Deck slab of steel bridges was deteriorated severely as compared to other bridge members. In general, damage of superstructure is greater than damage of substructure.

RSJ/BUC and RSJ/COR bridges were the most deteriorated types of bridge among other types. PSC/PRE bridges were mostly in good condition.

(2) Assessment of Preliminary Inspection Results

The purposes of the assessment are to study the general tendency of the damage in each bridge member based on the results of the inspection and to assist in the derivation of possible rehabilitation works.

A summary of preliminary inspection results from a structural viewpoint is shown in Table 3.4.1.

Table 3.4.1 Summary of the Assessment of Preliminary Inspection Results

Main Bridge Member	Dominant Damage Detected	Cause of Damage	Possible Rehabilitation Plan
Steel Girder Steel Truss	Corrosion	- Poor maintenance - Water leak no weep hole	- Repainting - Making weep hole - Partial replacement - Cantilever slab
Steel Buckle Plate or Corrugated Plate Slab	Corrosion	- Water leak - Poor maintenance	- Repainting - Redecking to RC slab
RCB	Flaking/Rebar exposure	- Inadequate cover - Poor workmanship	- Injection - Patching - Prepacked concrete
PSC/PRE	Flaking/PC tendon exposure	- Inadequate cover - Poor workmanship	- Patching
Abutment	Crack Wear abrasion Scouring	- Loose wedge stone - Non protection - Non masonry	- Injection - Cement grouting
Pier	Crack Wear abrasion Scouring	- Loose wedge stone - Non protection - Non masonry	- Protect concrete - Stone masonry - Mat gabion

3.5 Selection of Bridges for Detailed Survey

This Study involves two kinds of bridge selection; one is to select 10 typical bridges out of the 100 bridges shown in the Bridge Inventory, and the other is to select 3 bridges out of these 10 bridges for a static loading test.

3.5.1 Selection of 10 Bridges for Detailed Survey

(1) Selection Procedure of 10 Bridges for Detailed Survey

10 bridges shall be selected from the Bridge Inventory made based on the

Preliminary Bridge Inspection. The following 3 items were considered in the selection.

1) Various rehabilitation methods considered from damage/defect shall be selected as many as possible.
2) Bridges shall be selected, which have enough design data/information such as drawings, design condition, material strength, etc.
3) Bridges shall be selected, which have high priority for their rehabilitation.

However, difficulty was found on item 2), because most of bridge have almost no data/information. Therefore, 1) and 3) were mainly considered to select 10 bridges as follows:

<u>for item 1)</u>

Typical type of bridges in their structural aspects shall be selected, and various rehabilitation methods shall also be considered.

<u>for item 3)</u>

Priority of road rehabilitation shows its necessity based on its functional aspect. Taking it in consideration, a graph of which X axis is for bridge damage degree, and Y axis is for road rehabilitation priority shall be made for determination of bridge rehabilitation priority.

(2) Selection Results of Bridges for Detailed Survey

Since a rehabilitation plan was closely related to bridge construction material, bridge type and year of construction, 100 bridges were classified into kinds of bridge, material used and bridge age groups. In addition, major conceivable rehabilitation plans were prepared for each defective bridge member from structural viewpoints.

Through the above exercise, 10 bridges were selected as listed in Table 3.5.1, of which locations are shown in Figure 3.5.1.

3.5.2 Selection Results of Bridges for Loading Test

In order to select 3 bridges out of the 10 bridges for the loading test the following viewpoints were considered.

- Applicability of the test results to other same type of bridges
- Clearance for working space
- Traffic volume at bridge site

Based on the consideration, the following 3 bridges were finally selected for the loading test and their locations are shown in Figure 3.5.2.

Table 3.5.1 List of the 10 Bridges for Detailed Survey

SER No.	Route No.	Bridge No.	Traffic Volume	Year of Const.	Type of Bridge	Length (m)	Width (m)	Conceivable Rehabilitation Plan	RDA's List	
									Existing Defect/s	Proposed Treatment
85	AA001	91/2K	7,100	1894	ARCH/BR	68.90	6.30	Extension of footway at both sides	Narrow, Poor	RECONST/APP
77	AA019	3/2K	2,100	1869	ST.TR/T+RSJ/BUC	118.88	5.36	Construction of additional bridge (for widening)	Narrow	WIDEN/REDECK
53	AA021	36/3K	700	1899	ST.TR/T	39.95	3.37	Repairing of existing truss beam and Construction of additional bridge	Narrow	WIDEN/REDECK
33	B 157	12/3K	1,040		ST.TR/T+RSJ/RCS	68.85	3.30	Repairing of existing truss beam and Construction of additional bridge	Weak/Narrow	RECONST
59	B 157	43/4K	1,040	1924	RSJ/BUC	51.00	3.20	Extension of superstructure with re-decking + Extension of substructure (BUC to RCS)	Narrow	RECONST
20	B 264	25/7K	1,700		RSJ/COR	14.35	3.97	Repairing of outside main beam and redecking	Narrow	RECONST
70	B 295	3/6K	10,700	1960	RSJ/RCS	43.23	5.46	Extension of superstructure	Narrow	RECONST
7	B 425	20/4K	1,600		PSC/PRE+RCB	139.18	5.85	Replacement of superstructures	Weak	WIDEN/REDECK
211	B 146	8/3K	2,800	1942	RSJ/RCS	23.60	3.55	Extension of superstructure and substructure		
212	AA002	138/1K	4,400	1975	PSC/PRE	62.48	10.40	Repairing of superstructure		

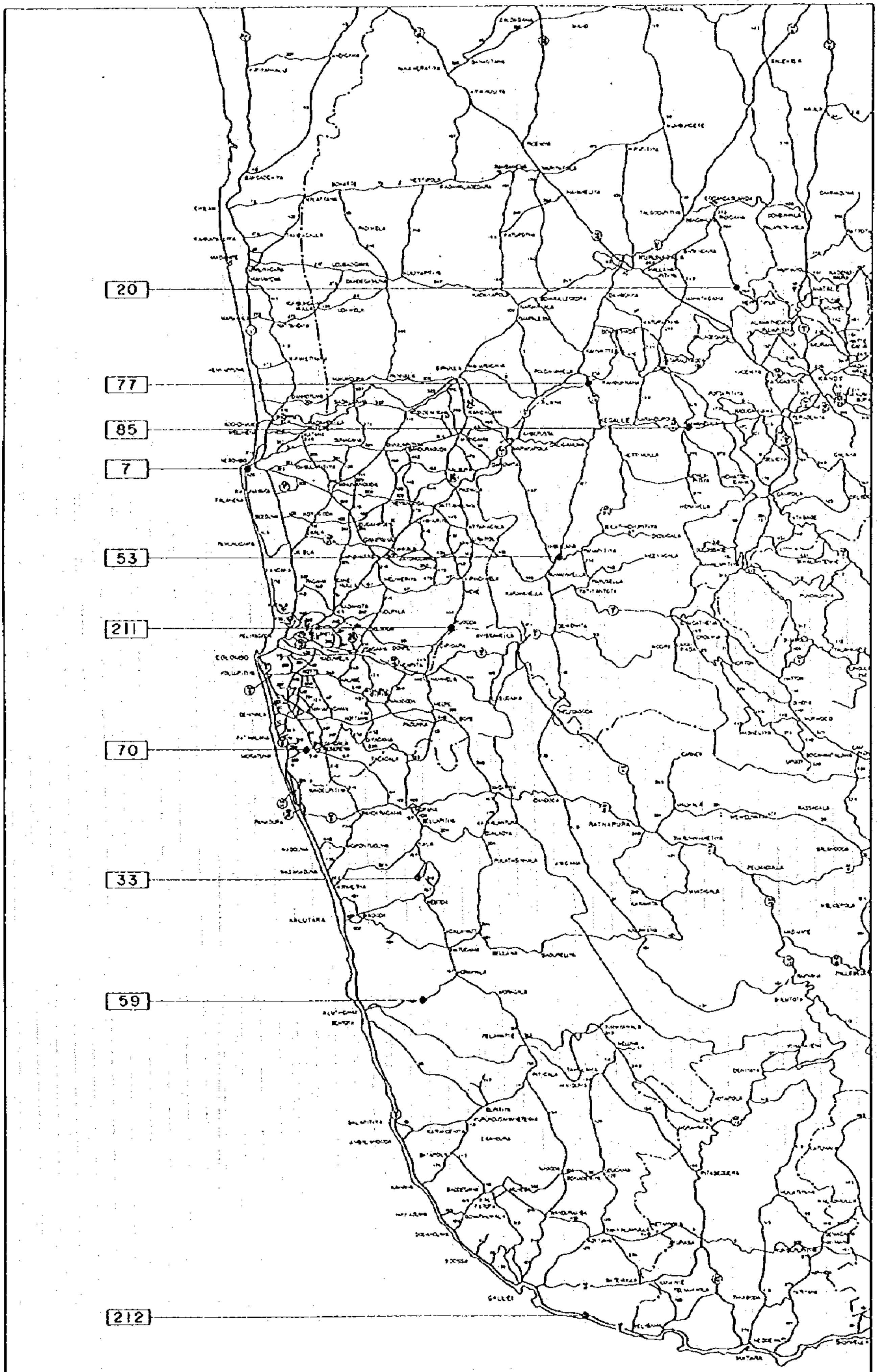


Figure 3.5.1 Location Map of the 10 Bidges Selected

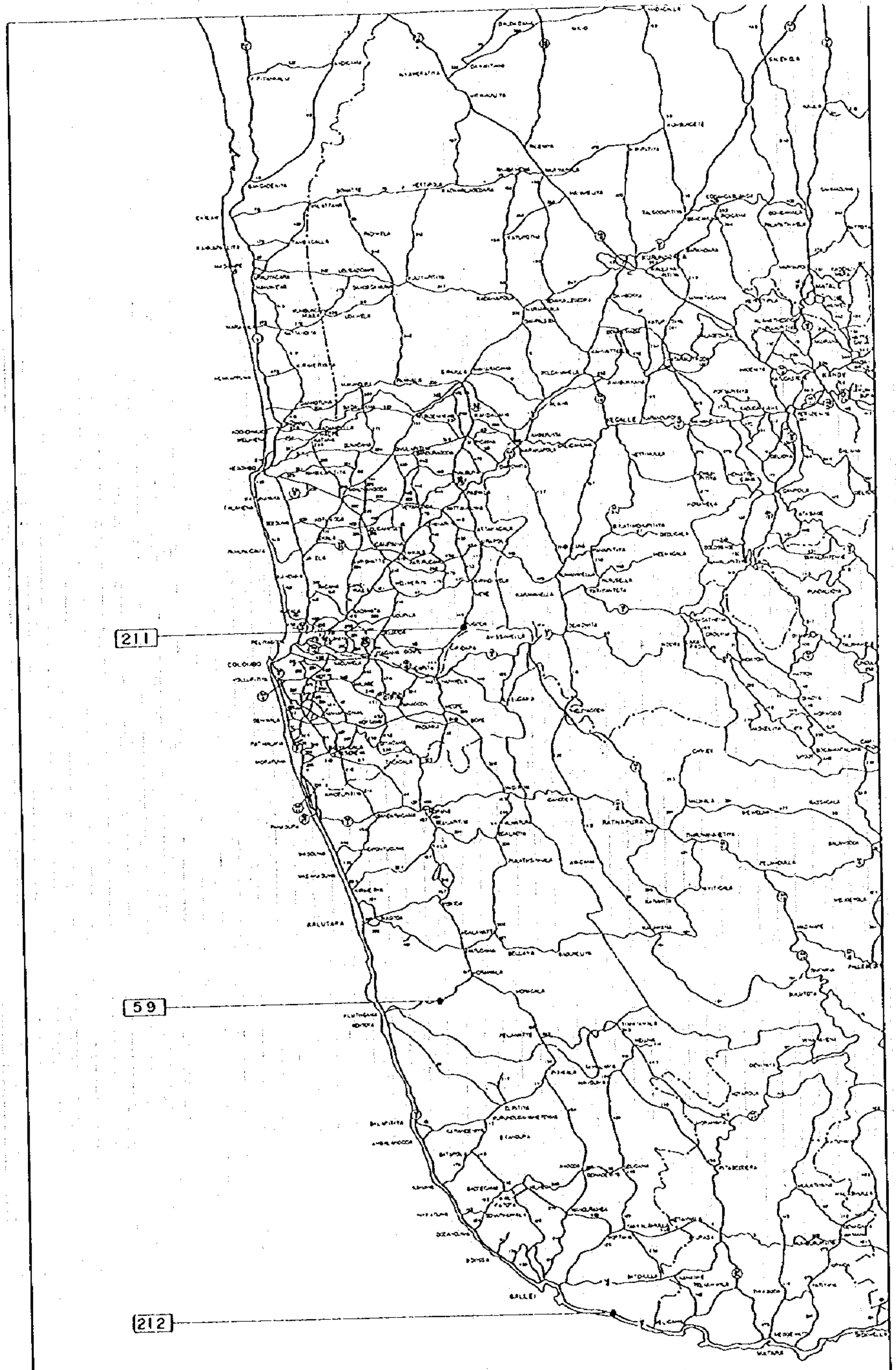


Figure 3.5.2 Location of Bridges Loading Test was Carried Out

SER No.	Route	Type of Bridge
59	B 157	RSJ/BUC
211	B 146	RSJ/RCS
212	AA002	PSC/PRE

3.6 Detailed Field Survey

The field survey, covering the 10 bridges, consists topographic and hydraulic study, geological survey, detailed visual inspection with Schmidt hammer test and full scale bridge loading tests.

3.6.1 Topographic Survey

(1) Topographic Survey

The topographic survey was carried out to obtain data and information for preparing Bridge Rehabilitation Plan. The followings are conditions of the survey.

- The RDA did not have National Coordinates, therefore, Arbitrary Coordinates and Meridian were used.
- Temporary bench marks were set near bridge site.
- Land registration map was not existed in Sri Lanka, so survey maps were prepared by using RDA pegs or any structures such as fences in order to clarify boundaries.

The principle objectives of the topographic survey are to visualize and illustrate the surrounding land, structure and river relative to the bridge. This topographic survey is essential since it provides the basic data for the following works:-

- Hydraulic calculations
- Determination of bridge scale for reconstruction plan
- Structural analysis for substructures

The survey work was sublet to a local survey consultant and commenced on 24th October, 1995 for a period of 30 days.

Elevations for vertical survey was basically based on Mean Sea Level (MSL) datum. Location and elevations of MSL Bench Mark (BM) established by the Sri Lanka Survey Department (SD) were obtained from the SD divisional offices. Records of all old SDBM within radius 4.5km from the site were obtained. From the investigations, the Survey Department Bench Mark was reopen and connected to MSL datum at 8 bridge sites. Then assumed datum level (ADL) were provided for other 2 bridge sites.

The results of the survey were shown in survey drawings as follows:-

-	Topographic Maps	1/500	11 sheets
		1/200	11 sheets
-	Center line and profiles		18 sheets
-	Road cross section		28 sheets
-	River cross section		10 sheets

(2) Hydraulic Survey

The main objectives of the hydraulic survey are as follows:-

- To establish hydraulic rehabilitation plans based on the assessment
- To determine appropriate bridge opening for reconstruction of the bridge

1) River Condition

Most of the Study area has been suffered from flood. The reasons of the flood are that; rainfall (2,000mm of mean annual rainfall) is quite heavy in the area, ground surface is composed of low porosity soils and the soils promote heavy run-off for the wet zone. High run-off is promoted by a combination of various factors such as steep gradients. Rivers in the wet zone like Kelani Ganga, Kalu Ganga and Gin Ganga show steep gradients in their upper courses and extensive flood plain in the lower courses.

Embankments or flood bunds have been built to provide protection to density populated areas within the flood plains. Others are left being in natural.

Generally, river bed tends to accelerate sedimentation of soil where the bridges locate in flat area. Therefore, the foundation of substructure are relatively in good condition.

However, the results of river cross section survey for SER No. 33 shows the elevation of river bed MSL-8.00. This may be caused by degradation of bed due to river bed errosion. Because very fast velocity (v=4.0m/sec) was shown in the hydraulic calculation as well as observation results in the field inspection. The river should be spanned by a center span (l=50m) in the reconstruction plan. Rehabilitation of the river is out of this Study.

2) Retaining Wall, Back-filling and Slope Protection of River Bank

As a general rule, many abutments jutted out into the river in order to shorten a bridge length in Sri Lanka. And wing wall is impossible to be connected with abutment because the structure type of abutment is stone masonry or brick masonry. Therefore, retaining wall is used to cover back-filling instead of wing wall. However, the foundation of retaining wall is not so strong compared with abutment, and it is seen that there are many large cracks caused by scouring or settlement of the ground surrounding foundation.

Whereas there are no protections at the side embankment of abutment, some parts of embankment have been washed away because of raining.

Slope protection of river bank should be provided at the front of abutment and surrounding area because water flow changes greatly. Embankment will be scoured unless this protection is carried out.

Therefore, careful consideration should be given to these countermeasures in the future designs and reconstruction of bridges.

3) Hydraulic Analysis

The method of analysis applied in the Study was determined considering river condition in Sri Lanka and further operation to be carried out by RDA.

The results of this study was reflected in reconstruction plan only but not in repair and rehabilitation of existing bridges. The major items to be considered in the reconstruction plan are as follows:-

- The design high flood water level should be determined on the comparison of hydraulic calculation with past flood water level, flood mark and interview with resident.
- In case the raising of the bridge elevation is difficult because of surrounding conditions, free board against design flood water was not be kept. However, the elevation of beam soffit of new bridge should not be lower than the existing one.
- The footings/piles cap should have enough embedded depth.

4) Summary of Hydraulic Defect and Rehabilitation Plan

The major hydraulic defect are shown together with the rehabilitation plans in Table 3.6.1

Table 3.6.1 Summary of Major Hydraulic Defects and Rehabilitation Plan

SER No.	Hydraulic Defect	Cause	Rehabilitation Plan
	Representative 10 Bridges		
212	– Exposure of caisson foundation (A2)	– Local scouring	– Protect concrete to foundation scoured
77	– Exposure of caisson foundation (P8 & P9)	– Local scouring – Insufficient embedded depth of foundation	– Reinforced concrete curtain wall
211	– Exposure of spread foundation (A1)	– Local scouring	– Protect concrete to foundation scoured
7	– Damage of wedge stone/brick wall (behind A1 and A2)	– Insufficient strength of wall	– Stone masonry and mat gabions
	Other 91 Bridges		
86	– Settlement of abutment (A1)	– Local scouring	– Protect concrete to foundation scoured
87	– Exposure of foundation	– Local scouring	– Protect concrete to foundation scoured
103	– Beams submerged	– Insufficient free board	– Raising of bridge (This rehabilitation shall be taken with raising of road in future.)
60	– Causeway	---	– Reconstruction
139	– Causeway	---	– Reconstruction
62	- Causeway	---	– Reconstruction
63	– Causeway	---	– Reconstruction
25	– Exposure of foundation (P1 to P3)	– Local scouring	– Protect concrete to foundation scoured
35	– Exposure of foundation	– Local scouring	– Protect concrete to foundation scoured

5) Recommendation from Hydraulic Aspect

Through the field inspection, it was observed in some bridges that the hydraulic effect have not been fully taken into account in the planning of bridges.

There is not a systematic waterway improvement plan on the rivers. Where the plan is not existed, the bridge planning shall be individually made considering the bridge site condition.

It is therefore recommended that the River Structure Standard in Japan should be a good reference and applied with some modification. Major items to be considered in crossing requirements for waterway are bridge opening, abutments, piers and bank protection.

3.6.2 Geological Survey

The objective of the survey is to clarify component and characteristics of subsoil at the bridge site. Important subsoil engineering parameters were obtained from this survey and adopted for the analysis, design, and selection of foundation types.

The geological survey was carried out on 8 bridges out of the 10 bridges.

The survey was sublet to a geological organization and commenced on 24th October, 1995 for a period of 30 days.

The geological survey comprises of the following works mainly:-

- Rotary wash boring technique which is common practice in Sri Lanka.
- Rotary core driving technique where the wash boring could not be applied to the subsoil such as rock or boulders existed.
- Field tests such as the Standard Penetration Test (SPT), including the collection of disturbed and undisturbed soil samples to conduct laboratory tests.
- Observation of under ground water levels.
- Laboratory tests to obtain soil index properties.

The results are reflected into the preliminary design regarding the following items:-

- Assumption of bearing stratum
- Determination of type of foundation
- Bearing capacity of foundation
- Soil coefficient for design of pile and caisson foundation

3.6.3 Detailed Visual Inspection

The objective of the detailed visual inspection is to obtain detailed engineering information for preliminary rehabilitation design. The detailed visual inspection consists of detailed structural measurement with deterioration degree measurement and material strength measurements.

(1) Detailed Structural Measurement

Detailed structural measurement consists of basic dimension measurement, crack/corrosion mapping and steel thickness measurement. The objective is to prepare drawings for each bridge, and all measurement results were compiled in drawing sheets.

(2) Material Strength Measurement

In order to obtain a concrete strength, non-destructive test was carried out by using Shmidt hammer at 6 bridges sites. The test results revealed that each member has sufficient strength.

3.6.4 Full Scale Bridge Loading Test

The main objective of a full scale bridge loading test is to confirm actual load carrying capacity of bridge in Sri Lanka and the test results were used to establish a determination of applicable live load.

In order to estimate load carrying capacity of bridge, theoretical calculation and full scale loading test can be considered as a practical method. Theoretical calculation needs all data of bridge design and can be used for a comparison with the results of full scale loading test. The results of full scale loading test indicates the actual loading capacity including a residual loading capacity, which depends on type of structure, construction materials and extent of defects or deterioration.

The primary purpose of a full scale loading test is therefore to estimate the residual loading capacity. To achieve this, comparison of deflection will be made between theoretically calculated values and those actually measured. The theoretical calculations were carried out by using a finite element method (FEM) in order to expect higher accuracy.

3 spans at three different bridges listed below were selected for a full scale bridge loading test.

The loading test is static loading tests under a known load in which loaded vehicles, and it was to measure deflection of main component part .

Flowchart shows the practical loading test procedure in Figure 3.6.1.

Results of the full scale loading test indicated that steel girder bridges act like a half-composite beam with some load distribution action by deck slab. PSC/PRE beam which is used as a standard design in RDA has an adequate lateral load distribution action without any transverse direction prestressing. A summary of the result is shown in Table 3.6.2.

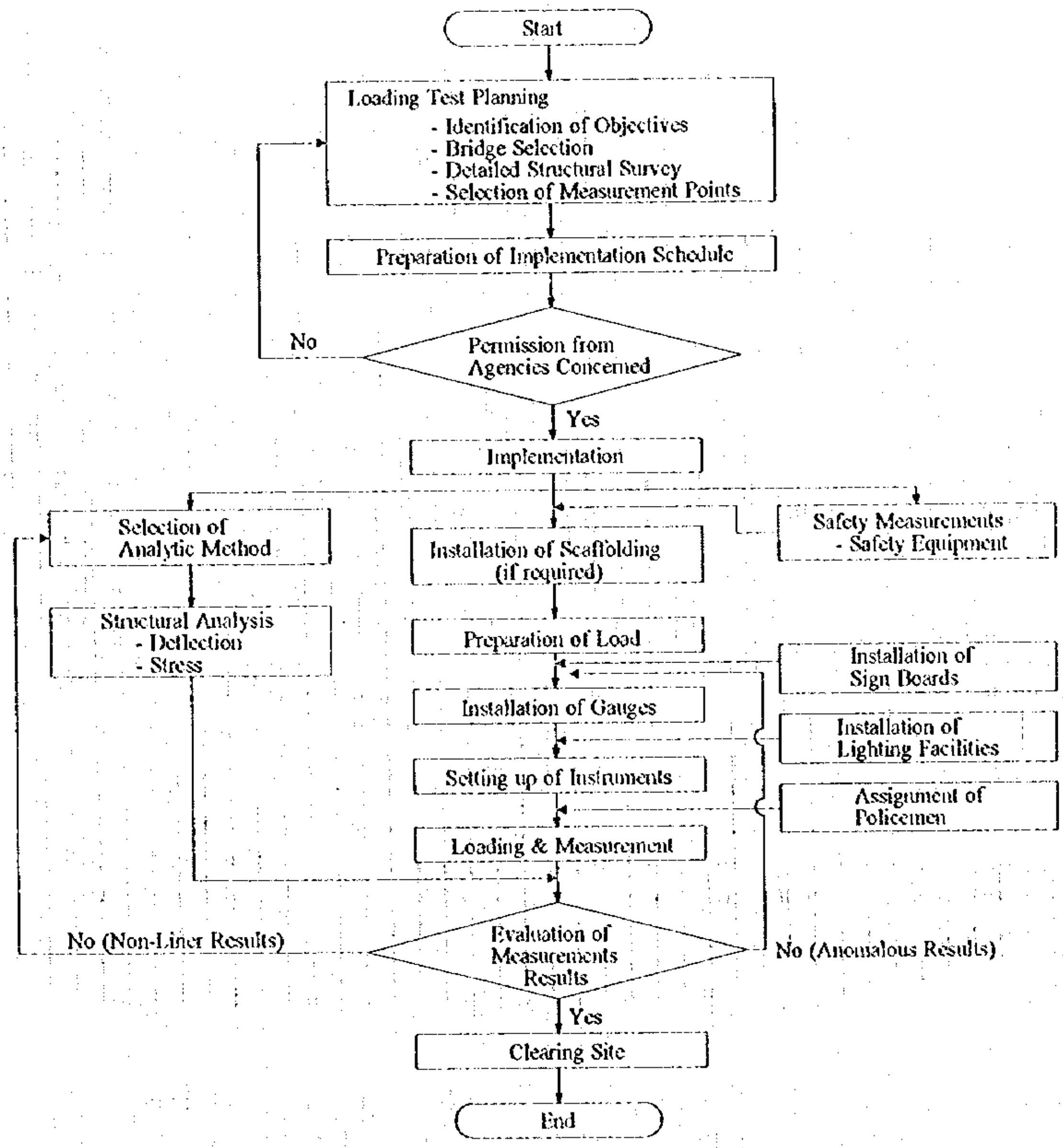


Fig. 3.6.1 Flowchart of Loading Test

Table 3.6.2 Summary of Assessment Result of Loading Test

SER No.	Type of Bridge	Summary of Assessment Results
59	RSJ/BUC	- The measured actual deflections meet with the calculation results. - Effect of composite action in RSJ/BUC can be expected sufficiently.
211	RSJ/RCS	- Deflection ratio (test result/calculation result) indicated that the beams acted as a half-composited beam. - Live load is distributed into and main girders by deck slab in some proportion.
212	PSC/PRE	- Deflection ratio (test result/calculation result) indicated that the actual rigidity of the bridge is greater than their value obtained in the preliminary calculation using FEM analysis. - In the FEM analysis, all of dimensions of the bridge was based on as built drawing, while the actual thickness of the bridge which includes a insitu concrete was greater than the designed value. The residual thickness of the insitu concrete was about 100mm and this means that the actual rigidity of the bridge is about 150% of the designed value. - Considering the differences between the actual model and the theoretical calculation, it seems to be quite all right to consider that the test result it relatively reliable and the calculation method is suitable. - Furthermore, the deflection diagram by FEM analysis meets with the distribution of actually measured value. Thus, it could be concluded that the pretension slab beam based on the standard design of RDA has enough durability even though stress due to dead load is added and design live load is applied.

3.7 Strength Test of Steel Samples

Materials mainly used for steel bridges in Europe have been changed as from time to time as follows:-

- approx. 1847 to 1895 : Wrought iron
- approx. 1855 to 1870 : Acid process Bessemer Steel (Acid Bessemer Steel)
- approx. 1870 to 1895 : Thomas process Bessemer Steel (Basic Bessemer Steel)
- approx. 1856 to 1930 : Low quality mild steel (early days of Open Heath Steel)
- approx. 1920 to : Mild steel (similar to Structural Mild Steel (SS400) used at present)

Some data and information from U.K. Department of Transport, Bridge Section, state some idea for material quality as follows:-

- Although there is no reliable data, steel produced before 1955 has its yield stress of 230N/mm2 (2,340kgf/cm2)
- Steel produced before 1922 has low quality.

It is known that the most of steel bridges are constructed during the dominion of

U.K. There should be a time lag between production of materials and construction of bridge if the girders were fabricated in U.K. and transported by ship to Sri Lanka. Therefore, the strength test was done by taking samples from bridges of which year of construction is known, and by sending them to Japan to carry out tensile tests, hardness tests, chemical analysis and micro scope observations for classification under year of construction and its strength.

Also, further study was carried out in order to find a simple non-destructive test method which was applicable in Sri Lanka to identify the material used in other old bridges.

(1) Selection of Bridges for Taking Steel Samples

At first, 7 candidate bridges were selected through discussions with RDA. The samplings had to be carried out on bridges.

1) which were abandoned or removed for reconstruction to avoid any traffic problem;
2) of which construction year had to be identified; and
3) of which members had less fatigue effect.

Considering these conditions, a pre-inspection trip was carried out upon the candidate bridges to confirm their identification and member to be taken.

Finally, 4 bridges were selected for the tests as follows:

Table 3.7.1 List of Bridges for Taking Steel Samples

No.	Name of Bridge	Year	Type	Members
1	Giriulla Bridge	1880	ST.TR (pin truss)	End post, Web plate
2	Kuruwita Bridge	1934	ST.TR (rivet truss)	Slab and plate
3	Warakatota Bridge	1909	ST.TR (rivet truss)	End post, Flange plate
4	Matara Old Bridge	1860 to 1870	RSJ	End of girder

(2) Results of Strength Test

The results of the strength test are shown in Table 3.7.2.

Table 3.7.2 Results of Strength Test

No.	Name of Bridge	Year	Steel Material Used	Allowable Tensile Stress
1	Giriulla Bridge	1880	Wrought iron	80% of No. 2
2	Kuruwita Bridge	1934	Mild steel	Equivalent to SS400
3	Warakatota Bridge	1909	Low quality mild steel or Bessemer steel	80% of No. 2
4	Matara Old Bridge	1860 to 1870	Low quality mild steel	80% of No. 2

(3) Classification of Steel Material

Steel materials can be classified into two major groups depending on their year of construction and allowable tensile stress as follows:

Table 3.7.3 Classification of Steel Material

Year of Construction	Steel Material	Allowable Tensile Stress
before 1930	Wrought iron or Low quality mild steel	80% of SS 400 (yield stress = 24kgf/mm2)
after 1930	Mild steel	equivalent to SS400

(4) Identification of Steel Species by Simple Method

In order to confirm the strength of the steel material used in other old steel bridges, the field test using the handy type ultrasonic hardness tester is suitable for simple non-destructive method. However, accuracy will not be reliable if the test is carried out on the rusted surface. Therefore, in order to obtain accurate results, the surface should be finished properly.

Then it could be distinguished whether the material is low quality mild steel/Bessemer steel or mild steel. The latter shows the hardness higher than the former one.

However, this simple method cannot be applied for wrought iron because of huge nonmetallic inclusion in the wrought iron. The wrought iron rusts differently from other steel materials. The rust have layers or layer crack because of its inclusion. Thus, the wrought iron can be classified by visual inspection.

3.8 Determination of Applicable Live Load

The following design live load were determined through examination and assessment on the existing traffic and loading conditions in Sri Lanka.

(1) Live Load for Repair

Specific live load was not determined for simple repair works such as repainting, mortar injection to cracks, etc. The repair works shall be done to maintein existing loading capacity.

(2) Live Load for Rehabilitation

Since the design data to determine loading capacity are not existed, the Japanese Bridge Design Specification is adopted with some modification of intensity of the live load, TL20, considering the results of Axle Load Survey.

In order to plan the optimum rehabilitation method, determination of proper design live load and allowable stress are principle factors.

(3) Live Load for Reconstruction

Present standard live load in Sri Lanka is adopted in this Study.

3.8.1 Determination of Applicable Live Load for Rehabilitation Plan

(1) Stress Check Applying Initial Live Load, TL20

The stress check with TL20 live loading, revealed that there were many steel bridges which had excessive stress.

(2) Determination of Basic Live Load

The basic design axle load of 12 tons applied to bridges on A-class roads was taken for the Study based on the consideration as follows:-

- 98% of vehicles is in the category of "axle load of under 12 tons" according to the axle load survey.

- Total vehicle weight of 12 tons is a standard size for national buses (SLTB BUS) in Sri Lanka.

(3) Determination of the Live Load to be Applied for Stress Check for Heavy Vehicles which Exceeds the Basic Live Load

The live load applied for stress check for the Rehabilitation Plan is determined as 18 tons for bridges on A-class roads based on the consideration as follows:-

- Vehicle weight of 18 tons covers 99.5% of all vehicles for short spanned bridge according to the axle load survey on A-class roads.

- Where increase rate for allowable stress is set at 1.5, live load for stress check is 18 tons.

On the other hand, 16 tons is applied for bridges on B-class roads based on the consideration as follows:-

- Axle load survey has not been carried out on B-class roads, however, the importance of B-class roads is assumed to be lower than that of A-class roads.

- The limit of total vehicle weight for B-class roads in the regulation is

15.275 tons for 2-axle truck.

(4) Design Vehicle Weight in Japan

The design vehicle weight reviewed recently in Japan is as follows:-

- According to the recent specification, TL25 consists of one front axle load of 5 tons and two rear axle loads of 10 tons each, stipulated by the regulation. Design axle load is considered to apply the total of rear axle loads of 20 tons for T loading.

- On the other hand, total weight of special vehicles are allowed up to 36 tons provided by the regulation. The difference of actual load and design load are allowed to a certain extent by some kinds of restrictions.

In addition, "Road Bridge Rehabilitation Guideline" (Japan Road Association) tells that "coefficient of load condition which is a factor to determine applicable design live load for the bridges to be rehabilitated shall be judged on the consideration of the loading of the bridges under normal traffic conditions."

On the other hand, the limits of total vehicle in Sri Lanka are 15.275 tons for 2-axle truck, 20 and 21 tons for 3-axle truck and 27.5 tons for 4-axle truck.

(5) Allowable Stress for Steel Material

The increase rate of allowable stress is set at 1.5. This value is less than 1.71 which is ratio between allowable stress and yield stress.

According to the axle load survey, only 2% of total numbers of axle load exceed 12 tons which is adopted as basic design axle load. So, an occasion of the increase rate for allowable stress (1.5) is applicable for axle weight of 12.1 tons

(6) Applicable Live Load for Rehabilitation Plan

Based on the results of the analysis of the axle load survey and consideration on the difference of traffic volume between Japan and Sri Lanka, the live load and increase rate of allowable stress used for the Rehabilitation Plan was set in this Study as follows:-

- A-class roads : 18 tons
  (increase rate for allowable stress shall be 1.5.)
- B-class roads : 16 tons
  (increase rate for allowable stress shall be 1.5)

These live load and the increase rate are set based on the present condition in Sri Lanka, therefore, the live load shall be re-set if any condition changes, such as an increase of traffic volume and a number of heavy vehicles.

3.8.2 Determination of Applicable Live Load for Reconstruction Plan

(1) Present Standard Live Load in Sri Lanka

It is known that most bridges in Sri Lanka are built or designed using British Standard though design data and information is not existed. In 1978, new bridge loading and a design standard known as BS 5400 (1978) were introduced to incorporate the application of ultimate limit state design philosophy in U.K. In 1982, the BS 5400 was introduced to Sri Lanka and has been used so far.

RDA has established its own design live load based on the BS 5400 as follows:-

Loading

- All bridges in Sri Lanka to be designed to satisfy the more severe effects of either HA or HB Loading as stipulated in the Code of Practice BS 5400. The design HB loading is to be taken as 30 units, for the above exercise, for both A & B class roads.

- In areas of special significance or industrial towns, 45 units of HB vehicles is to be checked, for the adequacy of the strength of the structure.

- For design purposes, in calculating load effects, the HB vehicles may be considered as straddling two notional lanes as defined in the Code of Practice BS 5400.

(2) Applicable Live Load for Reconstruction Plan

The HB vehicle has 4 axles, thus, the total weight of one vehicle reached 1,200 kN (120 tons).

According to the results of the Axle Load Survey, the heaviest vehicles of its total weight of about 41 tons and the heaviest axle load of about 18 tons were observed on A-class roads which are main corridors. Therefore, the weight of the HB vehicle seems to be conservative loading.

Taking into the consideration of RDA practice and their request, their Standard Live Load was adopted in the reconstruction plan in this Study.

3.9 Preliminary Rehabilitation Design

The purposes of preliminary rehabilitation design covering the 10 bridges are to prepare standard rehabilitation design, to estimate the work quantities of each bridge. The preliminary design was carried out based on the output from the preceding detailed survey.

Although preliminary rehabilitation designs for the 10 bridges were in various ways from repair to reconstruction, the above 10 rehabilitation methods were not enough to estimate rehabilitation costs for other 90 bridges. Therefore, preliminary design on reconstruction plan for each bridge was also carried out.

3.9.1 Structural Assessment Criteria

The structural assessment criteria applied in the Study are principally based on a new modified design practice established from various design standards including the Bridge Design Specification in Japan. The assessment criteria cover the following aspects.

- Geometric Design Standard

  RDA standard was applied for approach road design in the case of reconstruction plan.

- Bridge Width

  Bridge width applied for reconstruction is in accordance with RDA standard, while bridge width applied for rehabilitation is based on the sub-standard established in the Study.

- Free Board

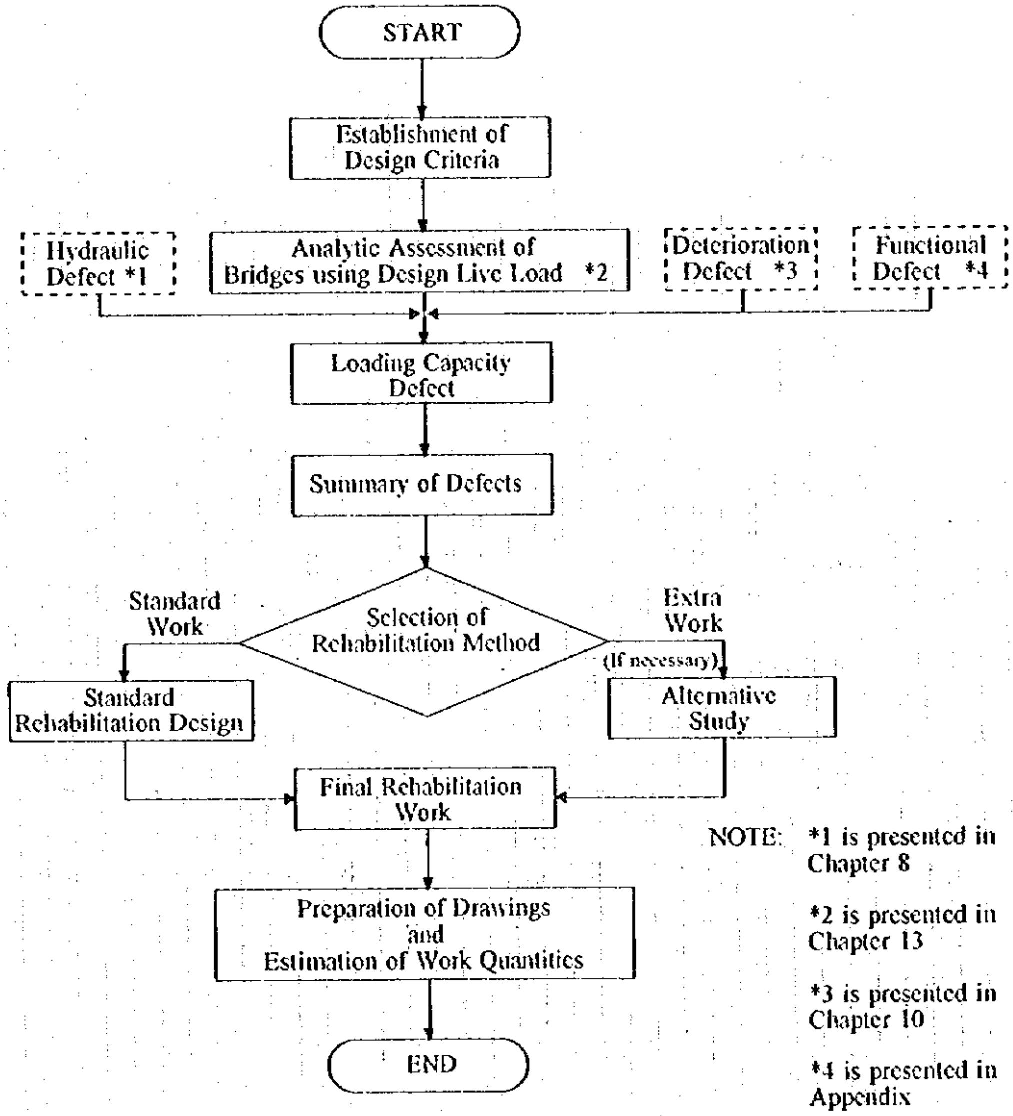
  Free board requirement is not specified in RDA standard, thus the recommendation given in "River Design Standard" in Japan is adopted with some modifications considering river condition in Sri Lanka.

- Bridge Loading

  The loads to be considered shall be dead load, footway load, breaking force, earth pressure and live load. As for live load, HA and HB loading were applied for reconstruction and T-loading is applied for rehabilitation.

- Assessment Method

  Analytic assessment and rehabilitation design on existing bridge members were carried out by using the elastic design method (allowable stress design).



NOTE: *1 is presented in Chapter 8

*2 is presented in Chapter 13

*3 is presented in Chapter 10

*4 is presented in Appendix

Figure 3.9.1 Flow Chart of Preliminary Design

Limit state design based on BS 5400 was applied for a reconstruction plan.

3.9.2 Preliminary Design for the Selected 10 Bridges

Based on the assessments carried out in the previous sections, all the types of defects and the corresponding causes were summarized.

From these results, a suitable rehabilitation method was selected for each bridge and a summary of the selected rehabilitation plans is shown in Table 3.9.1.

3.9.3 Standard Rehabilitation Method

To select standard rehabilitation methods which are applicable to each bridge was not only for 10 bridges for detailed survey but also for the other 90 bridges.

(1) Study for Rehabilitation for RSJ Bridge

Although many options can be considered for repair and reinforcement for RSJ bridges in general, practical methods shall be adopted for rehabilitation method considering various conditions in Sri Lanka. A summary of practical methods for rehabilitation is as follows:-

1) Painting
   - Tar painting

2) Reinforcement of deck slab
   - Partly-redecking of RCS
   - Injection of epoxy into cracks

3) Redecking
   - Redecking of BUC, COR, and DEC to RCS deck slab

4) Covering main beam with reinforced concrete
   - Reinforcement of main beam by covering of reinforced concrete

5) Additional main beam (widening)
   - Widening after redecking to RCS deck slab

(2) Study for Rehabilitation for Truss Bridge

Suitable rehabilitation methods for truss bridges were selected as well as the case of RSJ bridges. In the case of truss bridge, widening with additional main frames can not be applied in terms of structural properties. The followings are summary of practical methods for rehabilitation:

1) Painting
   - Tar painting

Table 3.9.1 Summary of Rehabilitation Plan

SER No.	TYPE OF BRIDGE	Structural Defects (Rating)		Existing Width		Proposed Width		Bridge Length (m)	Treatment	
		Super-structure	Sub-structure	Carriage-way	Overall	Carriage-way	Overall		Superstructure	Substructure
85	ARCH/BR	2.0	2.0	6.30	7.50	7.4	9.8	68.90	Additional Footway	Widening
77	ST.TR/T/RCS +RSJ/BUC	3.0	2.0	5.36	5.66	6.8	9.2	39.22 79.66	Reconstruction by PSC/PRE & PSC/POS	Reconstruction 4@10+2@20+4@10=120m
53	ST.TR/T/RCS	2.0	1.0	3.37	3.65	-	-	39.95	Repair of Main Frame	-----
33	ST.TR/T/RCS RSJ/RCS	4.0	2.0	3.30	3.64	7.4	9.8	51.00 17.85	Reconstruction by PSC/PRE & S/BOX	Reconstruction 16+50+10=76m
59	RSJ/BUC	2.0	2.0	3.20	3.56	4.0	5.0	51.00	Redeck and Widen	Widening
20	RSJ/COR	4.0	2.0	3.97	4.29	6.0	7.0	14.35	Redeck and Widen	Widening
70	RSJ/RCS	2.0	3.0	5.46	5.93	6.5	7.5	43.23	Redeck and Widen	Widening
7	PSC/PRE +RCB	4.0	3.0	5.85	6.85	-	-	139.18	Repair of RCB	Repair
211	RSJ/RCS	2.0	2.0	3.55	3.83	6.0	7.0	23.60	Redeck and Widen	Widening
212	PSC/PRE	4.0	3.0	10.40	11.90	-	-	62.48	Repair	Repair

2) Reinforcement of deck slab
- Partly-redecking of RCS
- Injection of epoxy into cracks

3) Redecking
- Redecking of BUC, COR, and DEC to RCS deck slab

4) Reinforcement of main structure
- It shall be adopted only for substantially damaged members.

5) Weepholes
- Weepholes shall be made on the bottom flange of the lower chord (π) for drainage purpose.

6) Placement or addition of knee brace
- Knee brace shall be placed for bridges which do not have it and of which main structure is swaying..

7) Adding of footway
- Footway shall be added outside of main structure of bridges if necessary.

(3) Study for Concrete Members

The standard rehabilitation methods are broadly divided into the following two categories:-

- Protection work to concrete
- Reinforcement work to concrete

Considering various conditions in Sri Lanka, suitable rehabilitation methods for concrete members were selected as follows:-

1) Protection work to concrete
- Epoxy injection

2) Reinforcement work to concrete
- Prepacked concrete

(4) River Rehabilitation Works

River rehabilitation work consists of slope protection, foot protection, river bed protection and river alignment. The followings are selected for the river rehabilitation work:-

1) Slope protection
   - Stone masonry
   - Concrete block masonry

2) Foot protection
   - Dumped stone
   - Wire mesh gabion
   - Concrete block mattress

3) River bed protection
   - Wire mesh gabion
   - Dumped stone and wire mesh gabion

4) River realignment
   - Spur dike by stone masonry

3.9.4 Preliminary Design for Reconstruction

Preliminary design for reconstruction was carried out for 9 bridges out of the 10 bridges to assist cost estimations for other 90 bridges.

At first, bridge planning was carried out based on the results of detailed survey.

(1) Selection of Structural Type

1) Superstructure

RDA has prepared its own standard of PC concrete beams and they are being used for construction of bridges.

According to the RDA design practice, bridge span is determined by using these standard of concrete beams.

The strength of the standard concrete beams (PSC/PRE) were confirmed in the full scale loading test.

Considering the present situation mentioned above, it can be judged that the standard beams are reliable to be adopted in this Study except for the center span of the bridge SER No. 33. Steel box girder is recommended for the span with 50 meters long. Since the steel box girder is very common type of superstructure in Japan, there is a lot of useful design data. Therefore, calculation was omitted by utilizing of these data to determine the dimensions and steel weight of the steel bridge.

2) Substructure

The type of foundation applied in this Study was determined considering current design practices in Sri Lanka and they are as follows:-

- Spread foundation
- Piled foundation (RDA standard - R.C. square piles 355 X 355)
- Caisson foundation (open caisson)

(2) Results of Reconstruction Design

Preliminary drawings for the 9 bridges were prepared, and work quantities of the work items for each bridge were also computed together with construction period.

An applicable specification for reconstruction work is in principle based on RDA Standard Specifications for Construction and Maintenance of Roads and Bridges, 1989 and briefly described in the drawings.

3.9.5 Preliminary Design for Steel Bridges

(1) Stress check on RSJ

RSJ Bridges have been constructed for short spans, 3.7m to 10.5m. Slab type of BUC, COR, DEC and timber should be redecked with RCS. Since design standards for deck slab to determine slab thickness and arrangement of reinforcement has not yet been established in Sri Lanka, the standards is prepared in this section. In addition, the study of load distribution expected by deck slab only was carried out. The study of composite action on existing non-composite beam bridges was also carried out. The stress check was then carried out based on the results of above studies.

1) Design standard for deck slab regarding slab thickness and arrangement of reinforcement

Slab thickness and arrangement of reinforcement were determined in accordance with Specification for Highway Bridges, March 1987 and 1994 issued by Japan Road Association.

2) Load Distribution by Deck Slab

Comparison of reaction force was carried out for load distribution by deck slab using the data obtained from 1-0 method and FEM analysis on SER No. 59 and 211 bridges, on which the loading tests were carried out.

Table 3.9.2 Summary of Stress Check and Rehabilitation Plan for all RSJ Bridges

SER No.	Stress check		Reconstruction needed by		Rehabilitation Plan
	Without Concrete Cover	With Concrete Cover	Calculation	Damage	
44	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
89	Excessive stress	OK			Covering of main beam with RC
2	Excessive stress	OK			Covering of main beam with RC
36	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
102	OK	-			-
65	OK	-			-
52	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
77	-	-		O	Reconstruction by PSC/PRE
106	OK	OK			-
108	Excessive stress	OK			Covering of main beam with RC
119	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
175	-	-		O	Reconstruction by RCB
120	OK	-			-
30	OK	-			-
55	Excessive stress	OK			Covering of main beam with RC
56	OK	-			-
127	OK	-			-
31	-	-		O	Reconstruction by PSC/PRE
57	OK	-			-
131	OK	-			-
209	OK	-			-
210	OK	-			-
211	OK	-			-
33	-	-		O	Reconstruction by PSC/PRE
58	OK	-			-
59	OK	-			-
67	OK	-			-
18	-	-		O	Reconstruction by PSC/PRE
68	OK	-			-
133	OK	-			-
78	OK	-			-
135	OK	-			-
20	Excessive stress	OK			Covering of main beam with RC
38	-	-		O	Reconstruction by PSC/PRE
136	Excessive stress	OK			Covering of main beam with RC
195	OK	-			-
70	OK	-			-
138	OK	-			-
173	OK	-			-
39	OK	-			-
144	-	-		O	Reconstruction by RCB
147	OK	-			-
148	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
21	OK	OK			-
40	OK	-			-
17	Excessive stress	OK			-
32	-	-		O	Reconstruction by PSC/PRE
150	OK	-			-
151	OK	-			-
154	OK	-			-
24	Excessive stress	OK			Covering of main beam with RC
25	Excessive stress	Excessive stress	O		Reconstruction by PSC/PRE
35	-	-		O	Reconstruction by PSC/PRE
74	OK	-			-

- The dead load is not distributed by deck slab.
- 10% of live load distribution can be expected.

3) Composite Action on Non-Composite Beams

Comparison of actual value and design value of deflection of beam was carried out to diagnose composite action on non-composite beams. The actual value was obtained from full scale loading test and the design value was obtained from FEM analysis on SER No. 59 and 211 bridges.

- A half composite action can be expected although the RSJ bridges are composed of non-composite beams, therefore, 10% of live load distribution can be expeced.

4) Results of Stress Check for RSJ Bridges

The stress check was extended to all RSJ bridges studied, 54 nos. The summary of stress check is tabulated together with the corresponding rehabilitation plans in Table 3.9.2.

(2) Stress Check on Truss Bridges

Truss bridges have been constructed with its span range of small to medium, 10.9 to 51.0m. Many of the bridges have about 20m spans. Therefore, SER No. 77 (L=19.7m) was selected as a representative bridge to be checked the stress of its main frame.

Table 3.9.3 Results of Stress Check on ST.TR

Live Load	Members	Increased Allowable Stress	Stress
T-20	Upper & Lower Chord	Taken 1.5 of increase rate of allowable stress	Excessive stress of 3 to 4%
L-20	Upper & Lower Chord	Taken 1.5 of increase rate of allowable stress	Excessive stress of 12 to 14%
T-18	Upper & Lower Chord	Taken 1.5 of increase rate of allowable stress	No excessive stress

According to the above results, it is assumed that other truss bridges are in some excessive stress in case of T-20 or L-20 live load is applied as the same as SER No. 77.

3.10 Maintenance and Rehabilitation Programme for 100 Bridges

Planning of maintenance and rehabilitation works covering all the study bridges (100 bridges) was carried out based on the preliminary inspection results and the results of preliminary rehabilitation design.

3.10.1 Setting Up of Criteria in Selecting Rehabilitation Plan

In the selection of bridge rehabilitation method, the criteria were set up considering the items below.

(i) Evaluation of structural condition through preliminary (visual) inspection
(ii) Carriageway width determined by the traffic volume
(iii) Possibility of repair and reinforcement by the results of preliminary (visual) inspection
(iv) Capability of adding footway
(v) Existing road alignment condition
(vi) Results of high-water level study (free board)
(vii) Scouring of foundation detected in the preliminary (visual) inspection
(viii) Construction year of the bridge (deterioration by year, loading capacity and design standard)

The selection criteria are classified into 3 categories such as structural aspect, road functional aspect and hydraulic aspect.

(1) Selection Criteria for Structural Rehabilitation Methods

The structural rehabilitation methods can be divided into 3 ways such as repair, reinforcement and reconstruction. Each method has various kinds depending on the types of damage and its range and degree, and also cause of damage. Therefore, establishment of the criteria shall be made for engineers to select a particular method against the structural defects easily, such as weak members and structurally insufficient loading capacity.

1) Repair

The repair was selected to the structures which had enough loading capacities based on the results of structural study for the 10 bridges. For concrete members, the repair covers non-aggressive cracks due to shrinkage and creep, light deterioration/damage caused by insufficient construction such as honeycomb, flaking and crack. And for steel/iron members, repainting is required. In addition, change of bridge accessories is also applicable.

The repair varies depending on the types of damage, its range, degree and also the cause of damage. Each type of rehabilitation method is defined together with the corresponding application criteria.

2) Reinforcement

The reinforcement was selected to the bridge component which has serious structural damage or insufficient loading capacity determined from the results of study in section 3.8. The serious structural damage which needs reinforcement is the defects such as progressive cracks due to bending or shearing, remarkable settlement and large area of section lack, etc. There are variety of reinforcement methods, which depends on the types of damage, its range and degree and also the cause of damage. Each type of the rehabilitation method is defined together with the corresponding application criteria.

3) Reconstruction

Reconstruction basically was selected for bridges with overall rating of 4.0 and/or bridges with inadequate loading capacity. If the Study result shows difficulties of economical repair/reinforcement, the reconstruction is applicable for the bridge component or whole bridge. The bridge component which has serious structural damage or in adequate loading capacity shall be replaced with proper bridge members.

Additionally, where the bridge needs complex reinforcement due to many defects such as functional defects and hydraulic defects with structural damage, it is recommended to reconstruct the bridge.

(2) Selection Criteria for Functional Rehabilitation Methods

The functional rehabilitation is categorized as widening of carriage way and adding footway.

1) Widening carriageway

As the necessity of widening is generally determined by present traffic volume and future traffic volume projection, RDA has own standard on carriageway width. (7.4m is for standard and 6.8m is for less traffic volume bridge on A-route. On B-route the width is determined considering the existing site conditions.)

2) Adding footway

The necessity of adding footway is determined based on a situation whether the bridge locates inner-city or near public facilities such as school, hospital and temple, etc. or not. In the preliminary study, these surrounding conditions were reported in the preliminary environmental examination.

3) Rising

In the preliminary inspection, some data and information regarding flood level were collected through RDA and interview to resident at the site.

Generally, the bridge height shall be risen where the bridge submerges in the water flow. However, rising of vertical alignment sometimes causes adverse effects because of no consideration given to surrounding.

Therefore, the rising of vertical alignment was not considered in the Study.

(3) Selection of Criteria for Hydraulic Rehabilitation

The hydraulic rehabilitation covers river protection, slope foot protection, river bed consolidation work and river re-alignment work as follows:-

1) River protection is applicable to protect erosion at river slope around abutment.
2) Slope foot protection is applicable to protect slope failure caused by river bed scouring at foot of river slope.
3) River bed consolidation work is applicable to protect scouring around river bed.
4) River re-alignment work is applicable to protect remarkable erosion caused by irregular flow at upstream side of the bridge.

Hydraulic rehabilitation methods is determined depending on river flow condition, scale of river, flood flow velocity shape of foundation and soil conditions.

Type of rehabilitation method for each plan is designed together with the corresponding application criteria.

3.10.2 Planning Results of Maintenance and Rehabilitation Works

A summary of planning results for the 100 bridges is shown in Table 3.10.1.

Table 3.10.1 Summary of Rehabilitation Plan for the 100 Bridges

SER No.	Route No.	Bridge No.	Year Built	Type of Bridge	Length Exist (m)	Nos. of Span	Overall Width Exist.	Overall Width Propd.	Damage Rating Deck	Main Frame	Abut.	Pier	Wing Wall	Overall	Rehabilitation Plans from Structural View Point	Work Period (month)
1	AA002	98/1K		RCB	30.00	3	9.30	11.00	4	4	2	2	2	4.0	Reconstruction by RSC/PRE	18.5
175	AB027	1/2M		RSJ/COR	4.40	1	9.70	9.80	3	4	3	-	3	4.0	Reconstruction by RCB	7.0
122	B 045	19/1K		ST.TR/T/RCS	18.50	1	3.68	9.20	2	4	1	-	1	4.0	Reconstruction by PSC/POS	14.0
129	B 127	2/7K	1900	ARCH/BR	4.60	1	5.25	9.20	-	4	3	-	3	4.0	Reconstruction by RCB	7.0
33	B 157	12/3K	1945	ST.TR/T/RCS RSJ/RCS	68.85	3	3.64	9.80	3	4	2	2	1	4.0	Reconstruction by St.BOX & PSC/PRE	28.0
18	B 158	16/7K	1935	RSJ/RCS	31.20	3	3.70	9.20	2	4	2	2	2	4.0	Reconstruction by PSC/PRE	18.5
72	B 248	9/4K		ST.TR/T/COR	12.10	1	4.30	9.20	2	4	2	-	2	4.0	Reconstruction by PSC/PRE	13.0
38	B 265	8/1K		RSJ/T	17.02	3	3.49	9.20	4	4	4	4	4	4.0	Reconstruction by PSC/POS	14.0
144	B 379	1/1K		RSJ/RCS	3.10	1	6.38	9.80	4	4	2	-	2	4.0	Reconstruction by RCB	7.0
31	B 114	3/3M		RSJ/RCS	12.38	2	3.45	9.20	2	4	2	4	3	4.0	Reconstruction by PSC/PRE	13.0
32	B 437	2/1K		RSJ/COR	10.20	1	3.70	9.20	3	2	4	-	2	4.0	Reconstruction by PSC/PRE	13.0
35	B 454	3/1K	1945	RSJ/RCS	22.30	5	3.30	9.20	2	2	4	4	4	4.0	Reconstruction by PSC/PRE	14.0
86	AA002	199/3K		PSC/PRE	7.40	1	9.80	-	2	3	4	-	2	4.0	Repair (patching for soffit of beam)	1.5
202	B 304	14/5K	1993	BAILEY	9.15	1	4.80	-	-	-	(4)	-	(4)	(4.0)	Repair (protection of abutment against scouring)	1.0
212	AA002	138/1K	1975	PSC/PRE	62.48	3	11.90	-	2	4	3	2	2	4.0	Repair (patching for soffit of beam, crack injection for super & substructure)	1.5
91	AA004	169/9K		RC/BOX	13.80	3	7.30	-	-	4	4	3	-	4.0	Repair (grouting and crack injection for main slab)	1.0
7	B 425	20/4K		PSC/PRE, RCB	139.18	18	6.85	-	1	4	3	1	4	4.0	Repair (prepacked concrete for RC-beam, patching for substructure, crack injection for super & substructure)	6.0
20	B 264	25/7K		RSJ/COR	14.35	2	4.29	7.00	3	4	2	1	2	4.0	Rehabilitation (redecking, replacement of damaged girder, widening of super & substructure)	9.0
150	B 444	4/5K		RSJ/COR	7.90	1	4.31	7.00	4	4	3	-	3	4.0	Rehabilitation (redecking, widening of super & substructure)	8.0
61	B 379	7/6K		BAILEY	33.50	1	4.75	-	(4)	(1)	-	-	-	(3.2)	Repair (redecking by steel plate)	2.0
62	B 423	29/3K		CAUSEWAY	15.02	4	3.66	9.20	-	4	3	2	-	4.0	Reconstruction by PSC/PRE	12.0
63	B 423	27/2K		CAUSEWAY	7.00	3	3.30	9.20	-	4	4	3	2	4.0	Reconstruction by PSC/PRE	10.0
68	B 164	1/5K		RSJ/BUC (+PSC/PRE)	46.90 50.60	4 5	4.55	5.00	3	3	4	3	3	4.0	Rehabilitation (redecking, widening of super & substructure, grouting for abutment)	9.0
128	B 097	15/4K	1915	ST.TR/T/RCS	14.67	1	3.09	-	4	3	4	-	3	4.0	Rehabilitation (redecking, repair of substructure)	5.0
208	B 172	10/4K		BAILEY	18.30	1	4.12	-	(3)	(1)	-	-	-	(2.4)	Repair (redecking by steel plate, mat gabion for scouring)	2.0
119	AB026	3/1K		ARCH/BR RSJ/	10.37	1	7.05	7.00	4	2	2	-	2	3.2	Reconstruction by PSC/PRE	13.0

SER No.	Route No.	Bridge No.	Year Built	Type of Bridge	Length Exist (m)	Nos. of Span	Overall Width		Damage Rating						Rehabilitation Plans from Structural View Point	Work Period (month)
							Exist.	Propd.	Deck	Main Frame	Abut.	Pier	Wing Wall	Overall		
78	B 199	5/5K	1918	RSJ/BUC	124.40	12	4.52	7.40	4	3	2	1	2	3.2	Rehabilitation (redecking, widening of super & substructure)	15.5
80	AA003	96/7K	1898	ST.TR/T/COR	104.03	4	4.24	-	4	3	2	2	2	3.2	Rehabilitation (redecking, repair of main frame)	11.5
34	B 264	7/1K		ST.TR/T/COR	27.23	2	4.33	-	4	2	2	2	2	3.2	Rehabilitation (redecking, repair of main frame)	6.0
40	B 421	66/2K	1930	RSJ/BUC	21.00	2	4.70	7.00	4	3	2	2	2	3.2	Rehabilitation (redecking, widening of super & substructure)	9.0
42	B 464	5/1K	1904	ST.TR/T/COR	59.20	3	4.29	-	4	2	2	2	2	3.2	Rehabilitation (redecking, repair of main frame)	8.0
44	AA004	196/7K		RSJ/BUC	31.15	3	4.50	5.00	4	2	2	3	3	3.2	Reconstruction by PSC/PRE	18.0
87	AA002	256/1K		PSC/PRE	4.85	1	5.60	-	4	2	3	-	2	3.2	Repair (grouting for loose stone of abutment)	1.0
178	AA004	192/2K		ST.TR/D/COR	43.60	4	4.60	-	4	2	2	2	2	3.2	Rehabilitation (redecking, repair of main frame)	7.5
21	B 421	8/1K	1930	ST.TR/T/COR RSJ/BUC	26.22 10.50	1 1	4.22	-	4	2	2	2	2	3.2	Rehabilitation (redecking, repair of main frame)	8.0
24	B 454	19/2K		RSJ/T	13.60	2	3.06	5.00	4	2	2	3	2	3.2	Rehabilitation (redecking, widening of super & substructure)	8.0
55	B 093	8/10K		RSJ/BUC	20.90	2	4.50	5.00	4	2	1	1	1	3.2	Rehabilitation (redecking, widening of super & substructure)	6.0
56	B 093	3/7K		RSJ/BUC	10.10	1	4.57	5.00	4	2	1	-	1	3.2	Rehabilitation (redecking, widening of super & substructure)	5.0
74	B 466	6/5K	1940	RSJ/BUC	10.30	1	5.60	5.60	4	2	2	2	3	3.2	Rehabilitation (redecking, widening of substructure)	5.0
127	B 093	12/2K		RSJ/COR	10.20	1	4.25	4.50	4	2	3	-	1	3.2	Rehabilitation (redecking, widening of super & substructure)	5.0
133	B 188	5/2M		RSJ/BUC	9.00	1	3.60	5.00	4	1	1	-	1	3.2	Rehabilitation (redecking, widening of super & substructure)	6.5
27	AA002	87/1K	1898	ARCH/ST	35.20	3	7.60	9.80	-	1	2	3	3	3.0	Reconstruction by PSC/PRE	18.0
66	B 111	7/1K	1930	ST.TR/T/COR	36.80	2	5.50	-	2	3	2	2	1	3.0	Repair (main frame)	3.5
70	B 295	3/6K	1960	RSJ/RCS	43.23	5	5.93	7.50	2	2	3	2	2	3.0	Rehabilitation (redecking, widening of super & substructure)	10.0
75	AA002	62/2K	1932	ST.TR/T/RCS	40.50	1	5.68	-	3	3	2	-	3	3.0	Rehabilitation (redecking, repair of main frame)	7.5
108	AA033	5/3K		RSJ/BUC	5.70	1	3.70	7.50	3	3	2	-	2	3.0	Rehabilitation (redecking, widening of super & substructure)	5.5
120	AB029	12/2K		RSJ/RCS	4.25	1	7.03	7.50	3	3	2	-	2	3.0	Repair (recovering of main girder with RC)	3.0
197	B 288	10/3K	1918	ST.TR/T/DEC	52.80	2	5.48	-	2	3	2	2	2	3.0	Repair (main frame)	3.5
17	B 437	3/1K		RSJ/BUC	10.35	1	3.42	5.00	3	2	3	-	2	3.0	Rehabilitation (redecking, widening of super & substructure)	8.0

SER No.	Route No.	Bridge No.	Year Built	Type of Bridge	Length Exist (m)	Nos. of Span	Overall Width Exist.	Overall Width Propd.	Damage Rating Deck	Damage Rating Main Frame	Damage Rating Abut.	Damage Rating Pier	Damage Rating Wing Wall	Damage Rating Overall	Rehabilitation Plans from Structural View Point	Work Period (month)
47	AA007	70/8K	1918	ARCH/ST	14.57	1	6.30	7.50	-	2	3	-	1	3.0	Rehabilitation (widening of arch, repair of wing wall)	5.0
93	AA005	21/4K	1926	ST.TR/T/BUC	98.30	2	9.01	-	2	2	2	3	2	3.0	Repair (main frame)	5.0
102	AA010	25/2K	1920	RSJ/COR	17.20	2	5.54	7.50	3	3	2	2	2	3.0	Rehabilitation (redecking, widening of super & substructure)	12.0
123	B 079	23/2K		RCB	12.02	2	4.28	7.00	3	1	3	1	3	3.0	Rehabilitation (widening of super & substructure)	2.0
151	B 445	14/2K		RSJ/BUC	10.10	1	4.66	7.50	3	3	3	-	2	3.0	Rehabilitation (redecking, widening of super & substructure)	8.5
154	B 445	14/3K		RSJ/BUC	10.35	1	4.60	5.00	3	3	3	-	2	3.0	Rehabilitation (redecking, widening of super & substructure)	5.0
52	AA017	2/2K		RSJ/COR	10.50	1	4.30	7.50	3	3	1	-	1	3.0	Reconstruction by PSC/PRE	13.0
65	AA011	24/3K	1967	RSJ/RCS	9.70	1	5.65	7.50	2	3	2	-	2	3.0	Rehabilitation (redecking, widening of super & substructure)	8.5
77	AA019	3/2K	1869	RSJ/BUC ST.TR/T/COR	79.66 39.22	8 2	5.66	9.20	3 3	3 3	2 -	2 2	3 -	3.0	Reconstruction by PSC/POS & PSC/PRE	30.0
89	AA004	163/9K		RSJ/COR	4.80	1	4.22	7.50	3	2	3	-	3	3.0	Rehabilitation (redecking, widening of super & substructure)	7.5
147	B 419	6/2K		RSJ/BUC	9.84	1	4.68	7.00	2	3	3	-	2	3.0	Rehabilitation (redecking, widening of super & substructure)	8.0
148	B 419	24/2K		RSJ/BUC	8.40	1	3.60	7.00	3	3	3	-	2	3.0	Reconstruction by PSC/PRE	8.0
173	B 304	17/1K	1940	RSJ/BUC	6.80	1	5.70	7.00	2	3	3	-	2	3.0	Rehabilitation (redecking, widening of super & substructure)	7.5
209	B 146	21/1K	1861	ARCH/ST RSJ/COR	4.40	1	7.26	-	3	3	2	-	2	3.0	Rehabilitation (redecking)	4.5
19	B 207	10/3K	1890	ST.TR/T/COR	32.38	1	4.28	-	2	3	3	-	3	3.0	Repair (main frame)	3.5
26	B 462	10/1K		ST.TR/T/COR	19.00	1	4.26	-	3	2	2	-	1	3.0	Rehabilitation (redecking, rapair of main frame)	5.5
30	B 014	8/1K		RSJ/COR	20.70	2	5.60	7.00	3	3	2	3	3	3.0	Rehabilitation (redecking) Repair (crack injection for abutment)	6.0
39	B 349	30/2K	1927	RSJ/COR	23.10	3	3.87	7.00	2	3	2	2	2	3.0	Rehabilitation (redecking, widening of super & substructure)	9.0
57	B 116	2/2K		RSJ/BUC	9.20	1	5.65	7.10	3	3	2	-	2	3.0	Rehabilitation (redecking, widening of super & substructure)	5.0
131	B 127	1/2K	1900	RSJ/COR	4.73	1	4.27	7.00	2	3	2	-	2	3.0	Reconstruction by RCB	5.0
135	B 249	5/9K		RSJ/BUC	9.30	1	4.60	5.00	3	3	3	-	3	3.0	Rehabilitation (redecking, widening of superstructure)	5.0

SER No.	Route No.	Bridge No.	Year Built	Type of Bridge	Length Exist (m)	Nos. of Span	Overall Width Exist.	Overall Width Propd.	Damage Rating Deck	Damage Rating Main Frame	Damage Rating Abut.	Damage Rating Pier	Damage Rating Wing Wall	Damage Rating Overall	Rehabilitation Plans from Structural View Point	Work Period (month)
136	B 272	15/2K		RSJ/DEC	30.50	5	4.28	7.00	1	2	3	2	3	3.0	Rehabilitation (widening of super & substructure)	8.5
25	B 454	6/6K		RSJ/RCS	24.20	4	3.28	5.00	2	2	2	3	2	3.0	Reconstruction by PSC/PRE	9.0
41	B 454	15/3K	1924	RCS	10.30	2	3.63	-	-	2	3	2	3	3.0	Repair (hand rail)	1.0
67	B 157	23/2K	1960	RSJ/BUC	19.10	4	3.34	5.00	2	2	3	2	2	3.0	Rehabilitation (redecking, widening of super & substructure)	9.0
69	B 188	5/4K		ST.TR/T/RCS	12.60	1	3.06	-	1	3	2	-	-	3.0	Repair (main frame)	2.5
76	AA002	62/1K	1929	ST.TR/T/RCS	90.90	2	6.25	-	2	2	2	2	2	2.0	Repair (main frame)	4.5
79	AA003	43/1K	1918	ST.TR/T/COR	69.20	3	5.18	-	2	2	2	1	3	2.0	Repair (main frame)	3.5
84	AA001	110/2K	1933	ARCH/S	68.30	3	7.80	-	3	1	1	1	1	2.4	Rehabilitation (redecking)	12.0
85	AA001	91/2K	1894	ARCH/BR	68.90	4	7.50	-	-	2	2	2	1	2.0	Rehabilitation (additional footway, widening of super & substructure)	12.0
99	AA009	5/1K	1860	ST.TR/D/COR	124.80	6	10.30	-	3	2	2	2	3	2.4	Rehabilitation (redecking, repair of main frame)	12.0
195	B 288	10/2K		RSJ/COR	5.50	1	6.06	7.50	-	2	1	-	1	2.0	Rehabilitation (redecking, widening of super & substructure)	7.5
201	B 288	10/5K		ARCH/CO	7.20	2	8.06	-	-	1	2	-	2	2.0	Repair (grouting for wing wall)	1.0
36	AA010	48/1K		RSJ/COR	31.12	3	5.52	7.50	2	2	2	1	2	2.0	Reconstruction by PSC/PRE	18.0
138	B 304	25/3K		RSJ/BUC	10.30	1	5.47	7.00	3	2	2	-	2	2.4	Rehabilitation (redecking, widening of super & substructure)	8.0
211	B 146	8/3K	1942	RSJ/RCS	23.60	3	3.83	7.00	2	2	2	1	1	2.0	Rehabilitation (redecking, widening of super & substructure)	9.0
210	B 146	6/3K		RSJ/RCS	23.70	3	4.20	7.00	1	2	1	1	2	2.0	Rehabilitation (redecking, widening of super & substructure)	9.0
2	AA010	75/1K		RSJ/COR	122.60	12	5.55	7.50	2	2	1	1	2	2.0	Rehabilitation (redecking, widening of super & substructure)	17.0
43	AA004	206/9K		ARCH/BR	39.40	3	4.70	-	-	2	2	1	2	2.0	Repair (cleaning & grouting)	1.0
45	AA004	209/1K		ARCH/CO	28.40	2	4.25	-	-	2	1	1	2	2.0	Repair (cleaning & grouting)	1.0
58	B 157	44/3K	1930	RSJ/RCS (covered with concrete)	10.35	1	3.96	5.00	2	2	2	(4)	-	2.0	Reconstruction by PSC/PRE	15.0
59	B 157	43/4K	1924	RSJ/BUC	51.00	5	3.56	5.00	2	2	2	2	2	2.0	Rehabilitation (redecking, widening of super & substructure)	9.0
103	AA012	16/1K	1970	RCS	6.64	1	6.64	-	-	-	2	-	2	2.0		-
130	B 127	7/1K	1917	ST.TR/T/COR	24.73	1	4.54	-	1	2	1	-	2	2.0	Repair (main frame)	3.0
53	AA021	36/3K	1899	ST.TR/T/RCS	39.95	1	3.65	-	1	2	1	-	1	2.0	Repair (main frame)	3.5
60	B 300	15/6K	1933	CAUSEWAY	7.87	3	4.60	9.20	-	2	1	1	2	2.0	Reconstruction by PSC/PRE	9.0
46	AA007	73/5K		ARCH/ST	11.70	1	5.80	7.50	-	1	1	-	1	1.0	Rehabilitation (widening)	6.0

SER No.	Route No.	Bridge No.	Year Built	Type of Bridge	Length Exist. (m)	Nos. of Span	Overall Width		Damage Rating						Rehabilitation Plans from Structural View Point	Work Period (month)
							Exist.	Propd.	Deck	Main Frame	Abut.	Pier	Wing Wall	Overall		
106	AA026	69/1K		RSJ/RCS	16.30	2	4.70	7.50	2	1	1	1	1	1.6	Rehabilitation (redecking, widening of superstructure)	9.0
22	B 431	2/3K	1978	BAILEY	162.30	5	4.17	-	(2)	(1)	(1)	(1)	-	(1.6)	-	-
71	B 227	1/5M	1994	PSC/PRE	16.20	1	5.98	-	1	1	1	-	1	1.0	-	-
73	B 423	44/3K		RCS	7.60	2	4.00	-	1	-	1	1	3	1.5	Repair (grouting for substructure)	1.0

3.11 Environmental Examination

To examine the impacts of the bridge improvement on the environment, a preliminary environmental examination and a site inspection were carried out. Based on their results, an Initial Environmental Examination (IEE) and scoping were carried out.

(1) The Results of the IEE on 10 Bridges due for detailed Survey

Based on the results of the site inspection and the bridge improvement plan, the impacts of the bridge improvement on the environment were predicted. Then, measures to mitigate the environmental impact were examined and an Environmental Impact Assessment was judged as to whether it was necessary or not.

The bridges due for detailed survey are as follows:

SER No. 85, 212, 77, 53, 211, 33, 59, 20, 70, 7

According to the result of IEE, the following measures are required to mitigate the environmental impact:

A. Relocation of Residents and Rights of Way

- Relocation of residents at permanent buildings shall be avoided in planning the bridge improvement.

  SER No. 211, 7

- Important facilities shall not be disturbed by the bridge improvement plans.

  SER No. 85 (kindergarten), and 7 (fishing port)

- Acquisition or lease of private land shall be minimized in planning the bridge improvement.

  SER No. 85, 77, 53, 211, 59, 20, 70, 7

- Parties concerned shall be consulted prior to any land acquisition.

  SER No. 85, 77, 53, 211, 33, 59, 20, 70

- Compensation for the acquired land or alternative measures shall be considered.

  SER No. 77 (well), 53 (coconut trees), 20 (unauthorized buildings)

- Poor drainage shall be improved.

  SER No. 59

B. River-use

- Consideration shall be given to intake for water supply.

  SER No. 77 (domestic use), 33 (industrial use), 20 (agricultural use)

- Consideration shall be given to bathing, washing, and sand mining.

  SER No. 85, 77, 53, 211, 33, 20

- Consideration shall be given to river flow and water traffic

  SER No. 59, 70, 7

C. Traffic Jam (vehicles and pedestrians)

- Traffic control and pedestrian safety shall be ensured at the bridge improvement work site.

  SER No. 85, 70

- Student's safety at the bridge improvement work site shall be ensured.

  SER No. 53

Environmental impact will be mitigated by implementing the above measures. Therefore, Environmental Impact Assessment (EIA) will not be required for the proposed improvements on 10 bridges.

(2) The Results of Scoping for 91 Bridges due for Preliminary Survey

Based on the results of the preliminary environmental examination and the site inspection, scoping was carried out for the 91 bridges due for preliminary environmental examination (out of 101 bridges excluding 10 for which an IEE was conducted). Then, the environmental examination details involved in the bridge improvement were selected and the environmental check points were proposed.

Certain impact will be given to the environment and therefore consideration should be given to the bridge improvement project at 80 bridges out of the 91(Refer to Table 16.3). The environmental examination items were determined as follows:

A. Relocation of Residents and Rights of Way

B. River-use
C. Traffic Jam (Vehicles and Pedestrians)
D. Others (Remains, Cultural assets, Scenery)

The items for environmental consideration are:

A. Relocation of Residents and Rights of Way
- A-1 Avoiding relocation of residents of permanent buildings
- A-2 Consideration for important facilities including public, religious and industrial facilities
- A-3 Consideration for acquisition or lease of private land
- A-4 Consideration for temporary building illegally invaded by squatters
- A-5 Discussions with parties concerned in advance
- A-6 Compensation or alternative measures at acquisition of land
- A-7 Improvement of poor drainage

B. River-use
- B-1 Consideration for water intake (for water supply, agricultural use, and industrial use)
- B-2 Consideration for bathing, washing, and sand mining
- B-3 Consideration for problems against river flow and water traffic

C. Traffic Jam (Vehicles and Pedestrians)
- C-1 Traffic control and pedestrian safety
- C-2 School children's safety at the bridge improvement work site

D. Others
- D-1 Consideration for remains and cultural assets.
- D-2 Consideration for landscape

Regarding 80 bridges, it is necessary to examine the improvement plan and traffic control during the improvement project; to carry out an IEE; and to examine the environmental considerations.

3.12 Planning of Bridge Maintenance and Management

First of all existing system of bridge maintenance and management of RDA has been investigated.

3.12.1 Organization

Engineering Services Division in RDA has 4 sections including Bridge Design Section which is responsible for designing new bridges. In Traffic Planning Section there are some staff who review the existing bridges and prepare rehabilitation plans of damaged bridges. Other offices are Highway Design and Land Acquisition Offices. The Maintenance Management and Construction Division are in charge of implementation of roads and bridges rehabilitation and construction with the Provincial Offices.

The expenditures of RDA allocated to bridge investment are found, which has been increased at a rate of more than input to roads. In 1994 the amount was Rs.156 million (6%) while that on roads was Rs.1,520 million (57%). (The percent is in the RDA's total expenditure). However, the maintenance of roads and bridges are not shown separately. It means bridge maintenance works are mixed with road maintenance and management in the past.

3.12.2 A Proposal for Bridge Maintenance and Management

A new section should be established which covers inventory filing, plans and designing using standardized methods, cost estimate and related studies for bridges in RDA. The section should be establishd newly in Engineering Services Division and should gather up all staff related to bridge plan and maintenance programme at the beginning year.

The section will enroll several engineers and several assistants. Specified staff needed in province and local offices should be mobilized for some months from highway engineers as they are necessary. When the work burden becomes heavy, regular local staff should be recruited in each province or regional office.

3.12.3 Guideline

A guideline for preparing of the Manual for Bridge Inspection, Maintenance and Rehabilitation has been prepared in a separate file.

The guideline consists of three components as shown in Figure 3.12.1. The inspection covers data collection, filing of the existing conditions of bridges, design documents and related data. RDA has already been conducting the bridge inventory surveys and keep some of them in their files. It is advised that those filing system be restructured in accordance with this guideline. Basic approaches in field inspection and use of equipment are suggested. The guideline also suggests assessment procedures.

The results of assessment of bridges are grouped and classified whether they shall be maintained or rehabilitated under routine maintenance and others requiring rehabilitation work.

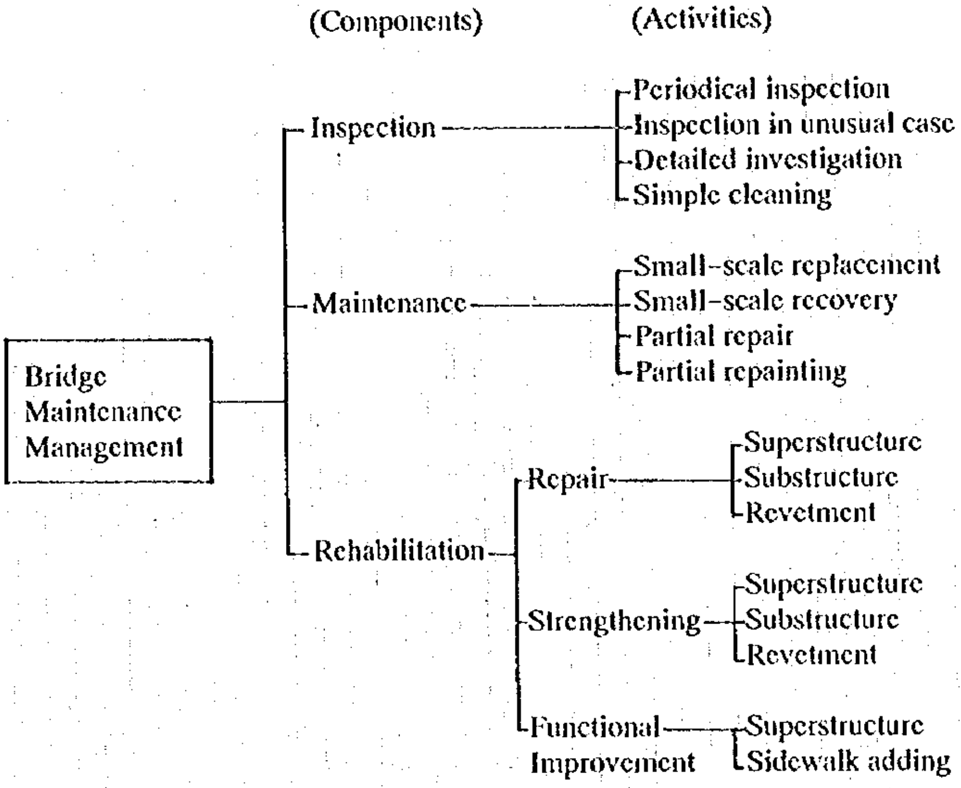


Figure 3.12.1 Definition and Functions of Maintenance Management

3.12.4 Cost Estimate for Bridge Maintenance and Management

(1) Inspection

Table 3.12.1 Total Cost of Bridge Maintenance and Management per Year

(Unit: Mil. Rs.)

	Maintenance Center in Engineering Division / RDA, Head Office	Maintenance Section in each Provincial Office	Total
Personnel	2.0	4.0	6.0
Plant, Equip. & Tool	3.6	1.0	4.6
Office, etc.	1.2	0.6	1.8
Contingency	0.4	0.6	1.0
Total	7.2	6.2	13.4

Note: 1. Depreciation of plant, equipment and tool shall be estimated for the duration of 15 years.
2. Repair fee is estimated by 20%.

(2) Routine Bridge Maintenance including Minor Repair

Since the accounting method of the routine maintenance is not shown separately for bridges and roads, it is hard to determine the budget cost. However, Rs.1.5 million for the bridge maintenance shall be suggested. The total cost for inspection, inventory filing and routine maintenance shall be Rs.14.9 million.

As discussed in Table 19.7, Chapter 19 of Main Text, the cost would be about Rs.53 million for the case in 1995. The above estimate of Rs.14.9 million is 28% of the total budget of Rs.53 million. The estimated cost seems agreeable, since the remaining 72% is thought to be used for material, transport, etc.

(3) Bridge Rehabilitation

As shown in Chapter 19 of Main Text, the cost for bridge rehabilitation is divided into two categories: (1) is the project cost for 100 studied bridges, (2) is the project cost for 253 bridges which require some rehabilitation in the near future. The above 253 brides include 100 studied bridges, and the total cost of rehabilitation for these bridges is estimated Rs.3,445 million in 1995 prices.

The cost of works seems to have a surplus of the budget by Rs. 599 million while the assumed budget allocation for rehabilitation works is Rs. 4,044 million for 1996-2010. If the inventory surveys of 4,430 bridges by RDA would recommend more bridges for rehabilitation works, the above surplus should be reviewed.

3.13 Cost Estimate

The Study objective is to estimate the rehabilitation and reconstruction cost for selected 100 bridges.

Based on the results of the Preliminary Rehabilitation Design, the cost estimate was carried out for the 10 representative bridges. Further, extra calculation was carried out for them assuming reconstruction. These results were extended to the cost estimate for the remaining 90 bridges.

The following procedures were taken in this Study.

- Assessment of the indirect cost items and project cost composition and determination of multiplier factors of these items.

- Review of main work items derived from the preliminary rehabilitation design and identification of the associated subsidiary work items.

- Analysis on the unit price of each work item or each rehabilitation method based on above consideration.

- Establishment of standard unit prices applicable to all the bridges of the Study based on assessment of the unit prices analyzed.

- Assessment of foreign and local portion and estimate of economic cost based on the analysis of project cost in recent studies conducted in Sri Lanka together with consideration of tax and duties.

3.13.1 Unit Price Analysis

(1) Basic Conditions

Basic conditions considered in the cost estimate are as follows:-

- Price level of labour, material and equipment are based as on October, 1995.

- The unit prices are prepared based on RDA standard and market investigation.

- Since the data of rehabilitation cost is limited in Sri Lanka, the data obtained from rehabilitation in Japan is applied supplementarily.

- Except direct construction cost, other cost such as indirect cost, engineering fees, and contingencies are computed by using the multiplier factors.

(2) Composition of Project Cost

Project cost consists of construction cost, land acquisition/compensation cost, engineering fees for detailed design and construction supervision, administration cost of the Government and contingencies. In addition, these cost can be divided into foreign portion, local portion and tax portion based on the analysis of project cost in recent studies conducted in Sri Lanka as follows:-

Table 3.13.1 Composition of Project Cost

	Foreign	Local	Tax	Total
Construction cost	(1) = 65% of (4) 65	(2) = 10% of (4) 10	(3) = 25% of (4) 25	(4) 100
Land acquisition /Compensation cost	-	-	-	-
Engineering fees	75% of (5) 7.5	15% of (5) 1.5	10% of (5) 1	(5) = 10% of (4) 10
Administration	-	2% of (2) 0.2	-	0.2
Contingency	20% of (1) 13	20% of (2) 2	20% of (3) 5	20% of (4) 20
Total [in %]	85.5 [65.7]	13.7 [10.5]	31 [23.8]	130.2 [100.0]

(3) Unit Price Analysis

Unit prices applied in this Study were calculated by the procedure as follows:-

1) Unit Rate for Labour, Material and Equipment

The unit rates for cost of labour, material and equipment were estimated on the basis of RDA standard and data from market survey.

2) Work Item Rate

The work item rates for concrete work, transportation, formwork, excavation, etc. were estimated on the basis of RDA standard and the data from the market survey. The rate covers overhead and profit for contractor.

3) Unit Price

Unit prices for work items such as concrete works of abutment, concrete works of pier, construction of PSC/PRE per square metres were estimated using the work item rate.

3.13.2 Standard Unit Price

Standard unit prices applied to other 90 bridges were prepared based on the assessment of the unit price for the 10 bridges.

(1) Cost Estimate for 10 the Bridges

Rehabilitation cost for the 10 bridge was estimated on each work items based on its rehabilitation method determined. Simultaneously, reconstruction cost for 9 bridges were estimated. The contents are as follows:-

for 9 bridges were estimated. The contents are as follows:-

SER No.	Proposed Rehabilitation Plan	Reconstruction Plan
85	Additional footway	-
77	Reconstruction	-
53	Repair of superstructure	O
33	Reconstruction	-
59	Redeck & widen	O
20	Redeck & widen	O
70	Repair of superstructure	O
7	Repair of super & substructure	O
211	Widen and repair of substructure	O
212	Repair of super & substructure	O

(2) Standard Unit Price

The standard unit prices applied to the 90 bridges are prepared based on the results of above estimate on the 10 bridges.

3.13.3 Project Cost Estimate

The project cost of each bridge was obtained by adding each work amount assigned. The amount was calculated by multiplying the estimated quantity of rehabilitation work by the corresponding standard unit price.

Table 3.13.2 shows the project cost classified into priority of rehabilitation and type of superstructure.

3.13.4 Economic Cost

Economic cost of the project in recent F/S studies (road) conducted in Sri Lanka is shown in terms of percent of the financial cost. The percentages vary in 83 - 89% for the total cost of the project while they are in 76 - 80% if the share in the cost of structure and bridges are taken up. Taxation system is complex in Sri Lanka where additions of turnover tax and defense levy have been implemented beside the customs and the excise duties and other charges. In 1994 the defense levy increased from 3.5 to 4.5% on the CIF. Detailed analysis need to be conducted in the stage of detailed engineering study.

When the project is formulated by bridges and structures such as this master plan study, the transfer elements of such taxes and charges will be higher than common road projects since bridge project depend much on imported machines. It is determined to calculate the economic cost by multiplying 76% of the financial cost.

Table 3.13.2 Financial (Project) Cost of Rehabilitation for the 100 Bridges

(Unit : Rs)

Bridge type	Span	1st Priority: Reconst (No.)	1st Priority: Reconst (Cost)	1st Priority: Repair & Reinforcement (No.)	1st Priority: Repair & Reinforcement (Cost)	2nd Priority (No.)	2nd Priority (Cost)	Others (No.)	Others (Cost)	Total (No.)	Total (Cost)
RSJ/BUC RSJ/COR RSJ/RCS RSJ/DEC	RSJ/T l= 3.7m ~ l= 10.5m	9	97.335.000	7	75.970.000	22	94.357.000	16	212.442.000	54	480.104.000
ST. TR/T/RCS ST. TR/T/DEC ST. TR/T/COR ST. TR/D/COR ST. TR. T. BUC	l= 9.3m ~ l= 51.0m	3	360.381.000	5	35.571.000	9	218.210.000	5	6.957.000	22	621.119.000
ARCH/S	l= 22.8m	-		-		1	8.440.000	-		1	8.440.000
BAILEY	l= 18.3m ~ l= 33.5m	-		3	4.938.000	-		1		4	4.938.000
RCB RCS RC/BOX	l= 3.8m ~ l= 9.7m	1	43.988.000	2	516.000	1	2.246.000	3	139.000	7	46.889.000
PSC/PRE PSC/POS	l= 4.9m ~ l= 16.2m	-		4	30.870.000	1	9.000	1		6	30.879.000
CAUSEWAY	l= 2.6m ~ l= 3.7m	2	67.493.000	-		-		1	25.213.000	3	92.706.000
ARCH/BR ARCH/CO ARCH/STO	l= 3.6m ~ l= 17.2m	3	61.444.000	-		4	11.566.000	3	1.673.000	10	74.683.000
Total nos. of bridge types (Total nos. of bridges) FINANCIAL COST		18(16)	630.641.000	21(19)	147.865.000	38(35)	334.828.000	30	246.424.000	107(100)	1.359.758.000

3.14 Economic Evaluation

3.14.1 General

This master plan study will present a rehabilitation program for 100 bridges selected through discussions with RDA. They have been inspected and studied from viewpoints of physical conditions, traffic volumes, functional category of roads, and so on. Various comparative ratings were conducted, resulting in the classification of 3 groups in the order of priority to be realized in 15 years up to 2010. Economic evaluation is conducted to justify this grouping policy by calculating economic returns of each group and each bridge.

Financial framework and overall rehabilitation cost for 15 years from 1996 to 2010 is estimated, which indicate the need to enlarge the financial framework for bridges.

3.14.2 Economic Evaluation

(1) Staged Schedule and VOC

The project covering 100 bridges was divided into the following packages in accordance with the priority;

The first group	: 35 nos. years	1996-2000
The second group	: 35 nos. years	2001-2005
The third group	: 30 nos. years	2006-2010

Economic benefits are discussed commonly in various project evaluation. It should be emphasized that there are quantitative and qualitative benefits. The quantification is by estimating savings in the vehicle operation cost (VOC) with and without project., while qualitative ones are assessment in different viewpoints as social, cultural and environment, etc. VOC has been studied in other feasibility studies in recent years. In similar manner to those studies, it is updated in prices of 1995 by reviewing those studies, prices in the market and tax-duty elements in May-June in 1995. The results were filed in a table of economic cost of VOC assuming normal conditions on surfaced 2-lane roads.

(2) Bridge Unusable Probabilities

Only a few records are found of bridge history such as years of construction, improvement, as well as design documents, materials, etc. Although the oldest year of construction recorded on the bridge or documents was 1932, it is said there are many bridges constructed and rehabilitated in the year older than it. Majority are thought to have some type of rehabilitation works after construction to now. Since sufficient records are not found, a statistical inference is used to determine the difference in probabilities of bridge damage between 'with a rehabilitation and without it'. The differences are incorporated in the savings together in using VOC data.

An example of damage probability for a bridge with assumed age of 30 years is shown in Figure 3.14.1. The age 30 means the remaining years in calculation is 20 since all are assumed to have 50 years in life. Four curves can be drawn each responding to its rehabilitation category. Reduced probability of the damage is shown in by shaded areas, which is used to estimate the savings for 20 years of project life.

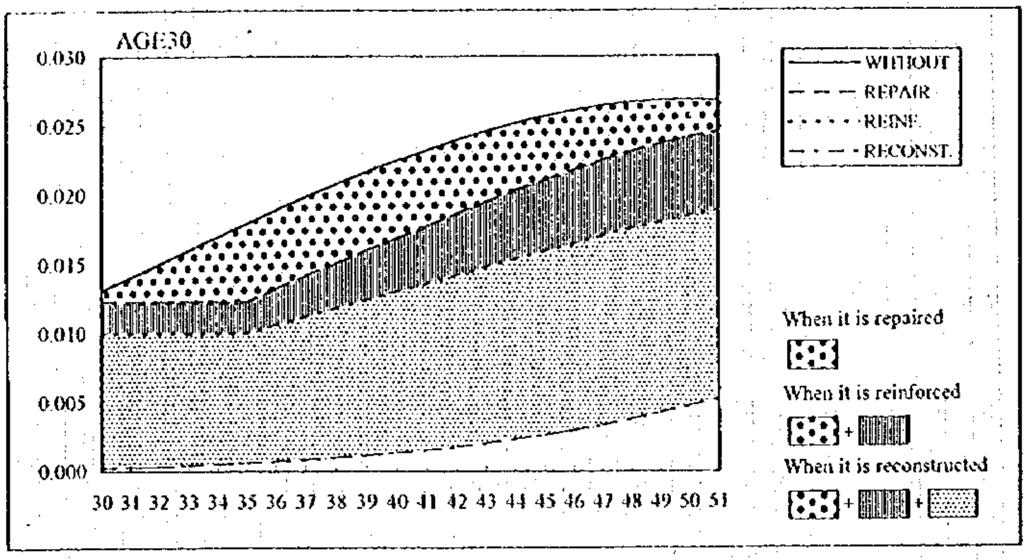


Figure 3.14.1 Probability Function for Comparison of Reduced Damages

(3) Cost

The economic cost of the designated rehabilitation is estimated by factoring 76% to the financial cost. Months of work in rehabilitation are also approximated. Annual maintenance cost is assumed at 1% of the rehabilitation and put in 20 years after the work is over.

(4) Conditions

- Traffic growth

A 5.7% per annum which is also used for benefit stream. If ADT exceeds 5,000 vehicles, the rate of 4.7% is adopted

- Large truck conversion

The percent composition of large trucks (3 axles and more) are very small at about 1% according to traffic data. Savings estimated by converting 2 axle trucks to larger ones are considered minimal, and not taken in the benefits.

(5) Economic Benefits

Benefits are composed of 1) savings in VOC resulted from smooth flow of traffic because of widening and 2) savings in VOC to be realized by the rehabilitation which would not require the traffic to detour the longer and poor conditioned road.

- Widening

It is common the traffic in one direction on the one lane bridge need to stop letting the traffic on another directio to pass through. When the existing one-lane bridge is replaced or reinforced to have 2 lane width, traffic will have smooth movement with no need of waiting and queuing. The benefits is measured. In this case the traffic can reduce the VOC when they travel the widened bridge, and the VOC per km is estimated to be less by 30% after the widening.

- Savings in VOC

When the bridge is damaged, traffic is supposed to run the detour route during the rehabilitation period. The running would have higher cost because of large and worse conditions. Under the circumstance VOC per km is estimated higher by 30% on the detour route.

When the rehabilitation work is over, the traffic can travel the normal route and realize the travel at less VOC. The balance of travel cost between the detour route and the normal route is measured as the savings (benefits) generated by the rehabilitation work.

(6) Results

Results of the calculation are summarized in Table 3.14.1. Each group showed justifiable return figures. There are some bridges with lower return values even in the first priority group. Main reasons are high cost caused by difficult natural conditions, small traffic, etc. However, it is concluded those are in minor numbers and there would be no need to restructure the groupings. The phased program of the master plan is recommendable.

Table 3.14.1 Summary of Economic Evaluation

Group	Nos. of Bridges	Tot. Fin. Cost Rs million	Tot. Econ. Cost Rs million	Averaged EIRR %	Economic NPV 12% Rs million	Economic B/C ratio 12%
1st	35	778.5	576.3	21.46	2.36	1.97
2nd	35	334.8	254.4	35.91	3.08	3.80
3rd	30	246.4	187.3	14.62	-0.01	1.40
Total	100	1359.7	1018.0	24.46	1.72	2.44

3.14.3 Financial Study

(1) Budgetary Expenditures of RDA

Expenditures of RDA during 1990-94 are studied. The total amount in 1990 was Rs 1155 million while it was Rs 2651 million in 1994. Expenditures were not stable in these years. The expenditure distribution in 1995 can be assumed as in Table 3.14.2 by reviewing the data of RDA.

Table 3.14.2 Estimated Expenditures, 1995

(Rs million in current prices)

	Rehabilitaion Invest.			Routine Maintenance			Admin.	Total
	Roads	Bridges	Total	Roads	Bridges	Total		
Rs mill	1856	212	2068			318	212	2651
(%)	(70)	(8)	(78)			(14)	(8)	(100)

(2) Forecast Expenditures up to 2010

It is evident the routine maintenance of bridges was included in 'roads'. However, bridge rehabilitation plan will develop as suggested in this master plan, certain amount should be allocated in 'bridge maintenance'. Thus a 2% is taken into consideration in Table 3.14.3.

Assuming the percent distribution in 1995 is stable over the coming years, the expenditures of RDA can be figured out in Table 3.14.3. Annual in crease of the amount is set at 5% per annum up to 2005 and 4% beyond that year by taking into account the growth trend of GDP.

Table 3.14.3 Forecast Expenditures of RDA, 1995-2010

(Rs million in prices of 1995)

Year	Rehabilitation Invest.			Routine Maintenance			Admin.	Total
	Roads	Bridges	Total	Roads	Bridges	Total		
Distrib.	0.70	0.08	0.78	0.12	0.02	0.14	0.08	1.00
1995	1856	212	2068	265	53	318	212	2651
1996-00	10482	1198	11680	1797	299	2096	1198	14975
Aver/Yr	2096	240	2336	359	60	419	240	2995
2001-05	11842	1353	13195	2030	338	2368	1353	16917
Aver/Yr	2368	271	2639	406	68	474	271	3383
2005-10	13062	1493	14555	2239	373	2612	1493	18660
Aver/Yr	2612	299	2911	448	75	522	299	3732
1996-2010 Total	35386	4044	39430	6066	1010	7076	4044	50552

(3) Bridge Rehabilitation Plan

The overall rehabilitation plan is composed by the 100 bridges of this master plan study and other 153 bridges. The other 153 bridges are the estimated number of bridges waiting for rehabilitation including North and North-East provinces. Table 3.14.4 is the summary of bridges, cost and implementation periods for the 253 bridges. The other 153 bridges is the estimated number of bridges requiring rehabilitation, but not recognized by inventory surveys, including those in North and North-East provinces.

The total cost of 253 bridges is estimated at Rs.3,445 million which is divided into three periods. The largest amount in the first period is caused by the programme to reconstruct those subject for urgent works.

Table 3.14.4 Rehabilitation Plan of 253 Bridges

(Cost in Rs million, 1995 Prices)

	Initial 100 Bridges		Secondary 153 Bridges		Total 253 Bridges	
	Nos	Cost	Nos	Using the Av. Cost	Bridges in number	Cost
	a	b	c	d	h	i
1996-00	35	779	51	695	86	1474
2001-05	35	335	51	695	86	1030
2006-10	30	246	51	695	81	941
Total	100	1360	153	2085	253	3445

(4) Budget and Master Plan Cost

Table 3.14.5 presents the budget scale and the cost of bridge rehabilitation. The budget estimated for bridge rehabilitation in Rs.4,044 million, while the estimated cost is Rs.3,445 million. The table shows a surplus of Rs.599 million in the total of 3 periods. It should be noted the surplus amount would change after thorough inventory surveys are completed in other bridges of 4,066.

Table 3.14.5 Budget Estimate and Rehabilitation of Bridges

(Rs million in 95 prices)

Year	Estimated Budget for Bridges	Bridge Rehabilitation Cost			Surplus or Shortage
		Initial 100 Br.	Secondary 153 Br.	Total 253 Bri.	
	a	b	c	d=c+b	e=a-d
1996-00	1198	779	695	1474	-276
2001-05	1353	335	695	1030	323
2006-10	1493	246	695	941	552
Total	4044	1360	2085	3445	599

(5) Other Bridges

According to the program of RDA, more than 4,000 bridges are subject of ongoing inventory filing. They are assumed to be managed by routine maintenance. If the inventory filing is completed including those in North and North-East provinces, there will be some which need rehabilitation, enforcing to restructure the rehabilitation plan for 253 bridges. Then the budget scale estimated would be much insufficient if this enlarged rehabilitation plan is implemented. Different options to adjust before the budget scale and the estimated cost should be explored at the earliest time.

(6) Summary of Recommendations

- Master Plan for Overall Bridges, 1996-2010

Table 3.14.6 Summary of the Master Plan

	Budget	Estimated Cost	Balance
Rehabilitation (1996-2010) in Total	4,044	3,445	599
Routine Maintenance (1996-2010) in Total	1,010	38	972

- The rehabilitation plans for 100 bridges classified in 3 stages are assessed in economic viewpoint. The grouped plan showed the average return of 24% which are well in the justifiable range.

- The estimated budgetary allocation Rs.4,044 million for bridge rehabilitation works seems enough for covering the cost of Rs.3,445 million under the current estimate.

- When the ongoing inventory survey of bridges over 4,000 by RDA is completed with findings of more bridges need of rehabilitation, the cost would become larger. Budgetary allocation should be reviewed to balance the budget and cost.

- Routine maintenance system should be established with an allocation of 2% of RDA's budget. The allocation would cover the cost of maintenance center/section and material/transport and other routine activities.

- Whenever RDA reviewes plans to update road network programmes, bridge rehabilitation plan should be reviewed and adjusted to be consistent with road rehabilitation/improvement programme. Periodic review of adjustment is recommended.

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