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JAPAN INTERNATIONAL COOPERATION AGENCY
ROAD DEVELOPMENT AUTHORITY
MINISTRY OF HEALTH, HIGHWAYS
AND SOCIAL SERVICES

MASTER PLAN STUDY ON BRIDGE DEVELOPMENT IN THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

FINAL REPORT

VOLUME I

SUMMARY

JULY 1996

JAPAN BRIDGE & STRUCTURE INSTITUTE, INC., TOKYO
PACIFIC CONSULTANTS INTERNATIONAL, TOKYO

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CURRENCY EQUIVALENT

(As of 13 th October, 1995)

US$1.00 = J. Yen 101.40

US$1.00 = Sri Lanka Rupees 52.05

Rs. 1.00 = ¥1.95

PREFACE

In response to a request from the Government of the Democratic Socialist Republic of Sri Lanka, the Government of Japan decided to conduct the Master Plan Study on Bridge Development in Sri Lanka and entrusted the study to the Japan International Cooperation Agency (JICA).

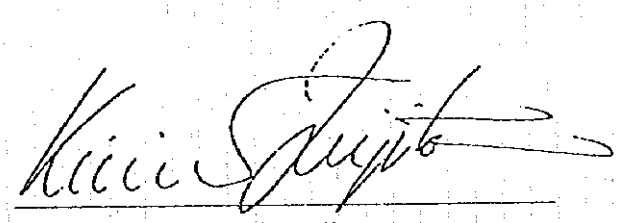
JICA sent to Sri Lanka a study team headed by Mr. Hiroshi Namba from Japan Bridge & Structure Institute, Inc., three times between March 1995 and May 1996.

The team held discussions with officials concerned of the Government of Sri Lanka, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

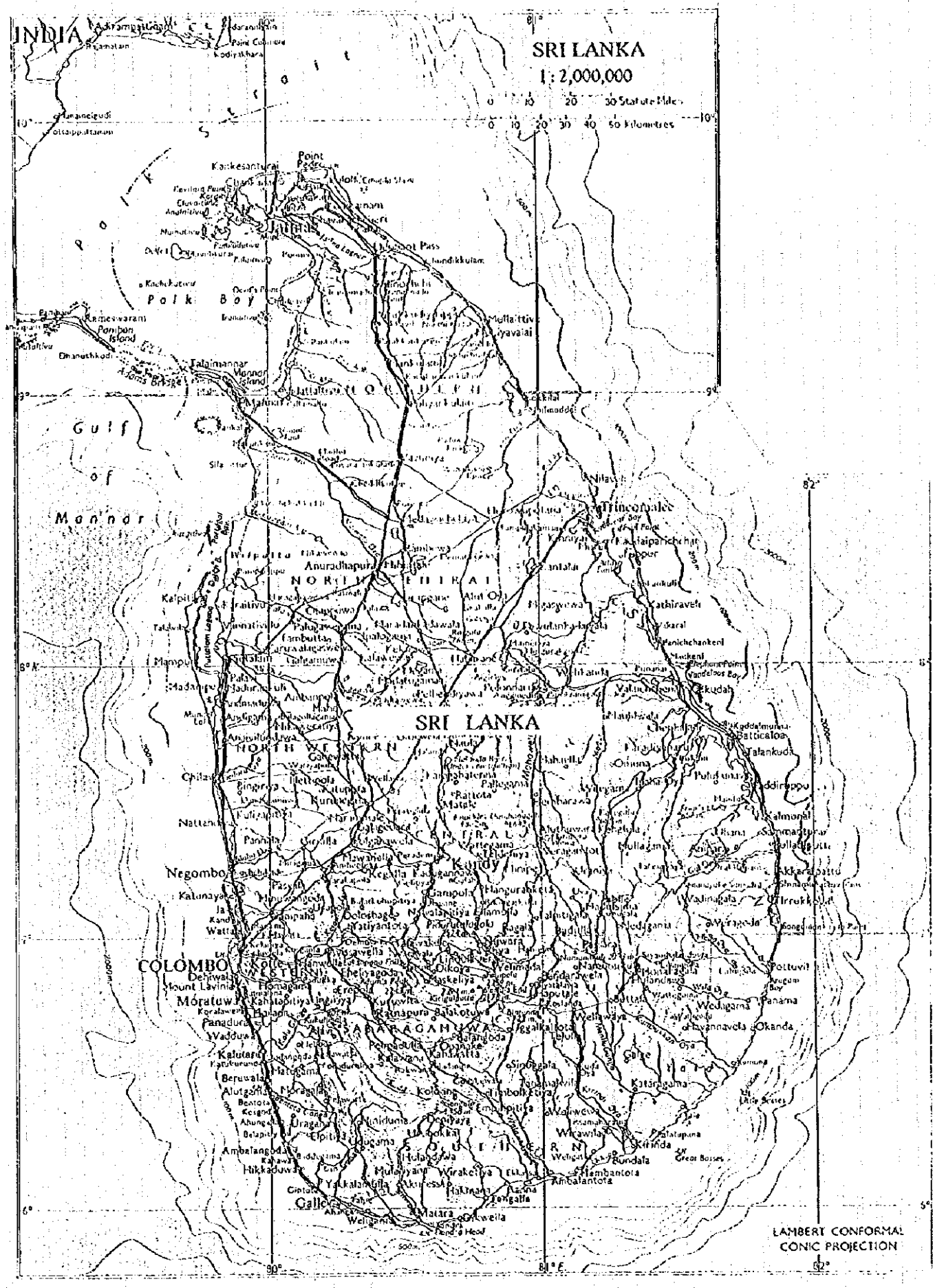
I wish to express my sincere appreciation to the officials concerned of the Government of Sri Lanka for their close cooperation extended to the team.

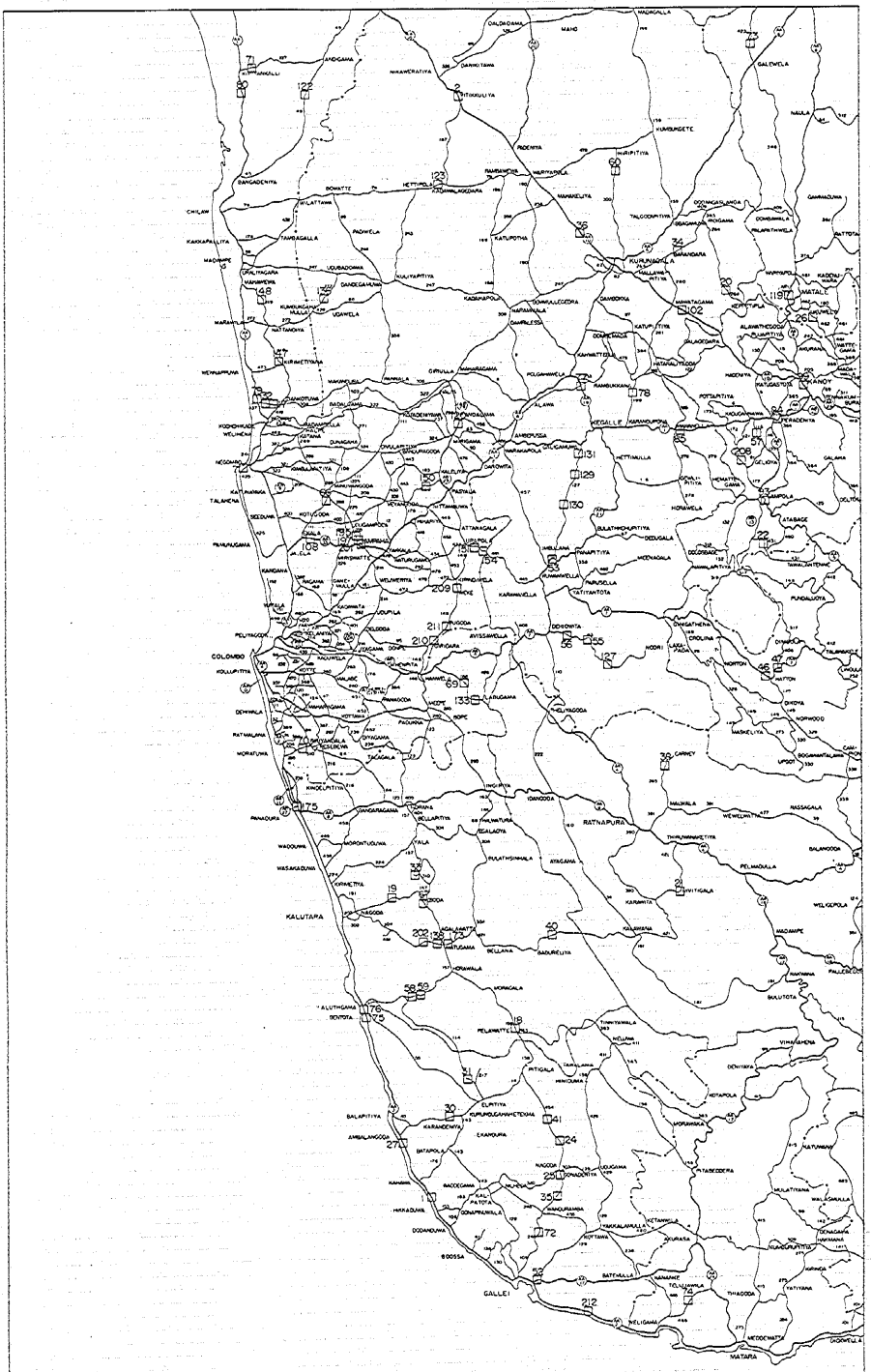
July 1996



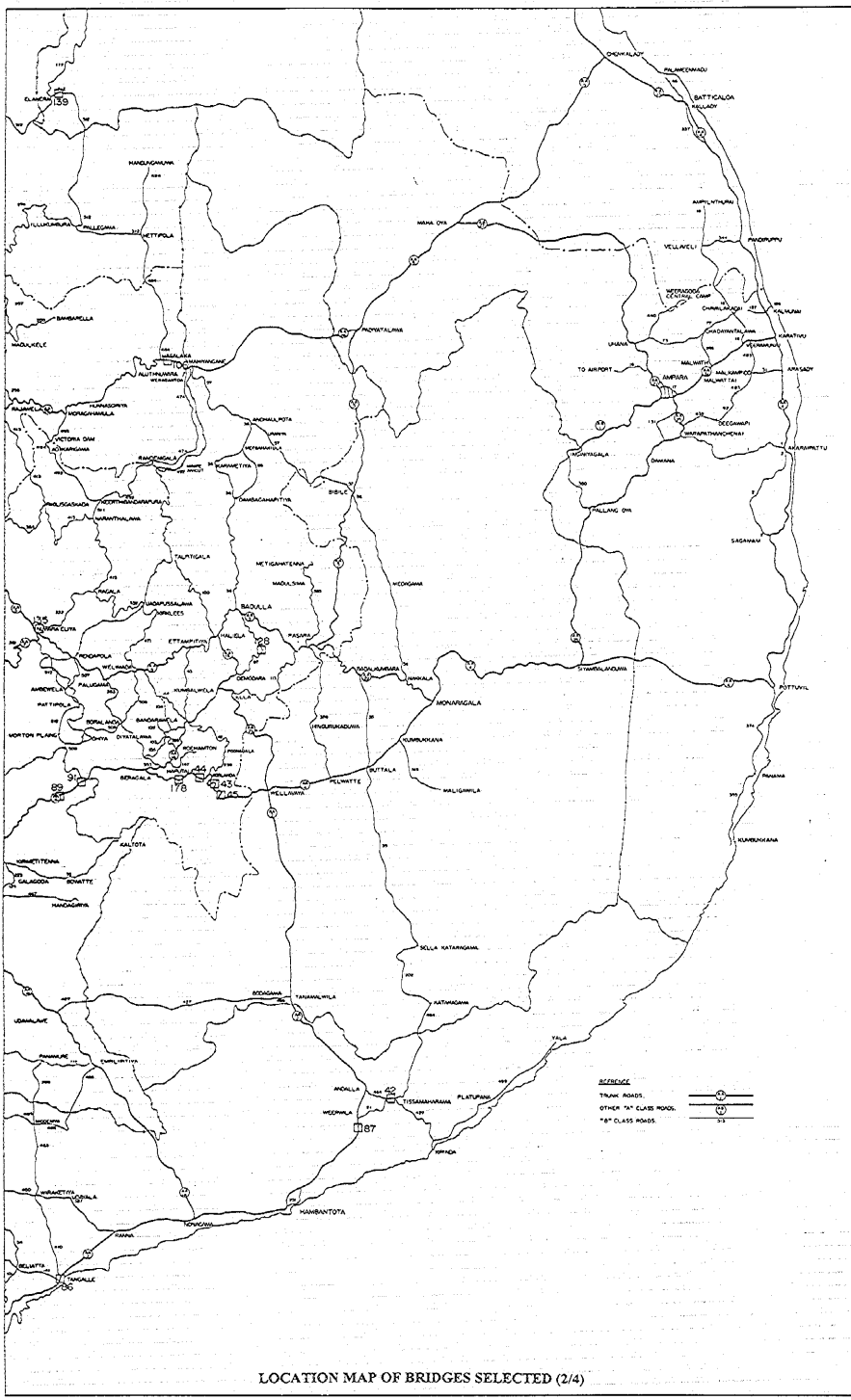
Kimio Fujita
President
Japan International Cooperation Agency

LOCATION MAP

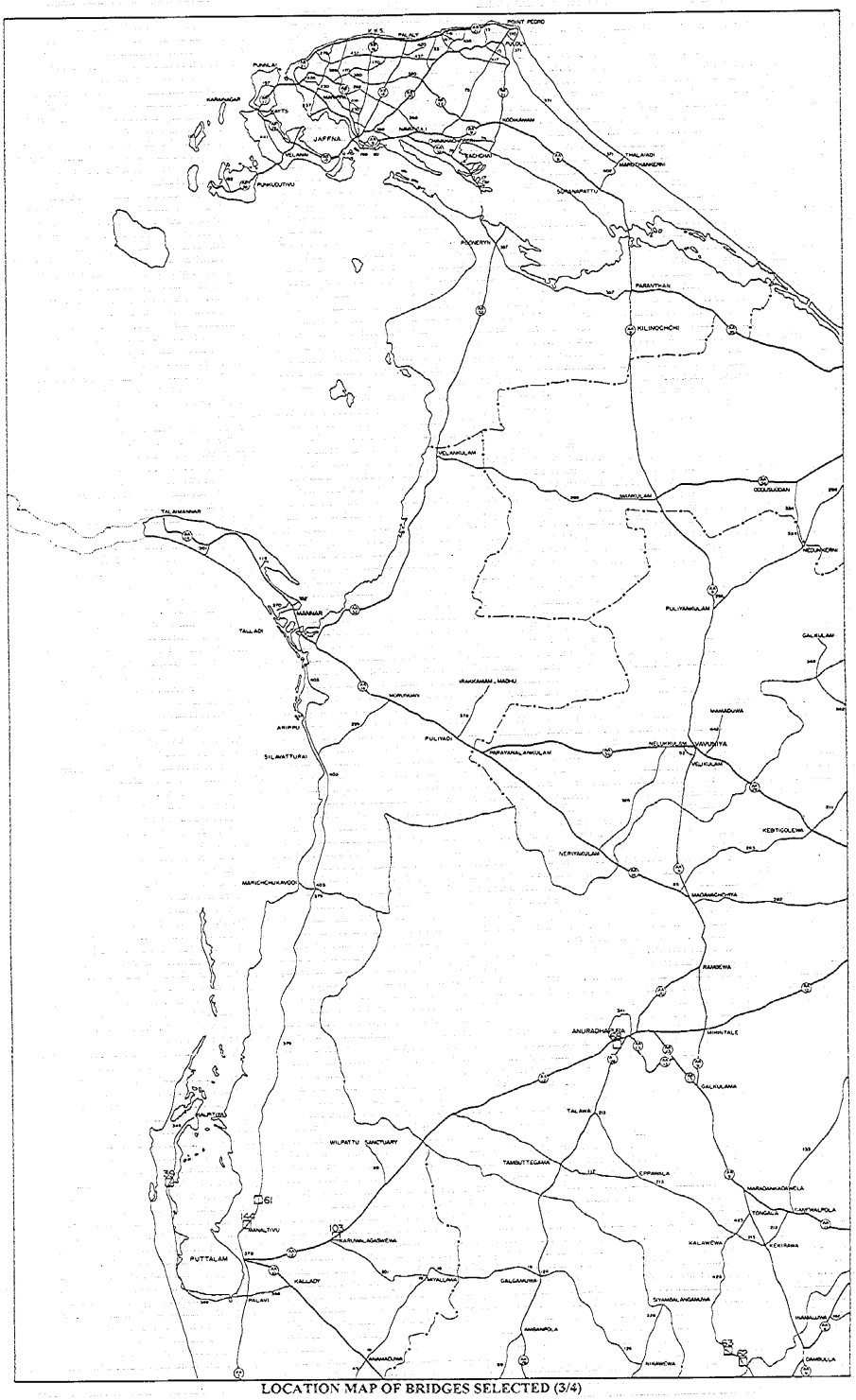




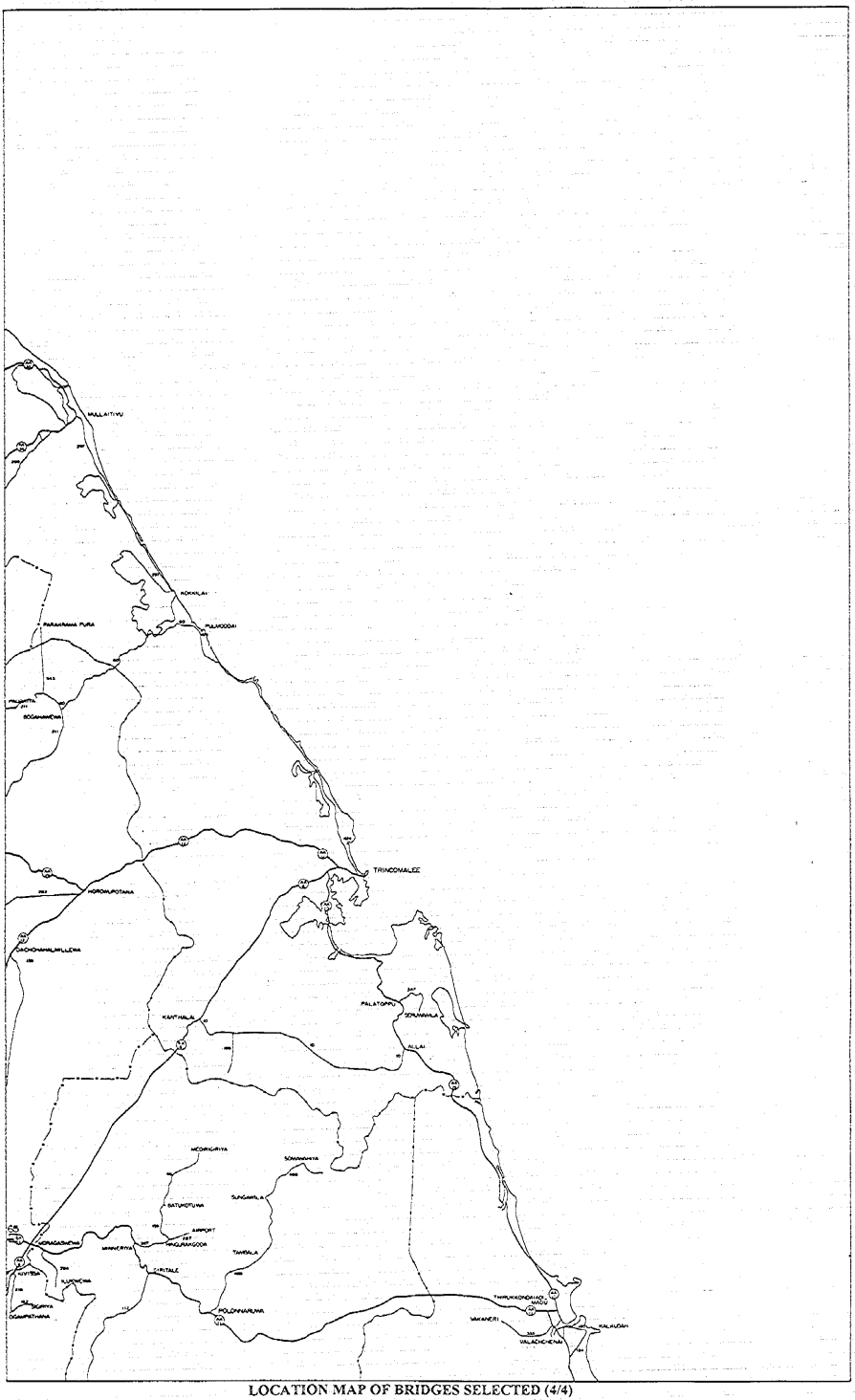
LOCATION MAP OF BRIDGES SELECTED (1/4)



LOCATION MAP OF BRIDGES SELECTED (2/4)



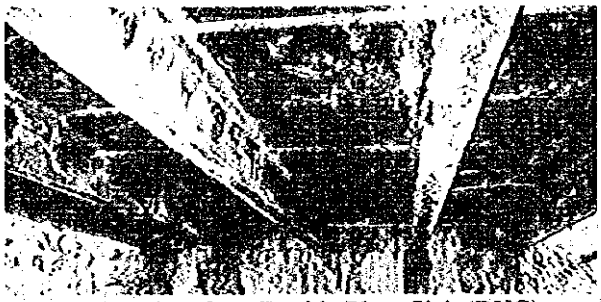
LOCATION MAP OF BRIDGES SELECTED (3/4)



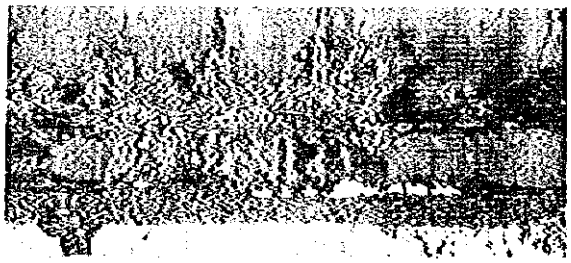
LOCATION MAP OF BRIDGES SELECTED (4/4)

PHOTOS

1. Steel Bridge

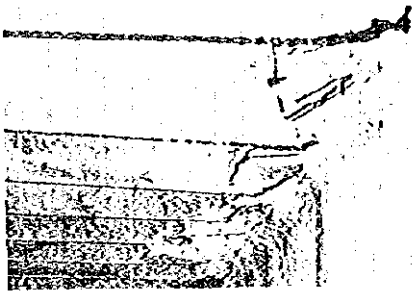


Free Lime from Buckle Plate Slab (BUC)

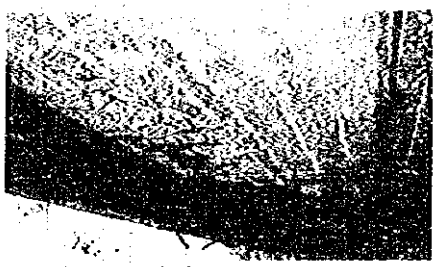


Corrosion on Main beam

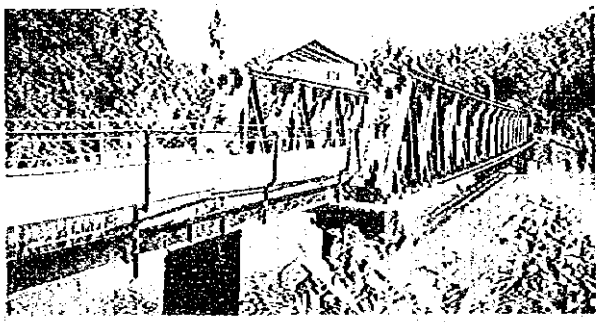
Rust on Main beam



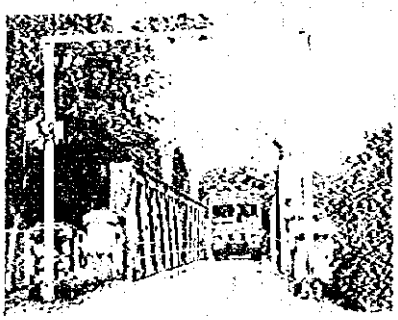
Corrosion on Corrugated Plate Slab (COR)



Crack and Reinforcement exposure on Reinforced Concrete Slab (RCS)



Remarkable Deflection of Main Chord of Pony Truss



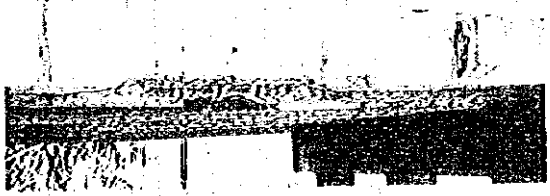
Narrow Width

Water Stagnation

2. Concrete Bridge

General View

Damage on Reinforced Concrete Beam (RCB)



Flaking of Cover Concrete on RCB

Flaking of Cover Concrete on Prestressed Pretensioned Concrete Beam (PSC/PRE)

Crack on Reinforced Concrete Box Culvert (RC/BOX)

3. Arch Bridge

General View

Scouring of Foundation on Stone Arch Bridge (ARCH/ST)

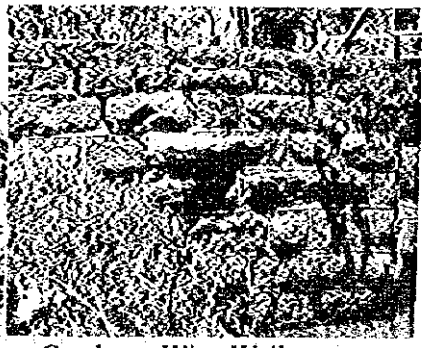
Vegetating on Brick Arch Bridge (ARCH/BR)

4. **Substructure**

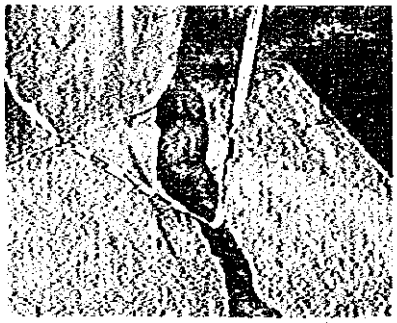
Scouring of Foundation in Beginning Stage

Loose Stone on Wing Wall

Cracks on Abutment

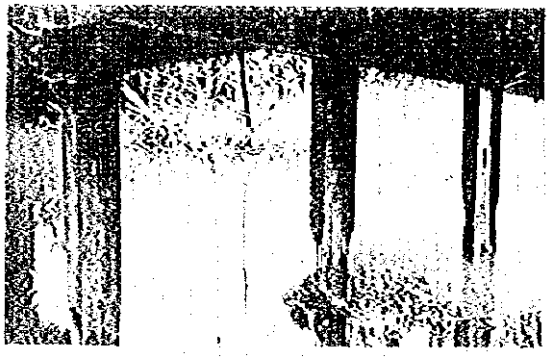


Cracks on Wing Wall



Major Crack on Brick Abutment

Scouring of Foundation



Corrosion on Additional Rolled Steel Joist (RSJ) Pier constructed later

Cracks on Concrete Pile

Master Plan Study on Bridge Development
in
The Democratic Socialist Republic of Sri Lanka

Study Period: March 1995 - July 1996
Counterpart Agency: Road Development Authority
Ministry of Health, Highways,
and Social Services

Executive Summary

1. Background of the Study

Road system is the most dominant transportation mode in Sri Lanka for both passenger and freight. Traffic surveys show that roads carry as high as 82% of the total passengers and 90% of the total freight in the country, and it is expected that also in the next decade the role of roads will be increased.

Since independence from Britain, Sri Lanka was given various assistance from developed countries including Japan for their infrastructure improvement. Road maintenance, therefore, had been started nationwide. However, although there is a lot of bridges which need to be repaired urgently, only 20% have been repaired and others remain untouched due to budget limitations and engineering aspects. These decrepit bridges are a serious hindrance to providing a larger and better network. Without repairing these bridges, further economic growth in Sri Lanka can not be expected.

2. Objectives of the Study

The Study aims at formulating a master plan for improvement and rehabilitation of bridges on A routes and selected bridges on B routes and preparing for the bridge inspection, maintenance and rehabilitation guideline.

3. Summary of the Project

3-1 Basic Conception

Most of the bridges can not withstand the loads of heavy commercial vehicles which have been increasing recently with socio-economic development. And there is a lot of bridges which have serious damages.

The improvement of the bridges are programmed in the Public Investment and carried out by RDA, however, it can not cope with the demand of traffic to promote regional development.

Therefore, in consideration of the present traffic condition and future development

trends, it is necessary to find a solution to improve and rehabilitate the bridges urgently.

This Study focused that the bridge development should be carried out by the year of 2010.

3-2 Studies on Bridges

This master plan was prepared on 100 bridges of which economic analysis was carried out. And the Guideline for Bridge Inspection, Maintenance and Rehabilitation was prepared to introduce how to manage all bridges in Sri Lanka considering the maintenance of bridges and technology transfer.

There are about 4,430 bridges on national trunk roads of A and B-class. 206 bridges were judged to need urgent rehabilitation and tabulated in the list by RDA. And out of these bridges, 101 bridges were selected based on the S/W and on the consideration that these bridges should summarize all bridges in Sri Lanka. Assessment applied in the Study is roughly divided into two categories; preliminary inspection on the 101 bridges and detailed survey on 10 bridges. However, one bridge which needs no rehabilitation was excluded from the 101 bridges.

The 10 bridges were selected from the Bridge Inventory made based on the preliminary inspection. Each of 10 bridges is representative bridge for preparing various rehabilitation plan, and all of them do not need to be urgently reconstructed.

3-3 Contents of the Project

The 100 bridges which need to be rehabilitated were selected and divided into 3 groups based on the priority of rehabilitation which was determined considering function of roads, traffic volume and damage degree of the bridges. Project Implementation Programme was prepared in accordance with the priority of rehabilitation as follows:-

First group	:	35 nos. of bridge	1996 - 2000 year
Second group	:	35 nos. of bridge	2001 - 2005 year
Third group	:	30 nos. of bridge	2006 - 2010 year

The contents of the bridge rehabilitation project are shown in Table-1.

Table-1 Summary of Rehabilitation Plan for 100 Bridges (unit: nos.)

	First Group (1996-2000)	Second Group (2001-2005)	Third Group (2006-2010)	Total
Repair	8	5	10	23
Reinforcement	11	26	15	52
Reconstruction	16	4	5	25
Nos. of Bridges	35	35	30	100

4. Project Cost

The project cost for 100 bridges divided into 3 groups is shown in Table-2.

Table-2 Project Cost for Rehabilitation of 100 Bridges

(Rs.million in 1995 price)

	First Group (1996 - 2000)		Second Group (2001 - 2005)		Third Group (2006 - 2010)		Total	
	Local	Foreign	Local	Foreign	Local	Foreign	Local	Foreign
Repair	12.9	24.8	3.3	6.3	1.5	2.9	17.7	34.0
Reinforcement	37.8	72.4	39.3	75.4	42.1	80.7	119.3	228.4
Reconstruction	216.3	414.3	72.2	138.3	40.9	78.3	329.4	630.9
Total	778.5		334.8		246.4		1,359.7	
No. of Bridges	35		35		30		100	

The budget for rehabilitation of bridges are figured out Rs.4,044 million for the years 1996 - 2010, which may cover the project cost for rehabilitation of 100 bridges subjected in the Study.

The total number of bridges managed by RDA are about 4,430. Therefore, the study results needed to be extended to these bridges, and it was assumed that 253 nos. of bridges needed rehabilitation. Table-3 shows the grouping of the 253 bridges and cost summary.

Table-3 Rehabilitation Plan of 253 Bridges (Rs. million in 1995 price)

	First Group (1996-2000)	Second Group (2001-2005)	Third Group (2006-2010)	Total
Initial 100 Bridges	779	335	246	1,360
Secondary 228 Bridges	695	695	695	2,085
Total	1,474	1,030	941	3,445
Nos. of Bridges	86	86	81	253

When the bridge rehabilitation cost of Rs.3,445 million is compared to the budget estimated, it appears a shortage of Rs.276 million in the first period while the surplus of Rs.599 million is calculated for the year of 1996 - 2010. It should be noted the surplus amount would change after through bridge inventory surveys are completed in other bridges of 4,066. Allocation of fund for bridge rehabilitation works should be reviewed by RDA.

5. Project Evaluation

This project is evaluated as feasible based on the results of economic evaluation, technical studies and environmental examination.

5-1 Economic Evaluation

Economic evaluation of each bridge rehabilitation plan is conducted by a routine process of calculation 'with and without project'. However, the bridge damage which will happen in the future can not be determined because bridge history file is not found.

Under the circumstances, the probability function of bridge unusable damage is developed for each rehabilitation category and for each priority group. Vehicle operation cost is estimated in economic terms and integrated in the vehicle travel cost with and without project, to which the probability of bridge damage is applied.

Results of the calculation are summarized in Table-4. 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 programme of the master plan is recommendable.

Table-4 Summary of Economic Evaluation

	First Group (1996-2000)	Second Group (2001-2005)	Third Group (2006-2010)	Total (1996-2010)
Average EIRR %	21.5	35.9	14.6	24.5
Evaluation B/C ratio in 12%	1.97	3.08	1.40	2.44
Economic NPV Rs.million 12%	2.4	3.1	0.0	1.7

5-2 Environmental Examination

Initial Environmental Examination for 10 bridges detailed-surveyed concluded that the Environmental Impact Assessment will not be required if appropriate countermeasures are taken for estimated environmental impact.

On the other hand, according to the results of scoping for other 90 bridges, 80 bridges will have certain impact to the environment, and therefore consideration should be given to them. The environmental examination items to be considered are as follows:-

- Relocation of Residents and Right of Way
- River-use
- Traffic Jam (vehicles and pedestrians)
- Others (remains, cultural assets and scenery)

It is necessary to carry out the Initial Environmental Examination for the 80 bridges and to examine the considerations for the improvement plan and traffic control during construction.

6. Recommendations

1) Need to prepare bridge inventory which covers all bridges and to plan maintenance and rehabilitation programme
2) Need to prepare own Manual for Bridge Inspection, Maintenance and Rehabilitation by RDA
3) Need to establish a solid organization for bridge management in Engineering Service Division, RDA
4) Neet to allocate budget for bridge management
5) Need to adjust relations between road network development plan

VOLUME - I

SUMMARY

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Table

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Sri Lanka built up their economy based on the exportation of tea, coconut, rubber, etc. to Western countries and the Middle East during the British Dominion Era. Further, transportation of those goods between plantation and port had stimulated the development of a domestic transportation network.

Of the national transportation system in Sri Lanka, roads are the most dominant transportation mode for both passenger and freight. Traffic surveys show that roads carry as high as 82% of the total passengers and 90% of the total freight in the country, and it is expected that also in the next decade the role of roads will be increased.

Since independence from Britain, Sri Lanka has been given various assistance from developed countries including Japan for their infrastructure improvement. Road maintenance, therefore, had been implemented nationwide. On the other hand, there are a lot of bridges which need to be repaired urgently. However, only 20% have been repaired, and others remain untouched due to budget limitations and inexperienced engineering. These decrepit bridges are a serious hindrance to provide a larger and better road network. Without repairing these bridges, further economic growth in Sri Lanka can not be expected.

Under these circumstances, the Government of Sri Lanka (GOS) asked the Government of Japan (GOJ) for their assistance in January, 1990, and GOJ carried out the Project Formation Study in February, 1993 to investigate and analyze the needs of these bridge projects. As a result, GOJ decided to conduct the Master Plan Study on Bridge Development in the Democratic Socialist Republic of Sri Lanka and entrusted the Study to Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of technical cooperation programme of GOJ.

JICA dispatched a Preparatory Study Team to Sri Lanka from 28th November to 11th December, 1994. Accordingly, JICA and RDA concluded and signed the Scope of Work (S/W) and the Minutes of Meeting (M/M) on 8th December, 1994. Subsequently JICA organized an Advisory Committee and selected a Study Team organized by the Consultants of Japan Bridge & Structure Institute, Inc. (JBSI) and Pacific Consultants International (PCI) in March 1995, which has conducted the Study.

The Study Team was dispatched to Sri Lanka on 30th March, 1995 and the Study officially commenced with the submission of the Inception Report to discuss and confirmed with GOS on the approach and methodology of the Study together with the Study schedule.

The Study was completed in July, 1996 with the submission of the Final Report.

1.2 Objectives of the Study

The principle objectives of the Study were two fold:-

(1) To formulate a master plan for bridge rehabilitation for all bridges on A routes and some selected bridges on B routes by the year 2010.

(2) To prepare guidelines for maintenance and rehabilitation by Sri Lankan authorities.

In addition to the above, the Study includes providing practical training to Road Development Authority (RDA) counterparts in various engineering aspects.

1.3 Scope of the Study

The Study covers 100 bridges which were selected from the List of 206 Bridges prepared by RDA. The Study also includes all bridges on A class roads and some bridges on B class roads which need to be rehabilitated urgently to prepare guideline for a implementation of maintenance and rehabilitation manual for Sri Lankan authorities use.

The Study carried out in the whole of Sri Lanka (except the north and east areas) includes; collection and review of related data, preliminary inspection on 100 typical bridges, detailed survey on 10 typical bridges including loading test on 3 bridges, formulation of the master plan for bridge rehabilitation with cost estimate and economic analysis for the 100 bridges, and preparation of the guideline.

The Study was carried out in 3 phases from March 1995 to June 1996. Figure 1.1 shows the major work items of the Study and their interrelationship.

1.4 Composition of the Report

The final report consists of four volumes as listed below:

- Volume I Summary
- Volume II Main Text
- Volume III Appendices
- Volume IV Drawings

In addition to the above, the bridge inspection sheet, bridge inventory on the 100 bridges, preliminary environmental examination sheet on the 100 bridges were prepared as a separate volume and submitted to RDA in the beginning time of Phase 2. And maintenance and rehabilitation manual was also prepared as a separate volume and submitted to RDA.

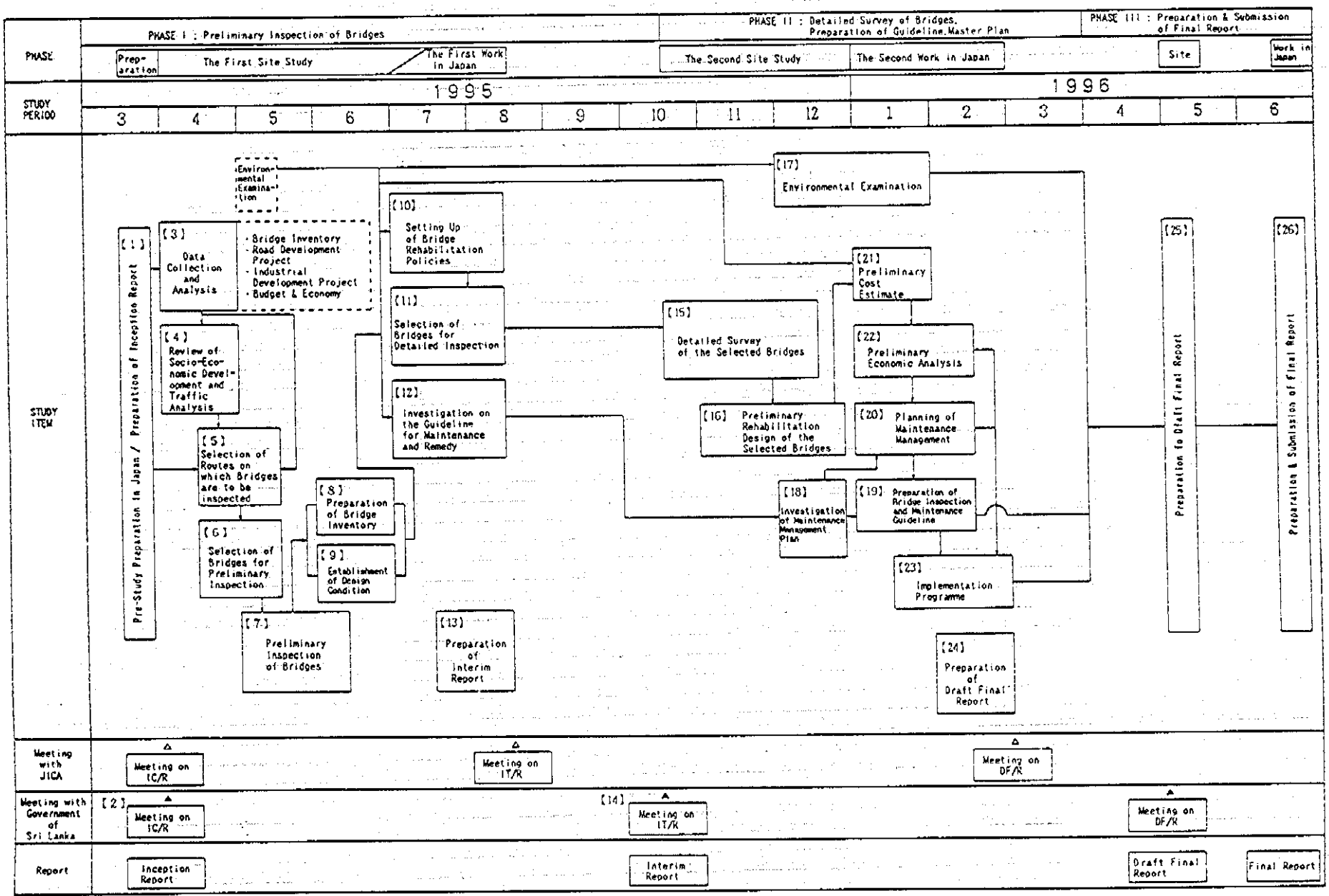

Figure 1.1.1 Flow Chart of the Study

CHAPTER 2 CONCLUSION AND RECOMMENDATIONS

2.1 Conclusion

2.1.1 Bridge Master Plan

(1) Studies on Bridges

The number of existing bridges on national trunk road (A-class road and B-class trunk road) in Sri Lanka is about 4,430. 206 bridges out of 4,430 were judged as candidate bridges for the Study by RDA, and 101 bridges were then selected for Study based on the S/W.

Assessment methods applied in the Study are broadly divided into two categories; preliminary inspection on 101 bridges and detailed survey on 10 bridges.

Of which 100 bridges were selected and studied from various engineering viewpoints. Traffic forecast passing those bridges were conducted to recognize the traffic demand on major corridors. A rate of 5.7% per annum was estimated as a general tendency of road traffic growth in the coming years.

Main results of the preliminary engineering surveys are summarized as in the following:

1) Member Condition of Each Main Structure

- Deck and main frame have suffered severer deterioration than other members do, such as abutments piers and wing walls.

2) Bridge Condition of Each Bridge Type

- Steel girder such as RSJ/BUC and RSJ/COR was found to be the most defective bridge.
- Truss bridge requires some weep holes on lower chord to prevent corrosion caused by water stagnation.
- Some of PSC/PRE have inadequate concrete cover for PC tendons at the soffit of beam.

3) River Hydrological Survey

- Generally, many abutments which were built in old days jutted out into the river in Sri Lanka. Retaining walls are used to

cover back-filling instead of wing wall. However, the foundation of the retaining walls is not so strong, and there are many large cracks caused by scouring or settlement.

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

- Slope protection of the river bank should be given to the front of abutment and surrounding area because the water level changes substantially. Embankment will be scoured unless this protection is carried out.

4) Structural Survey

- The cover of PC tendons at the soffit of PSC/PRE was inadequate and many flakings due to construction deficiencies were observed. In the new specification by RDA, the cover is changed from 25mm to 50mm.

- The Schmidt hammer test revealed, each concrete member has adequate compressive strength compared with a design strength.

5) Full Scale Bridge Loading Test

- The loading test has that steel girder bridge acts like a half-composite beam and some load distribution action by deck slab can be expected.

- PSC/PRE beam which is standard in RDA has an adequate lateral load distribution action without any transverse direction prestressing.

6) Environmental Examination

- An Initial Environmental Examination revealed that there was no necessity to carry out an Environmental Impact Assessment because an estimated environmental impact could be reduced by some countermeasures for the impact.

(2) Determination of Rehabilitation Priority

Prior to the preliminary rehabilitation design, rehabilitation priority was determined considering function of roads, traffic volume and damage degree of bridges.

The 100 bridges are grouped into 3 stages with priority order. In each stage,

the rehabilitation are categorized into repair, reinforcement and reconstruction. They are in Table 2.1.1 through Table 2.1.3.

Table 2.1.1 Connection between Function of Roads and Damage Degree of Bridge

Function of Road		Damage Degree of Bridges				
Road by Priority	Traffic Volume	4.0	3.2	3.0	2.4 to 2.0	under 2.0
1st	Over 5,000 veh./day	1,175	-	27,66,70, 75,108,120, 197	76,79,84, 85,99,195, 201	-
2nd	more than 3,000 veh./day	32,86,202, 212	119	17,47,93, 102,123, 151,154	36	46,106
3rd	more than 2,000 veh./day	91	78,80	52,65,77, 89, 147,148, 173,209	138,211,216	-
4th	more than 1,000 veh./day	7,18,20,33, 129,150	34,40,42, 44,87,178	19,26,30, 39,57,131, 135,136	2,43,45,58, 59,103,130	-
5th	less than 1,000 veh./day	31,35,38, 61.62,63, 68,72,122, 128,144,208	21,24,55,56, 74,127,133	25,41,67, 69	53,60	22,71,73
under going or planned		139				
Sub- Total		25	16	34	20	5

The priority of road section was determined based on the importance of the road function. The road function (which is for lows) was selected in the order of five ranking groups considering connection of provincial capitals and district centers and places of national importance.

The Damage Degree of Bridges (Rating) (which is for columns) shown in Table 2.1.1 indicates overall evaluation for bridges.

Table 2.1.2 Bridge Rehabilitation by Priority

	4.0	3.2	3.0	2.4 to 2.0	under 2.0
1	2	-	7	7	-
2	4	1	7	1	2
3	1	2	8	3	-
4	6	6	8	7	-
5	12	7	4	2	3
other	-	-	-	-	-
sub-total	25	16	34	20	5

Note: : first priority = 35 nos.

: second priority = 35 nos.

: others = 30 nos.

Table 2.1.3 Summary of Rehabilitation Plan for 100 Bridges

	Re pair		Rein forcement		Reconst ruction	
	Nos.	Cost	Nos.	Cost	Nos.	Cost
Group 1	8	37.7	11	110.2	16	630.6
Group 2	5	9.6	26	114.7	4	210.5
Group 3	10	4.4	15	122.8	5	119.2
Total	23	51.7	52	347.7	25	960.3

(in Million Rs. of 1995 Price)

(3) Conceptual Design for Rehabilitation

1) Conceptual Designs

- The conceptual engineering design of rehabilitation of selected 10 bridges were conducted to determine the standard methods of rehabilitation and typical costs which could be used for the cost estimate of similar type of works.

- Furthermore, since it was necessary to define a certain standard in order to diagnose a load carrying capacity of each bridge, analytic assessment applying TL-20 live load was carried out for all steel girder bridges (RSJ) which account for 50 percent of all studied bridges. The assessment revealed that all the bridges were inadequate to carry TL-20 load and 8 bridges should be replaced by a new bridge.

- Based on the above assessment results as well as the inspection results, each defect was picked up from viewpoints of material deterioration, load carrying capacity, bridge function and hydraulic adequacy. Thereafter, a suitable rehabilitation plan was selected for each of the 90 bridges.

- The summary of the rehabilitation methods for the 100 bridges is shown in Table 2.1.4.

2) Cost Estimate

- The summary of the rehabilitation cost for the 10 bridges is shown in Table 2.1.5.

Table 2.1.5 Summary of Rehabilitation Cost for the 10 Bridges

	Bridge No.	Financial Cost
Repair	53, 7, 212	32.2
Reinforcement	85, 59, 20, 70, 211	51.7
Reconstruction	77, 33	486.7

(in Million Rs. of 1995 Price)

Table 2.1.4 Summary of Rehabilitation Plan for 100 Bridges

	1st Priority			2nd Priority		Others		Total	
	Reconst I	Reconst II	Reinf & Repair	Reconst	Reinf & Repair	Reconst	Reinf & Repair	Reconst	Reinf & Repair
RSJ/BUC RSJ/T RSJ/COR ┌ l= 3.7m ┐ RSJ/RCS │ ≀ │ RSJ/DEC └ l= 10.5m ┘ RSJ/DEC	8 175. 33. 18 38. 144. 31 32. 35	1 119	7 20. 150. 108 78. 70. 68 120	4 77. 148. 44 52	18 40. 195. 17 102. 151. 154. 65 89. 147. 173. 21. 24 55. 56. 74. 127. 133 209	4 36. 131. 25 58	12 106. 138. 211 210. 2. 59. 30. 39 57. 135. 136. 67	17	37
ST. TR/T/RCS ST. TR/T/DEC ┌ l= 9.3m ┐ ST. TR/T/COR │ ≀ │ ST. TR/D/COR └ l= 51.0m ┘ ST. TR. T. BUC	3 122. 33. 72	-	5 66. 80. 128 197. 75	1 77	8 76. 79. 99 93. 34. 42 178. 21	- 	5 130. 19 26. 53. 69	4	18
ARCH/S [l= 22.8m]	-	-	-	-	1 84	-	-	-	1
BAILEY ┌ l= 18.3m ┐ │ ≀ │ └ l= 33.5m ┘	-	-	3 208. 202. 61	-	-	-	1 22	-	4
RCB ┌ l= 3.8m ┐ RCS │ ≀ │ RC/BOX └ l= 9.7m ┘	1 1	-	2 7. 91	-	1 123	-	3 41. 103. 73	1	6
PSC/PRE ┌ l= 4.9m ┐ PSC/POS │ ≀ │ └ l= 16.2m ┘	-	-	4 7. 86. 212 68	-	1 87	-	1 71	-	5
┌ l= 2.6m ┐ CAUSEWAY │ ≀ │ └ l= 3.7m ┘	-	2 62. 63	-	-	-	1 60	-	3	-
ARCH/BR ┌ l= 3.6m ┐ ARCH/CO │ ≀ │ ARCH/STO └ l= 17.2m ┘	1 129	2 119. 27	-	-	4 85. 47. 209 201	-	3 46. 43. 45	3	7
Total nos. of bridge types (Total nos. of bridges)	13 (12)	5 (4)	21 (19)	5 (4)	33 (31)	5	25	28 (25)	79 (75)

Note: Reconst I means reconstruction which is required by the damages.
Reconst II means reconstruction which is required by the stress check.

- The costs studies in the 10 bridges are applied to estimate the rehabilitation costs for 100 bridges which are summarized in Table 2.1.6 afterward. It shows the total cost of Rs. 1,410 million in 1995 prices.

Table 2.1.6 Project Cost (Million SLR)

Construction Cost		1,044
Engineering Cost	Detailed Design	63
	Supervision	42
Administration		2
Contingency		209
Total		1,360

(in Million Rs. of 1995 Price)

(4) Economic Evaluation and Financial Analysis

The economic evaluation using three economic parameters: EIRR, NPV and BCR was carried out for individual bridge and for the whole project covering 100 study bridges. The project covering 100 bridges was divided into the following three packages in accordance with the priority of rehabilitation plan described in Table 2.1.2.

First group	:	35 nos. of bridge	1996 - 2000 year
Second group	:	35 nos. of bridge	2001 - 2005 year
Third group	:	30 nos. of bridge	2006 - 2010 year

The summary of economic evaluation is shown in Table 2.1.7. Although there are some differences amount the values of average internal rate of return for each package, the internal rate of return is about 25% as a whole. A few bridges have shown less than 12% in the return calculation where reasons are small volumes of traffic or larger costs of the rehabilitation plan. However, those can be reviewed in the next feasibility study stage. The grouping can be recommendable from viewpoint of economic evaluation.

Table 2.1.7 Summary of Economic Evaluation

Group	Nos. of Bridges	Financial Cost Tot. Rs. million	Econ. Cost Tot. Rs. million	Average EIRR %	Economic NPV Rs.mill. 12%	Evaluation B/C ratio in 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	1,359.7	1,018.0	24.46	1.72	2.44

(5) Conclusion

- Most of the study bridges have suffered various distress or damages and some of them are in critical condition.

- Those bridges can be improved by standard repairing, strengthening works or reconstruction.

- The 100 bridges grouped into 3 packages in priority order are studied in economic analysis and found the grouping is justifiable.

2.1.2 Maintenance System

(1) Organization, etc.

Engineering Services Division in RDA has 4 sections including Bridge Design Section which is responsible for designing new bridges. In the Traffic & Planning Section there are some staff who do review the existing bridges and prepare rehabilitation plans of damaged bridges. They have file records of bridges but not yet completed in covering the whole bridges under RDA.

Implementation of bridge rehabilitation plan is in charge of Maintenance Management and Construction Division who manages field works with local offices.

The expenditures of RDA allocated to bridge investment are found which has increased at a rate more than input on 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 shown not separately. It means bridge maintenance works are mixed in road management in the past.

(2) Establishment of New Section 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 in Engineering Services Division and should gather up all staff related to bridge plan and maintenance programme at the beginning years.

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

(3) Guideline

For establishment of the manual for bridge inspection, maintenance and rehabilitation the guideline is prepared in a separate file.

2.1.3 Financial Aspect

(1) 4,430 Bridges Maintenance by RDA

RDA has been carrying out a data base filing of all bridges which RDA administers on A and B routes expected to be completed by March, 1996. Since the results of the above data base could not be used in the Study, the assessment for all 4,430 bridges was made based on the study results of selected 100 bridges.

The grouping of the RDA's overall bridges are in Table 2.1.8 where the completed bridges in the past years since 1980 are included together with the 100 bridges, 153 bridges and 4,066 bridges. While it is thought majority of those 4,066 bridges are in fair conditions and coverable by routine maintenance, the classification may be restructured when the data base filing is completed.

Table 2.1.8 Estimation to 4,430 Bridges

Group	First Priority		Second Priority	Third Priority	Sub Total	No Defects	Total
	Reconstr.	Others					
'80	66				66		66
'90	45				45		45
This Study	12	23	35	30	100	3,551	3,651
Not Surveyed	17	34	51	51	153	515	668
Total	86	57	86	81	364	4,066	4,430

Note) '80 means the numbers of bridge which was reconstructed in 1980's
'90 means the numbers of bridge which was reconstructed or will be reconstructed in 1990's.

(2) Estimated Project Cost for 253 Bridges

The master plan in the Study is planned for the 100 study bridges, while the cost of the 153 bridges in North and North-East provinces is approximated by studies over the 100 bridges. Table 2.1.9 is the summary of 253 bridges.

Table 2.1.9 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

(3) Budget and Rehabilitation Plan

Budget with sectional distribution of RDA are assumed by using available data in the Study. In which the investment for rehabilitation of bridges can be figured out Rs.4,044 million for the years 1996 - 2010.

If the bridge rehabilitation cost of Rs.3,445 million is compared to this budgetary scale estimated, it appears a shortage of Rs.276 million in the first period while the surplus of Rs.875 million is calculated for the remaining periods, being shown in Table 2.1.10. It should be noted there remain 4,066 bridges which are waiting for thorough investigation in the similar way done for the 100 bridges. The rehabilitation cost depends on the result of thorough investigation which should be better conducted urgently by RDA.

Table 2.1.10 Budget Estimate and Rehabilitation of 253 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

(4) Other 4,066 Bridges

The remaining 4,066 bridges are thought in fair conditions manageable by routine maintenance. The budget for routine maintenance for bridges is assumed at 2% of total budget for RDA in this Study. However, it should be noted that conditions of those 4,066 bridges change every year which may need to revise the budget scale and sectional allocation of RDA. If the

ongoing data base filing of bridges by RDA is completed, it will affect the budget scale and allocation additionally.

2.2 Recommendations

(1) Need to Prepare Bridge Inventory Rapidly and to Plan Maintenance and Rehabilitation Programme

At present stage, there are many points which are uncertain regarding the background of this master plan. However, at first bridge inventory study which can give a clear technical interpretation for the defects of each bridge should be completed. And all the inspection results and maintenance and rehabilitation records should be centralized in the Engineering Services in RDA Headquarters. From a practical point of view, the most important question is apparent; how to select a suitable rehabilitation method for each bridge. In order to implement the above works, "the Guide Line for Bridge Inspection, Maintenance and Rehabilitation" will be a great help. As for its application and correct method of usage, a professional training should be carried out periodically.

And it is evident that the method, which is suggested in the Study, is only preliminary and refinement of it should be achieved in the subsequent stage in the feasibility studies, designs and implementation. Together with these experiences, a comprehensive manual should be edited and utilized by RDA.

(2) Need to Prepare Own Manual for Bridge Inspection, Maintenance and Rehabilitation

To maintain bridges in sound state, early detection and rehabilitation of damage to bridges are essential. Overlooking any abnormality or damage in the early stage will allow such damage to grow further to result in accidents.

To prevent this, it is necessary to inspect the bridges' present state correctly according to the established inspection procedure and to prepare and to assess the inspection result on the basis of recognition of the characteristics and deformation of the structure. In order to implement the works systematically by themselves, it is recommended that their own manual be prepared based on the "Guideline for Bridge Inspection, Maintenance and Rehabilitation".

(3) Need to Establish a Solid Organization and Manpower for Bridge Management

In order to implement systematic bridge inspection, maintenance and rehabilitation, it is necessary for RDA to establish a solid organization for bridge management. Because those activities will, to a considerable extent, rely on the progress in organizational, managerial and training development.

Therefore, the following aspects are recommended:

- The Engineering Services in RDA Headquarters should be responsible for bridge management.

- The Engineering Services in RDA Headquarters should establish bridge inspection and maintenance teams, and frequent personal turnovers must be avoided to keep a certain technical level on the bridge management.

- The above teams should have the authority to give a professional training to engineers of each regional office of RDA on the job.

- The trainee shall become "manpower" to deal with the actual periodical inspection, and proper filing of bridge inventory and rehabilitation record. Therefore, the training shall aim them to understand the necessity and importance of the bridge management.

(4) Need to Allocate Budget for Bridge Management

The cost needed for the bridge maintenance and management is estimated at Rs. 14.9 million per year.

The cost consists of the expense of personnel, plant, equipment and office maintenance, etc., to manage the Maintenance Center which is to be established in the Engineering Services and the Maintenance Section in each province of RDA.

The cost is well within the budget, which is 28% of the budget for bridge maintenance in the amount of Rs. 53 million (estimated) for the year in 1995.

(5) Need to Adjust Relations between Road Network Development Plans

In general, economic evaluation for bridge rehabilitation project should be carried out following to road network development plans, while the road improvement projects are still ongoing in Sri Lanka. Considering these circumstances, bridge rehabilitation plans were prepared separately from road rehabilitation plans. However, it might cause an untimely implementation of the plan. To have rational and effective development plans to be realized, each plan has to be made, checked and altered considering other development plans including national plans for development to have a balance.

In this sense, it is necessary to continue look after the progress of road improvement projects. In the meantime, a long-term development plans must be determined simultaneously covering both of roads and bridges rehabilitation plans.

CHAPTER 3 ABSTRACT OF THE STUDY

3.1 Socio-Economic Framework and Traffic Demand Analysis

3.1.1. Population

Sri Lanka has a population of around 18 million in 1995. According to the census in 1946 the population was nearly 7 million, while the latest census of 1981 showed 15 million, a growth rate of 2.2% pre annum. The growth from 1981 to 95 has been slow down to 1.3% per annum. Despite a significant slow down of growth, the population share in urban sector increased from 21.5% in 1981 to 24% in 1995. Although urban drift has been modest, there is a considerable growth of population in the western part of the country particularly suurounding areas of the metropolis. Regional population distribution and growths are in Figure 3.1.1

3.1.2. Economy

Since 1990, Sri Lankan economy showed a growth with a rate of 5.4% during 1990-94 despite various political unstabilities. It marked a 6.9% growth in 1993 which was the highest since 1979. Statistics of the economy since 1989 are in Table 3.1.1.

Table 3.1.1 Economic Development by Industrial Sector
(Rs million in 1982 constant price)

	1989	1990	1991	1992	1993	1994
1. Agriculture, Forestry & Fishing	27,666	30,011	30,570	30,090	31,554	32,593
2. Mining & Quarrying	3,576	3,901	3,511	3,300	3,693	3,915
3. Manufacturing	20,488	22,427	23,949	26,059	28,806	31,418
4. Construction	8,514	8,761	9,033	9,765	10,400	11,024
5. Services	61,485	64,144	68,141	71,776	76,330	80,319
6. GDP	121,729	129,244	135,204	140,990	150,783	159,269

3.1.3 Motorization

A total of 1 million motorized vehicles was in 1994. The ownership increased at a high rate of 15% in 1986-94, while the car ownership increased at only 4% in the same period. The largest growth in number was in motorcycles. Selected data are in Table 3.1.2. A motorization rate at the number of 4-wheel vehicles per 1000 inhabitants was 19 in 1986 and 24 in 1994. Compared to such South Asia countries as Bangladesh (1), India (4), Indonesia (16), Philippines (16) she has higher figures, while far behind from those countries as Thailand (52).

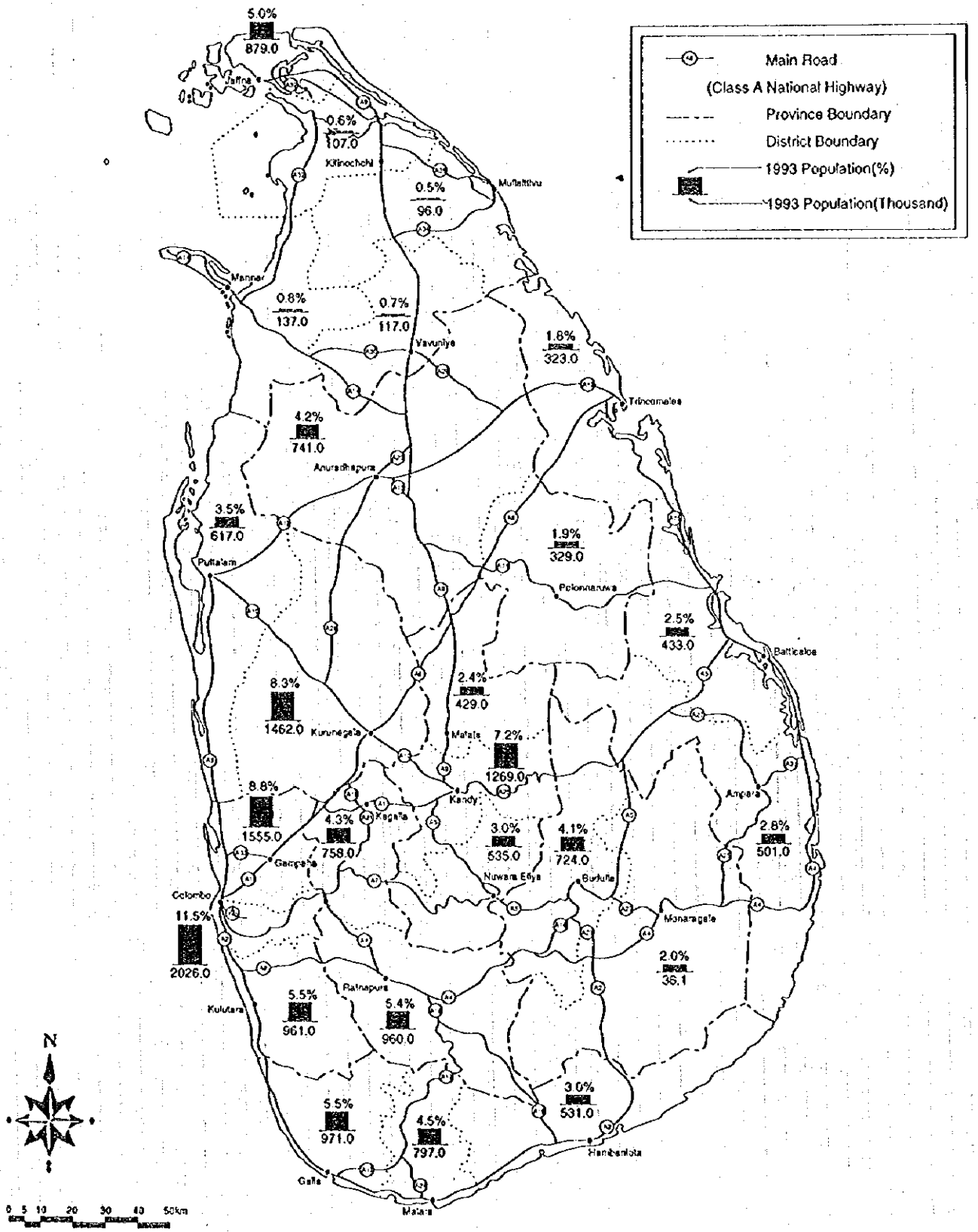

Figure 3.1.1 Regional Population Distribution, 1993

Table 3.1.2 Motorization Growth, Sri Lanka

Year	Vehicles by Type Motor Car	Buses	Trucks	Motor Cycle	Total	Total w/o MC
1986	155,224	40,214	106,067	187,717	489,222	301,505
1987	147,837	37,064	106,624	213,441	504,966	291,525
1988	155,194	37,977	111,658	240,869	545,698	304,829
1989	163,779	38,609	117,025	307,392	626,805	319,413
1990	173,519	39,147	124,959	391,732	729,357	337,625
1991	180,135	43,259	136,608	450,372	810,374	360,002
1992	189,477	46,162	151,583	516,205	903,427	387,222
1993	197,300	47,692	165,418	570,136	962546	392410
1994	210,013	51,512	180,396	606,924	1,048,845	441,921

3.1.4 Future Economic Framework

According to the Draft Public Investment Program 1995-00, which was prepared in April 1995, GDP and per capita GDP are forecast to grow at 6.9% and 5.7% respectively.

3.1.5 Future Population, GDP, and Motorization

The Department of Census and Statistics made a set of projections from which an estimate of population can be conducted. As in Table 3.1.3 the figure in 1991 was 17.3 million, which grows to 17.9 in 1995 and 19.8 million in 2005.

Table 3.1.3 Future Population 1995-2010.

Year	Population (in thousand)	Annual Average (growth rate in %)
1995	17,940	-
2000	18,830	0.97
2005	19,780	0.99
2010	20,690	0.90

GDP per capita is assumed to increase at 4% on average. Motorization data indicated more than 8% growth per annum in 1986-94, which would taper off to some extent in the future. Considering those forecast and development in other countries, the road traffic growth thus can be determined as follows

1995 2000	1.32
2000-2010	1.74
The period 1995-2010	2.30

The motorization growth is figured out in Figure 3.1.2 including data related to GDP per capita in other countries.

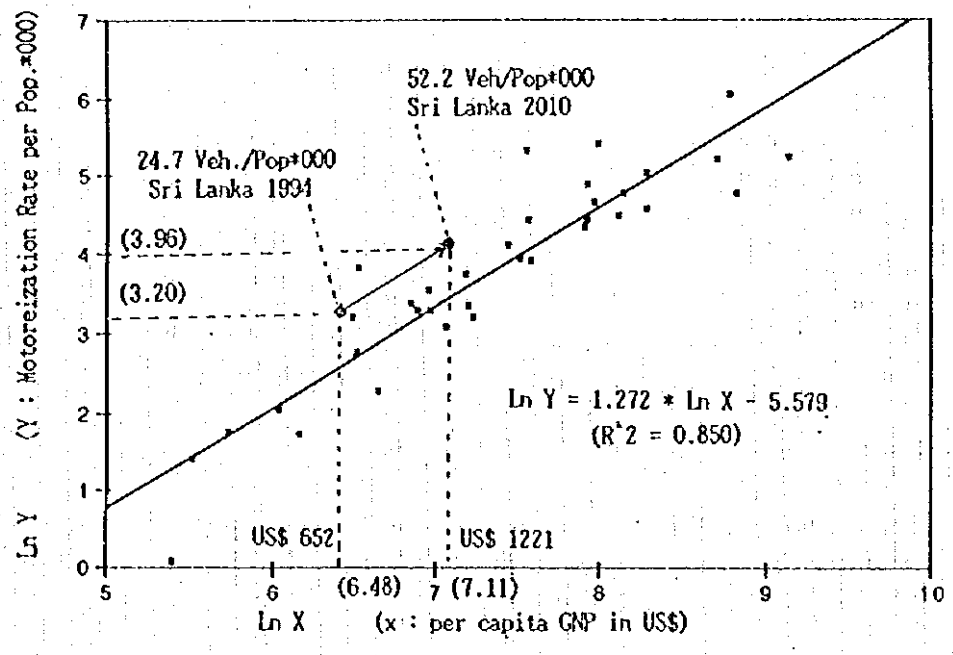

Figure 3.1.2 Relationship between Motorization and GDP per capita

3.1.6 Traffic Volumes 1995

Traffic count data are available for most of Class A and B roads in other than those of Northern and Eastern Provinces. Western Province followed by Central Province has a wide variety of stratified traffic volumes, but Uva Province has only road sections confined to small traffic volume less than 5,000 vehicles per day. The estimated 1995 traffic volumes are diagrammed in Figure 3.1.3.

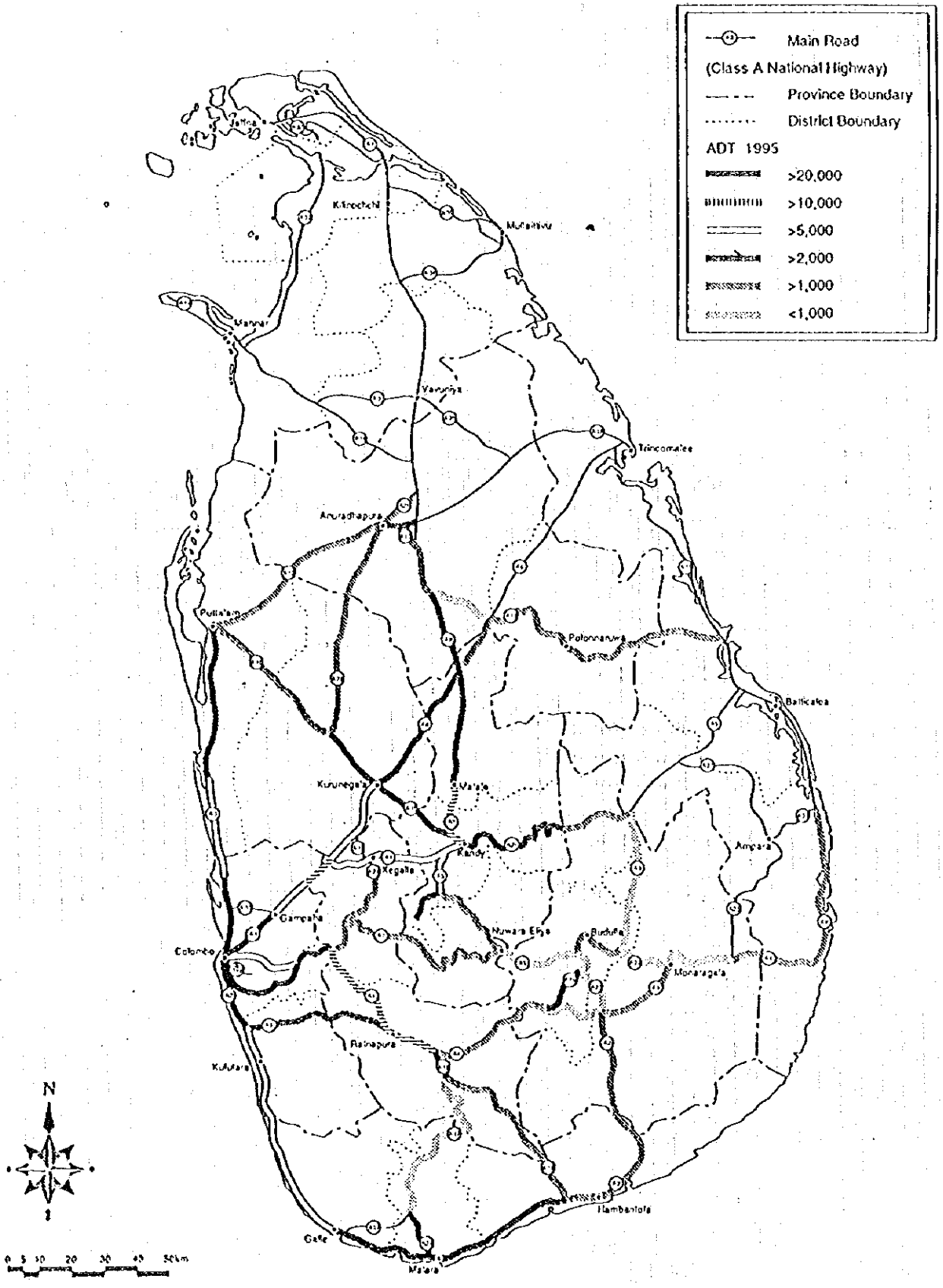

Figure 3.1.3 Estimated 1995 Traffic Volumes on Class A Roads

3.2 Route Selection for Preliminary Survey

3.2.1 Road Network

A major road network has been developed in radial directions from Colombo City. The classified roads have a hierarchical system designated as A, B, C, D, and E. In January 1990, the C, D and E class roads were handed over to the newly established Provincial Councils, while A and B class roads along with a selected set of roads providing access to places of national importance were categorized as National Highways. Presently, new Road Development Authority (RDA), who is the successor of the previous Department of Highways (DOH), manages these national Highways which adds up to a total of 11,130.96 km.

Major highway project groups are listed in Table 3.2.1 which is composed of those implemented since 1980 and others being under construction at present. They utilize various aids from foreign agencies. Several new highways and circular roads have been planned to meet the increaseing demand around the capital. The following eight highways are the examples at various stage of implementation which are in Figure 3.2.1 also.

a. Improvement of Baseline Road and Extension southwards
   - Inner Circular Highway to Colombo
b. Colombo - Katunayake Expressway (CKE)
c. Outer Circular Highway (OCH) to city of Colombo
d. Southern Highway from Colombo (OCH) to Galle and Matara
e. Highway from Colombo to Ambepussa via CKE
f. Highway from Colombo (OCH) to Ratnapura via Ingiriya
g. Highway from Colombo to Padeniya via CKE and
h. Highway from Colombo to Chilaw via CKE and 'Rata Meda Para'

Table 3.2.1 Highway Development Projects since 1980

WB 1st	1980s Completed	Rehabilitation: 200km, Periodic maint.: 200km, Bridge replace.: 40 bridges
ADB 1st	1980s Completed	Improve.: 228km, Bridge replace.: 4 bridges
WB 2nd	1980s Completed	Improve.: 292km, Bridge replace.: 22 bridges
ADB 2nd	1990 - 95 Ongoing	Improve.: 145km, Bridge replace.: 6 bridges
WB 3rd	1990 - 98 Ongoing	Improve.: 402km, Bridge replace.: 20 bridges
ADB 3rd	1994 - Ongoing	Improve.: 175km, Bridge replace.: 19 bridges
WB 4th	1995 - Ongoing	Rehabilitation: 7,000km, Bridges not finalized
OECFJ	1996 - Start soon	Baseline Rd., F/S by ODA (UK) '91, D/D ongoing
Kwuait	1995 - Start soon	Improve.: 28 bridges
OECFJ	1995 - Start soon	2nd phase of Victoria Br., Replacement
KOREA	1995 -	F/S & D/D ongoing for Katunayake - Anuradapura

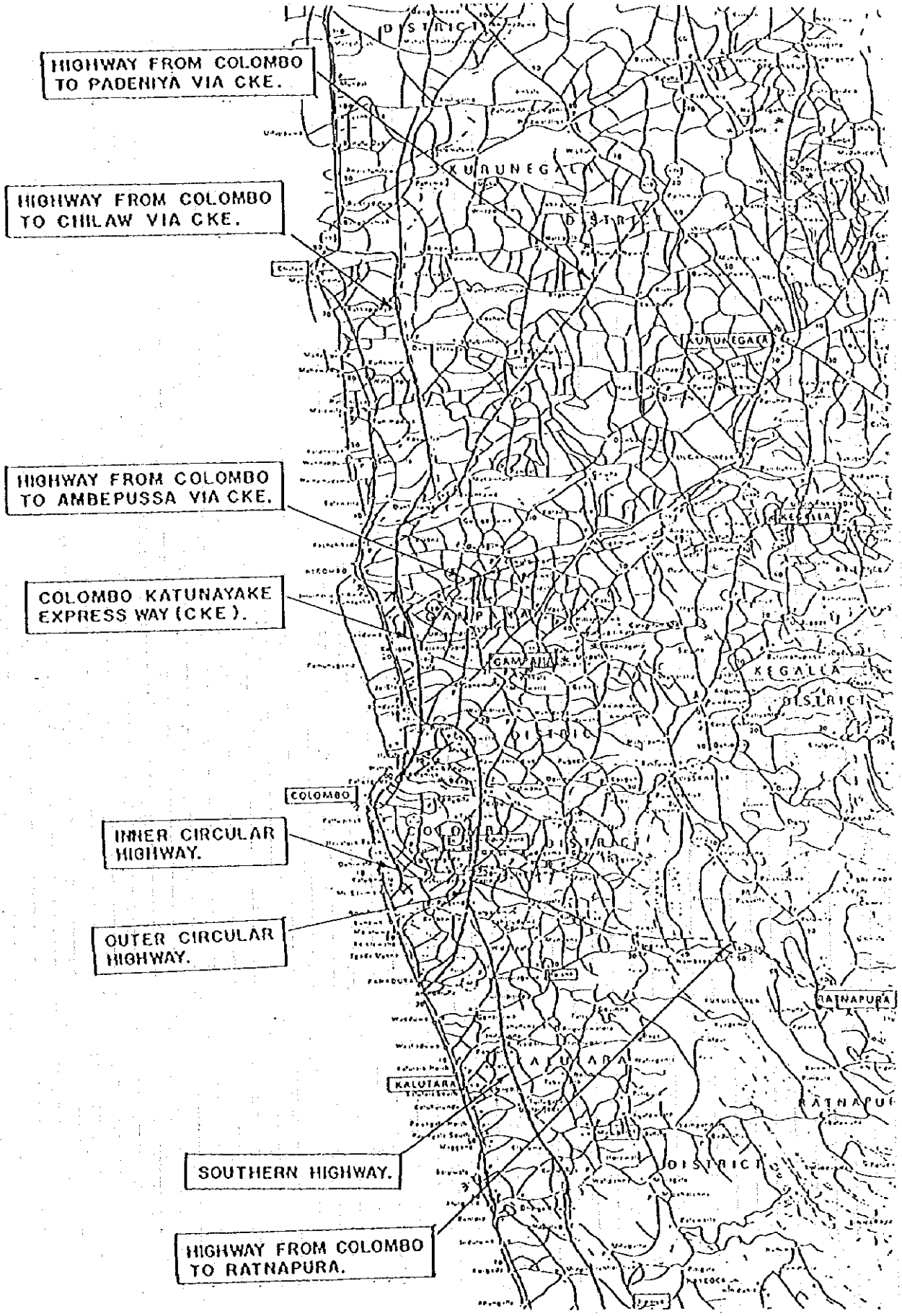

Figure 3.2.1 Locations of Priority Highway Plans

3.2.2 Urban Sectors

There are 53 Urban Authorities consisting of 12 Municipal Councils and 41 Urban Councils. There are greater numbers of small and medium sized towns. Slow rate of growth of larger towns is evident from the fact that the number of towns with population more than 50,000 increased from 5 in 1946 to 9 in 1981, while the number of towns with population between 5,000 to 50,000 increased from 25 to 94 in the same period.

Urban centers with more than 25,000 population in 1981 census are concentrated in the suburban area of Colombo. Figure 3.2.2 presents urban population distribution in 1981.

3.2.3 Route Priority

Class A and B roads are categorized as National Highways; the former connect 9 provincial capitals and 25 District Centers, and the latter is the secondary routes that connect up the network by A roads. There are other roads which link as access roads from the key urban centers to the national road network. Those are under the administration of RDA.

However, from the view point of urban centers spreading over the country and their development potentials in the future, route identifications with priority are considered necessary. In this sense traffic flows are used to classify the roads in the order with the volume. Bridge rehabilitation plans should mark this demand scale for priority determination of roads from the network.

Priority Ranking

Classification	Traffic Volume
1st	roads with ADT >= 5,000
2nd	roads with ADT >=3,000
3rd	roads with ADT >=2,000
4th	roads with ADT >=1,000 and
5th	roads with ADT < 1,000.

3.2.4 Priority Routes

Based on the previously mentioned criteria, priority road sections were selected in the order of five ranking groups. The road sections selected for a certain priority group are not necessarily connected in a reasonable manner. In order to delineate a meaningful route (road sections in continuity), sections that should be grouped into a lower ranking might be upgraded to form a coherent route. As the consequence, the priority routes for the preliminary survey (bridge rehabilitation planning) were selected. Figure 3.2.3 shows the case of National Highways.

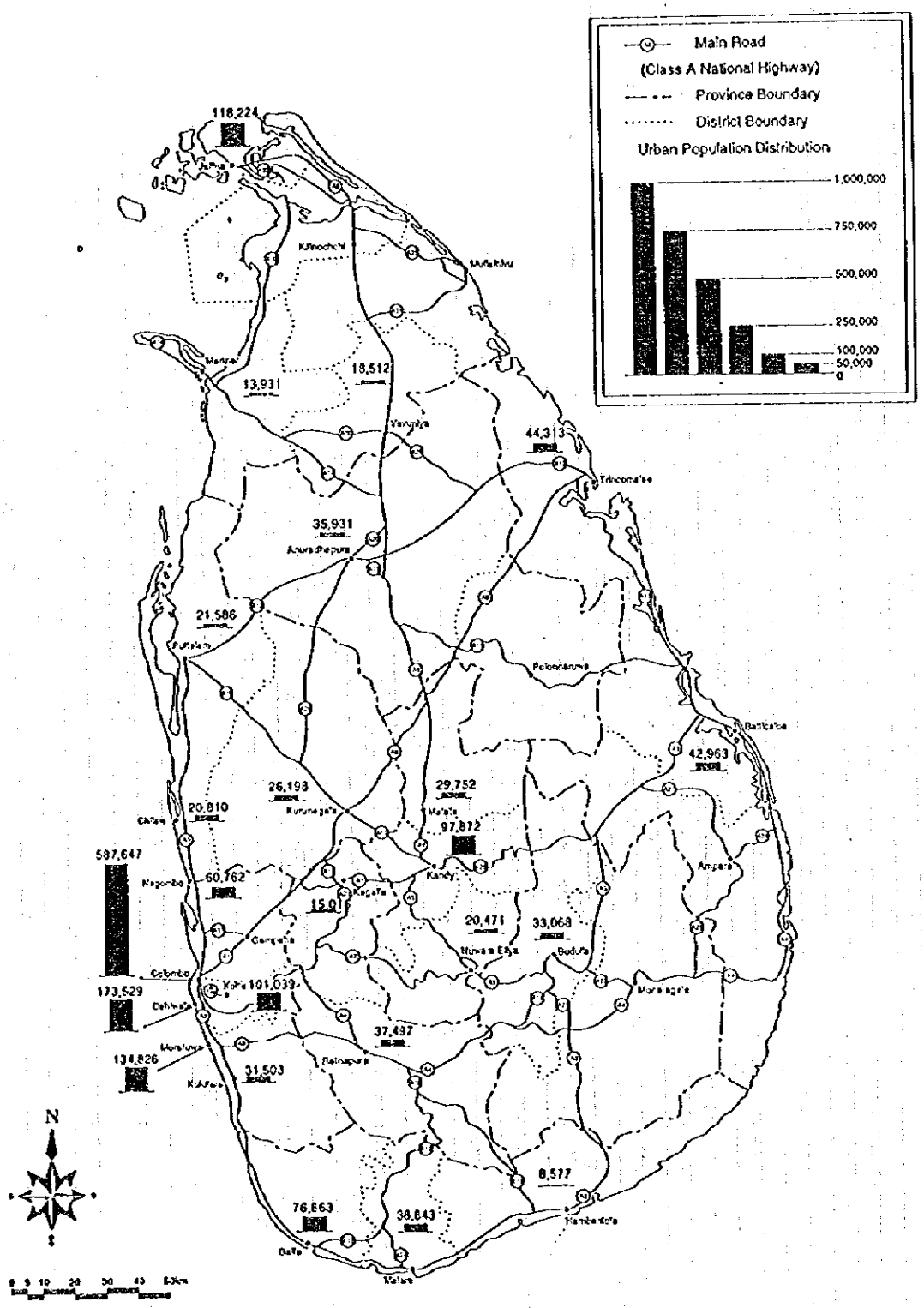

Figure 3.2.2 Distribution of Urban Population of Principal Towns in 1981

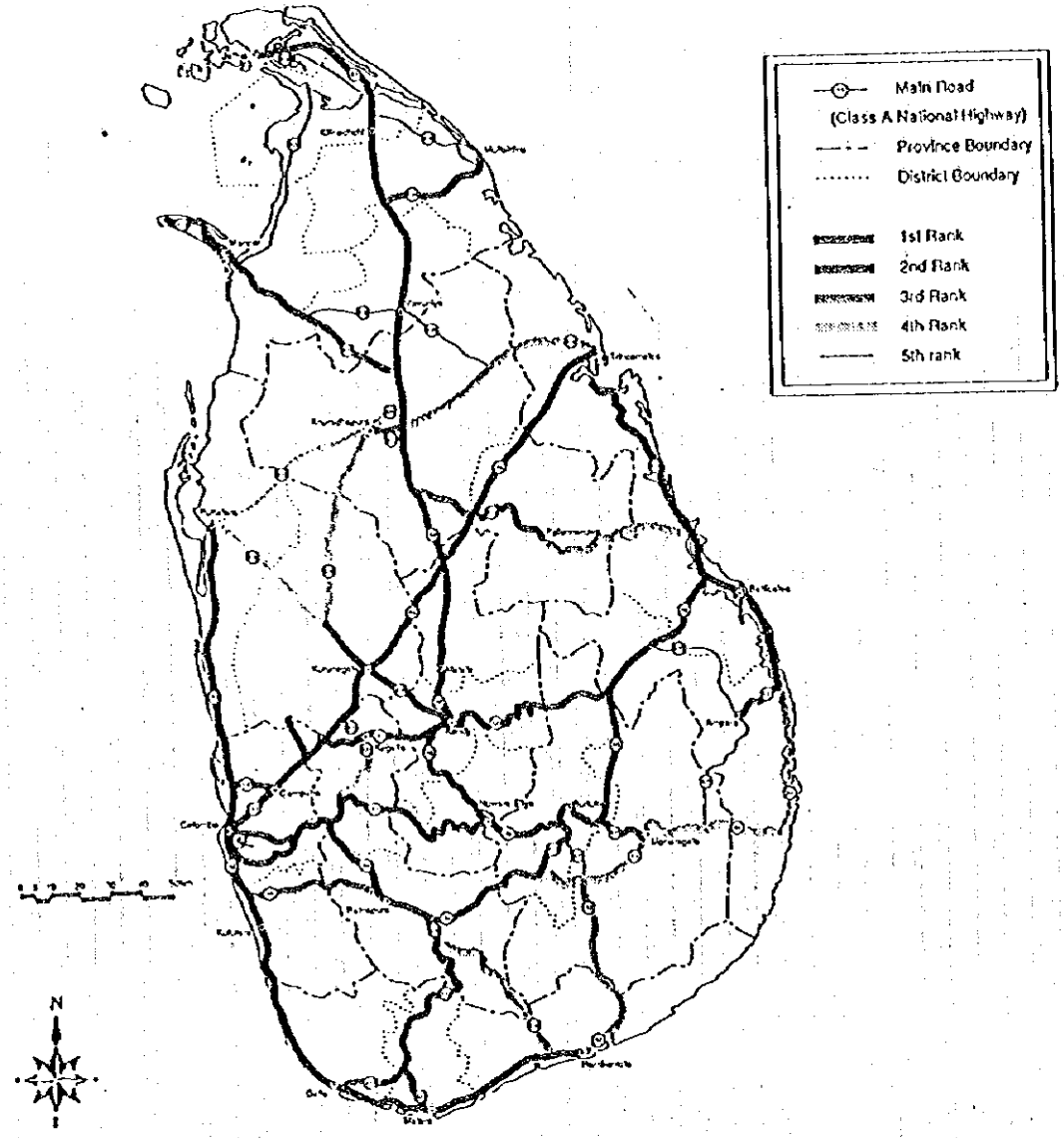

Figure 3.2.3 Priority Routes for Preliminary Bridge Survey
(National Highways Class A)

3.3 Selection of 100 Bridges for Preliminary Inspection

One of objectives of the Study is to formulate a Master Plan for improvement and rehabilitation of all bridges on A routes and some selected bridges on B routes, which need urgent rehabilitation.

Among 4,430 bridges, 1,713 nos. are on A-route, 2,717 nos. are on B-route, and in the List of 206 bridges prepared by RDA there are 86 nos. of A-route bridges and 120 nos. of B-route bridges.

The data base filing was not completed at the commencement of the Study, therefore the Study Team selected 100 typical bridges out of the List of 206 Bridges.

These 100 bridges could be representative for all the study bridges, and the inspection results on the study bridges were used to establish selection criteria for 10 bridges and to formulate a maintenance and rehabilitation programme of these 100 bridges.

3.3.1 Selection Procedure of 100 Bridges

The study bridges were selected through the following procedure:-

- Establishment of Socio-Economic Frame
- Traffic Demand Estimate and Analysis
- Investigation on Rehabilitation Priority of Routes
- Classification in various items (year of construction, type of construction, type of defect, type of proposed treatment)

And the procedure is charted in Figure 3.3.1.

3.3.2 Selection Results of 101 Bridges

It was necessary to select 101 bridges which covered all types of defects and conceivable rehabilitation plans. In addition, bridges were selected considering the following:-

- Excludes bridges which have extremely small traffic volume
- Excludes bridges which are located in northern and eastern areas
- Excludes bridges which already have been rehabilitated or planned realistically

Table 3.3.1 shows the bridge statistics in terms of bridge type for the selected 101 bridges.

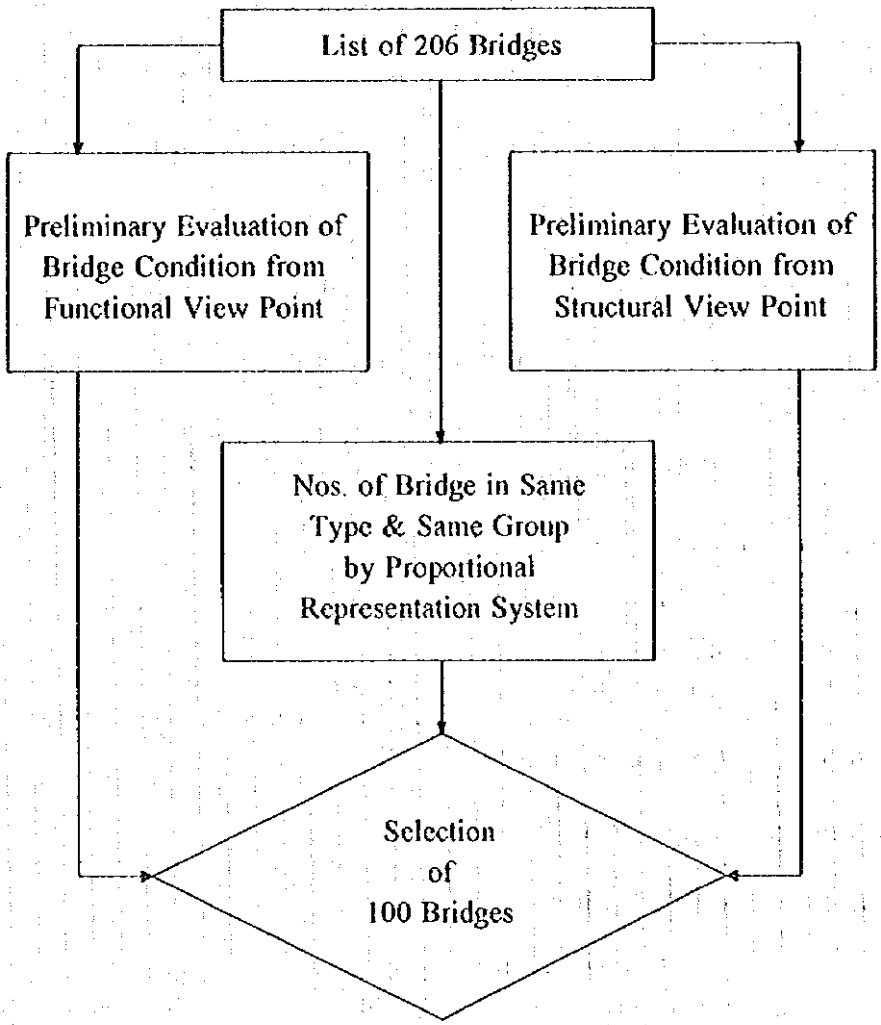

Figure 3.3.1 Selection Procedure for 100 Bridges

Table 3.3.1 Classification of Superstructure Type

Type of Bridge	No. of Bridge (%)		Type of Superstructure	No. of Bridge (%)	
Wrought Iron / Mild Steel Bridge	77	(71.3)	ST.TR/D	2	(1.9)
			ST.TR/T	20	(18.5)
			RSJ/DEC	54	(50.0)
			ARCH/S	1	(0.9)
Concrete Bridge	14	(13.0)	RCS	3	(2.8)
			RCB	3	(2.8)
			PSC/PRE	6	(5.6)
			ARCH/CO	2	(1.9)
Stone Masonry Bridge	3	(2.8)	ARCH/ST	3	(2.8)
Brick Masonry Bridge	5	(4.6)	ARCH/BR	5	(4.6)
Causeway	4	(3.7)	CAUSEWAY	4	(3.7)
RC Box Culvert	1	(0.9)	RC/BOX	1	(0.9)
Bailey Bridge	4	(3.7)	BAILEY	4	(3.7)
Total	108	(100.0)	Total	108	(100.0)

3.4 Preliminary Inspection

Preliminary Bridge Inspection has been carried out for the 101 bridges. One of the purposes of this inspection is to formulate bridge rehabilitation plan, and then the results of this inspection shall reflect the Maintenance & Rehabilitation Guideline. The other purpose is to demonstrate field inspection techniques, to introduce inspection recording methods to RDA and to recommend the necessary maintenance and rehabilitation works.

The inspection results for the 101 bridges are described in two separate booklets already submitted to RDA in October, 1995.

3.4.1 Preliminary Inspection Procedure

Preliminary inspection was carried out on each bridge and it involved visual inspection, measurement of basic dimensions, damage condition rating, taking photographs, field interview and assessment of possible rehabilitation plans.

Interviews with local residents at the bridge site were carried out to obtain data related to high flood level taken place and detour route. Damage condition rating was also carried out to quantify the damage or defect of various bridge members. The rating list and criteria were prepared based on the inspection sheets prepared by RDA and the Study Team.

Every defect or deficiency observed and general view of bridge were photographed for visual records. Assessment of rehabilitation plan at each bridge was then carried out for the type and degree of damage and the possible cause of the damage.

3.4.2 Damage Rating Criteria

It is important to observe any damage appeared on bridges along with the time passed by to understand the level of damage quantitatively. RDA, at present, carries out the visual inspection by rating "Good", "Fair", "Poor", and "Very Poor", and the Study Team basically have followed their rating criteria. Actual rating was carried out with released engineers from RDA for the following rating criteria.

Rating	Rating Criteria
1	No damage found in the results of inspection.
2	Damage found and requires routine maintenance inspection work.
3	Damage is critical and requires a detailed survey work to determine a necessity of rehabilitation works.
4	Damage is very critical and requires urgent rehabilitation work, load limitation or restriction.

Each bridge was evaluated quantitatively for easy judgment of damage. Each part of the bridge was evaluated with weighted factor depending on its importance and then considered for the overall evaluation. The overall evaluation is the most useful data to determine the priority for bridge rehabilitation in Sri Lanka.

The weighted factor for each part used in the Inspection is as follows:-

Part		Weighted Factor
Superstructure	Deck slab	0.8
	Main beam, Main frame	1.0
	Painting	0.5
Substructure	Abutment (incl. foundation)	1.0
	Pier (incl. foundation)	1.0
	Wing	0.5

3.4.3 Findings of the Preliminary Inspection Results

(1) General Condition of Bridges

A general condition of each main structure and each bridge type is as depicted in Figure 3.4.1 and Figure 3.4.2 respectively.

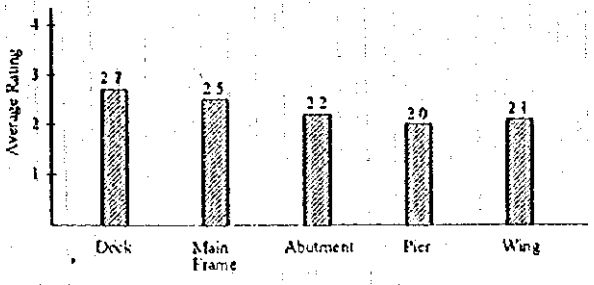

Figure 3.4.1
Average Rating of Each Main Structure

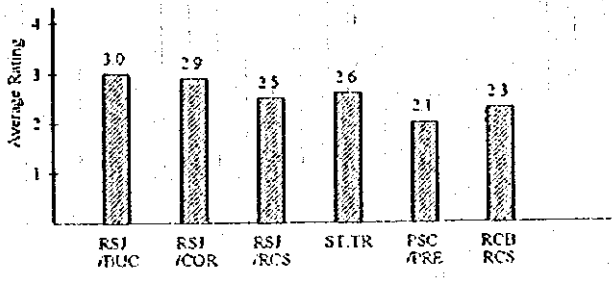

Figure 3.4.2
Average Rating of Each Bridge Type