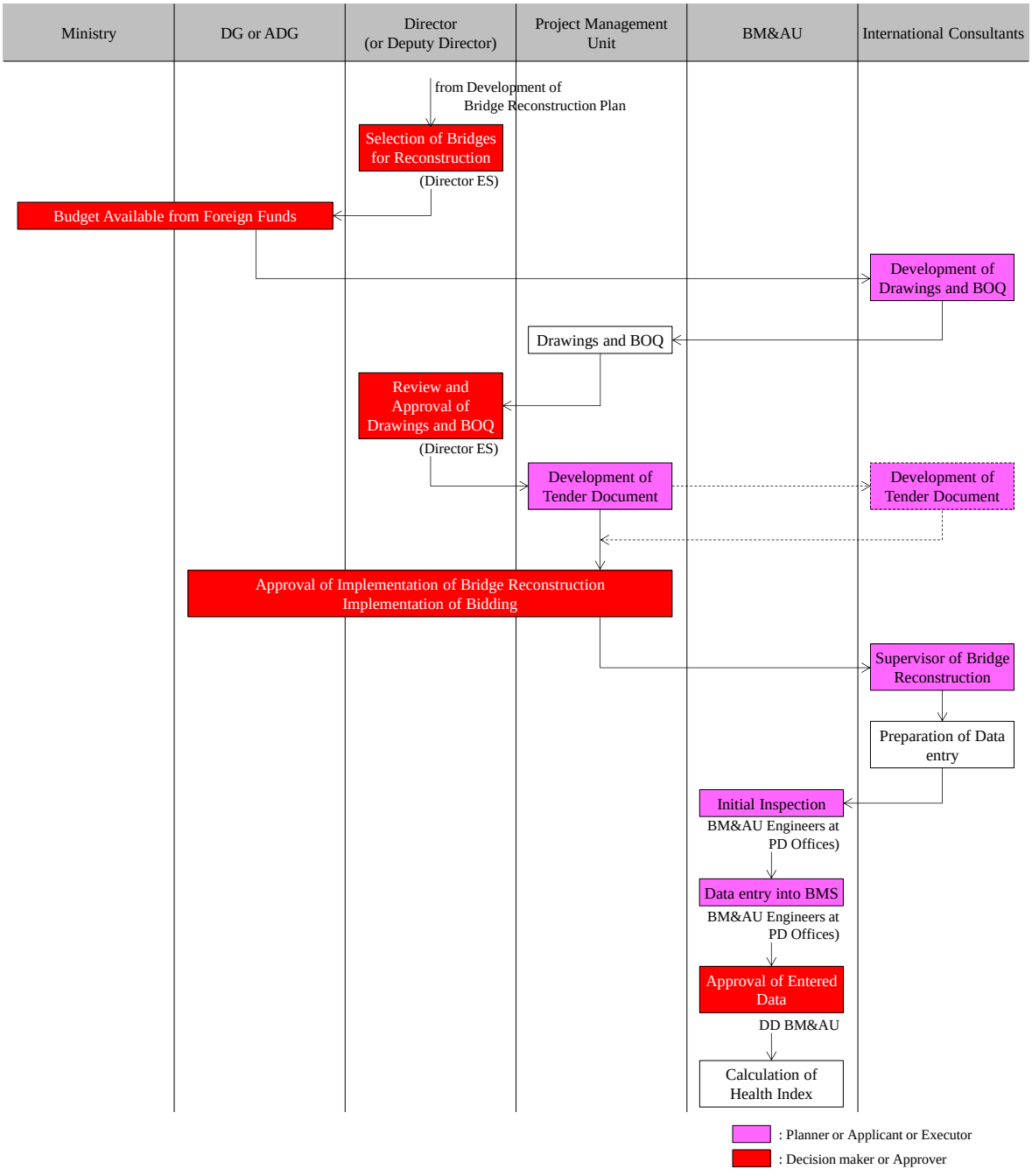

Figure 6-2 Procedure of Bridge Reconstruction by Foreign Fund
(Except World Bank, Kuwait, Saudi Funds)

- Selection of Bridges for Reconstruction

  - Director ES should select the bridges for the reconstruction by the foreign funds from the bridge reconstruction plan.

- Budget Available from Foreign Funds

  - After the selection of target bridges, the foreign funds should be determined.

- Development of Drawing and BOQ

  - The international consultants should develop the drawing and BOQ for the bidding, and report them to Project Management Unit.

  - Thereafter, the drawing and BOQ should be reviewed and approved by Director ES.

- Implementation of Bidding

  - Project Management Unit should develop the tender document in order to carry out the bidding. In JICA's fund, the international consultants should develop the tender document, and report it to Project Management Unit.

  - After the tender document is prepared, the procedure for approval of the construction should be started. The procedure should be implemented properly in accordance with the procedures and authorities prescribed by RDA.

  - The bidding and the contracting of the construction should be implemented after the approval. The procedures for the bidding and contracting should be carried out in accordance with the procedures and authorities prescribed by RDA.

- Implementation of Bridge Reconstruction

  - The international consultants should supervise the construction.

- Initial Inspection and Entry Data Entry into BMS

  - After the completion of reconstruction, the international consultants should collect the inventory data for the initial inspection.

  - BM&AU Engineer at PD Offices should input the updated data obtained by visual inspection / as built documents into the system, and may appoint a person to enter the data. BM&AU Engineer at PD Offices can appoint a person to perform the data entry. However, BM&AU Engineer at PD Offices must be held responsible for confirming the accuracy of the entered data. Support staff for the periodic inspection should be nominated from the engineer at EE Offices. (BM&AU Engineer at PD Offices trains the engineer from EE Offices to be candidate BM&AU Engineer.)

- Inspectors should wear personal protective equipment (PPE) during the inspection. (Refer to "Bridge Inspection and Diagnosis Manual") Inspectors primarily adopt visual inspection and add physical and hammering inspection as needed. In order to ensure the safety of the inspectors and drivers, the traffic restriction should be implemented when necessary.

- The registered data should be approved by BM&AU Head Office. After BM&AU Engineer at PD Offices enter the inspection data into the System, Heath Index (HI) is automatically calculated.

(3) Reconstruction by foreign funds other than JICA fund.

The bridge reconstruction by the local fund is conducted in accordance with the procedure in Figure 6-3, generally. The Fund may issue specific instructions from time to time overriding these.

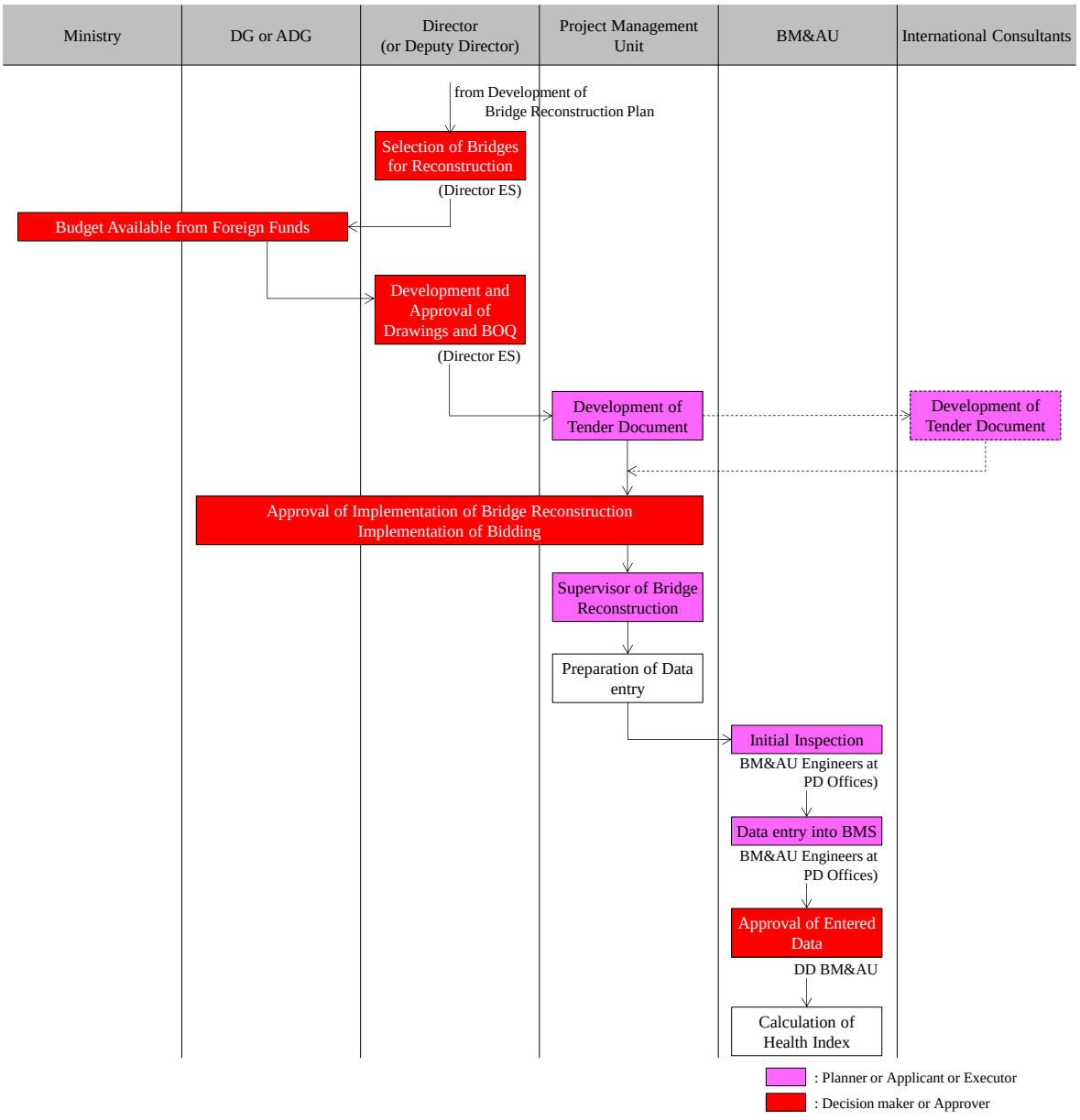

Figure 6-3 Procedure of Bridge Reconstruction by World Bank, Kuwait, Saudi Funds

- Selection of Bridges for Reconstruction

  - Director ES should select the bridge for the reconstruction by the foreign funds from the bridge reconstruction plan.

- Budget Available from Foreign Funds

  - After the selection of target bridges, the foreign funds should be determined.

- Development of Drawing and BOQ

  - Director ES should develop and approve the drawing and BOQ for the bidding.

- Implementation of Bidding

  - Project Management Unit should develop the tender document in order to carry out the bidding. In case of a part of World Bank's fund, the international consultants should develop the tender document, and report it to Project Management Unit.

  - After the tender document is prepared, the procedure for approval of the construction should be started. The procedure should be implemented properly in accordance with the procedures and authorities prescribed by RDA.

  - The bidding and the contracting of the construction should be implemented after the approval. The procedures for the bidding and contracting should be carried out in accordance with the procedures and authorities prescribed by RDA.

- Implementation of Bridge Reconstruction

  - Project Management Unit should supervise the construction.

- Initial Inspection and Entry Data Entry into BMS

  - After the completion of reconstruction, Project Management Unit should collect the inventory data for the initial inspection.

  - BM&AU Engineer at PD Offices should input the updated data obtained by visual inspection / as built documents into the system, and may appoint a person to enter the data. BM&AU Engineer at PD Offices can appoint a person to perform the data entry. However, BM&AU Engineer at PD Offices must be held responsible for confirming the accuracy of the entered data. Support staff for the periodic inspection should be nominated from the engineer at EE Offices. (BM&AU Engineer at PD Offices trains the engineer from EE Offices to be candidate BM&AU Engineer.)

- Inspectors should wear personal protective equipment (PPE) during the inspection. (Refer to "Bridge Inspection and Diagnosis Manual") Inspectors primarily adopt visual inspection and add physical and hammering inspection as needed. In order to ensure the safety of the inspectors and drivers, the traffic restriction should be implemented when necessary.

- The registered data should be approved by BM&AU Head Office. After BM&AU Engineer at PD Offices enter the inspection data into the System, Heath Index (HI) is automatically calculated.