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No. 10

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF PUBLIC WORKS
THE REPUBLIC OF CHILE

THE REHABILITATION AND CONSERVATION PROGRAM ON THE BRIDGES IN THE REPUBLIC OF CHILE (PHASE 2)

FINAL REPORT

MAIN REPORT

(VOLUME 2/8)

JULY 1998

PACIFIC CONSULTANTS INTERNATIONAL

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ABBREVIATION

AASHTO	American Association of State Highway and Transportation Officials
CADD	Computer Aided Design and Drafting
GDP	Gross Domestic Product
IEE	Initial Environmental Examination
JICA	Japan International Cooperation Agency
MOP	Ministry of Public Works
PC	Pre-stressed Concrete
PCI	Pacific Consultants International
Pre-EIA	Preliminary Environmental Assessment
RM	Region Metropolitan

CURRENCY EQUIVALENT

US$ 1.00 = 450 Chilean Peso (as of March1998)

PREFACE

In response to a request from the Government of the Republic of Chile, the Government of Japan decided to conduct the study on the Rehabilitation and Conservation Program on the Bridges in the Republic of Chile and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Chile a study team headed by Mr. Takashi Chujo, Pacific Consultants International from September 1996 to March 1998.

The team held discussions with the officials concerned of the Government of Chile, 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 the Republic of Chile for their close cooperation extended to the team.

July 1998

Kimio Fujita
President
Japan International Cooperation Agency

July 1998

Letter of Transmittal

Mr. Kimio Fujita
President
Japan International Cooperation Agency

Dear Sir,

It is our great pleasure to submit the final report of the study on the Rehabilitation and Conservation Program on the Bridges in the Republic of Chile.

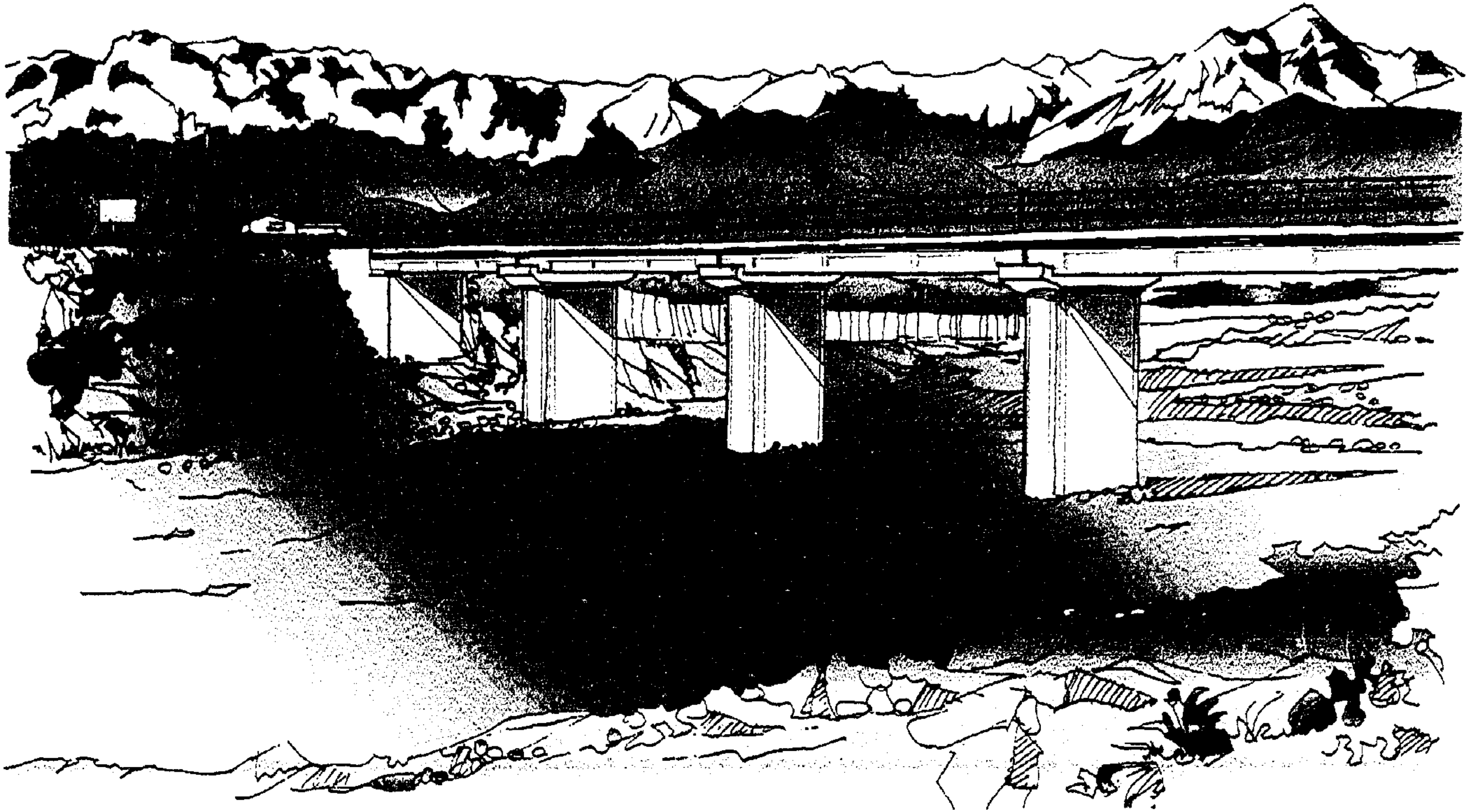
The study was carried out by Pacific Consultants International from September 1996 to March 1998 to work out rehabilitation plan, sample rehabilitation design, and standard bridge CADD program for the rural road bridges in Chile, based on the terms of references drawn up by the Japan International Cooperation Agency (JICA). The study results were collected in the final report, Volume 1 to 8.

We hope that the report will be useful for the MOP (Ministry of Public Works of Chile) to implement the rehabilitation.

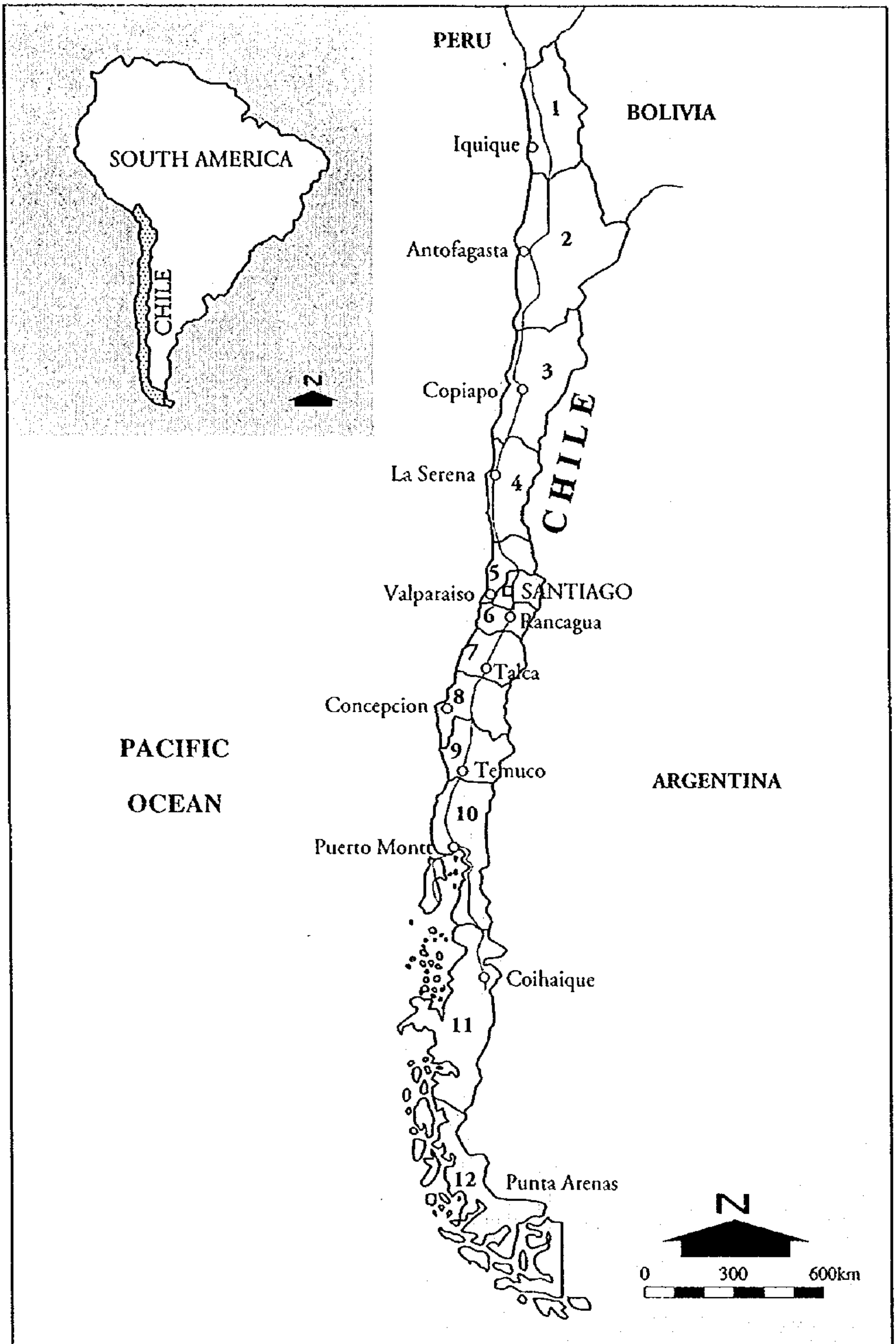
We wish to express our thanks to the JICA, the MOP, the Embassy of Japan in Chile for their cooperation given to us in the course of the study.

Yours faithfully,

Takashi Chujo
Team Leader
The Study on the Rehabilitation and
Conservation Program on the Bridges
in the Republic of Chile



David Garcia Bridge in Region V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Talca
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PACIFIC
OCEAN
ARGENTINA
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Puerto Montt
Coihaique
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12
Punta Arenas
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MAP OF CHILE

MAIN REPORT

CONTENTS

CHAPTER 3 BRIDGE REHABILITATION DESIGN

CHAPTER 4 STANDARD BRIDGE CADD SYSTEM

CHAPTER 5 CONCLUSION AND RECOMMENDATION

FIGURES

TABLES

CHAPTER 1

GENERAL

CHAPTER 1 GENERAL

1.1 INTRODUCTION

1.1.1 Introduction of the Study

In response to the request of the Government of the Republic of Chile (hereinafter referred to as 'the GOC'), the Government of Japan (hereinafter referred to as 'the GOJ') decided to implement the study on the Rehabilitation and Conservation Program on the Bridges in the Republic of Chile (Phase 2) (hereinafter referred to as 'the Study') in accordance with the Agreement on Technical Cooperation between the GOC and the GOJ signed in 1978.

Accordingly, the Japan International Cooperation Agency (hereinafter referred to as 'the JICA'), the official agency responsible for the implementation of the technical cooperation programs of the GOJ, started to undertake the Study, in close cooperation with the authorities concerned of the GOC.

In March 1996, the JICA dispatched the Preparatory Study Team headed by Dr. Koichi Yokoyama to the Republic of Chile (hereinafter referred to as 'Chile') for the purpose of discussing the Scope of Work for the Study (hereinafter referred to as 'the S/W'). The S/W together with the Study schedule was agreed upon between the Ministry of Public Works (hereinafter referred to as 'the MOP') of the GOC and the JICA Preparatory Study Team.

The JICA commenced the Study in August 1996 by employing a Japanese consultant "Pacific Consultants International" and completed it in July 1998.

1.1.2 Background of the Study

(1) Situation of Rural Bridges in Chile

The bridges for the Study are categorized in rural bridges and characterized by 'many and small timber bridges with low loading capacity' and 'few but heavy load traffic'. The MOP recognizes the existence of some 8000 rural bridges under its jurisdiction in the whole country.

- The most rural bridges are timber bridges. In reality, out of 200 bridges the Study Team inspected in the VIII, IX and X regions, 95 % were small timber bridges being guarded by load limits less than 12 tons.

- Very few traffic, only about 100 to 200 cars per day, was surveyed at most bridge sites, but the ratio of heavy vehicles was quite high on some bridges located on the lumber and construction material transport roads. Heavy lorries which seemed to load about 20 to 30 tons, are likely to damage the timber bridges. The lumber and mining industries have reinforced or built such timber bridges by themselves for transport of their products.

Timber bridges generally deteriorate depending on preservative treatment, faster than concrete and steel bridges. That is, all timber bridge elements must be periodically replaced; the regional MOPs have experienced minor replacement in about every 5 years and major replacement in 10 years.

Therefore, the rehabilitation of timber bridges has been one of the urgent issues in the MOP to be solved; about 40 to 50 timber bridges have annually collapsed in last 10 years for lack of maintenance.

(2) Rehabilitation Policy of the MOP

In recent years, situation of the timber bridges in Chile has changed: their advantages of low-cost and easy construction were rapidly lost, but on the contrary the problems specific to timber bridges have become conspicuous such as need of frequent maintenance and rise of timber cost. In such situation, the maintenance of timber bridges is now laborious and costly for the MOP compared with that of concrete or steel bridges. The MOP, therefore, intends to gradually replace timber bridges with permanent concrete or steel bridges.

1.2 OBJECTIVES OF THE STUDY

The Study has the following three major objectives to technically assist the MOP in rehabilitating the rural bridges:

① To prepare a rehabilitation plan for about 1000 bridges on rural and transversal roads,
② To prepare sample rehabilitation designs for 20 bridges, and
③ To develop a standard bridge CADD (computer aided design and drafting) program, and to prepare standard bridge design drawings using the CADD program.

1.3 SCOPE OF THE STUDY

In order to achieve the objectives mentioned above, the Study includes the following activities:

(1) Bridge Rehabilitation Plan

a. Concept of bridge rehabilitation plan.
b. Bridge inspection and inventory preparation.
c. Socio-economic and traffic survey.
d. Compilation of bridge inventory and traffic demand.
e. Bridge rehabilitation cost estimate.
f. Priority list for bridge rehabilitation.
g. Project investment plan for bridge rehabilitation.
h. Study of bridge management and maintenance.

(2) Bridge Rehabilitation Design

a. Survey on bridge design and construction practices in Chile.
b. Selection of object bridges.
c. Method for bridge inspection.
d. Bridge inspection.
e. Initial environmental examination.
f. Bridge rehabilitation design.
g. Bridge rehabilitation cost estimate.
i. Preparation of manuals.

(3) Development of Standard Bridge CADD Program

a. Survey on current computer use in Chile.
b. Types and design conditions for Standard bridge.
c. Proposed CADD program system.
d. Selection of computer-hard and soft-wares.
e. CADD programming.
f. Preparation of standard bridge design drawings by CADD programs system.
g. Preparation of manuals.

1.4 STUDY APPROACH AND SCHEDULE

The Study was carried out in principle based on the S/W which was agreed between the MOP and the JICA Preparatory Study Team in March 1996. The Study was divided into Phases I through III (three fiscal years) and these phases were further subdivided into a total of nine steps.

Phase I (August 1996-July 1997)

Step-1	Preparation to start the Study (Inception Report).	(Work in Japan)
Step-2	First Bridge Rehabilitation Plan and CADD Study (Progress Report (1)).	(Work in Chile)
Step-3	Development of CADD Program.	(Work in Japan)

Phase II (June 1997-March 1998)

Step-4	Bridge Inspection.	(Work in Chile)
Step-5	Bridge Rehabilitation Design (Interim Report).	(Work in Japan)
Step-6	Second Bridge Rehabilitation Plan (Progress Report (2)).	(Work in Chile)
Step-7	Preparation of Manuals (Draft Final Report).	(Work in Japan)
Step-8	Explanation of Draft Final Report and Seminar.	(Work in Chile)

Phase III (May 1998-July 1998)

Step-9	Completion of the Study (Final Report).	(Work in Japan)

The general work flowchart of the Study is shown in **Figure 1.1**.

1.5 STUDY ORGANIZATION

The JICA Study Team was organized by the JICA and comprised of the members of Pacific Consultants International (PCI). The Chilean counterparts were organized by the GOC and comprised of the members of the Bridge Department of the MOP. The organization chart is shown below.

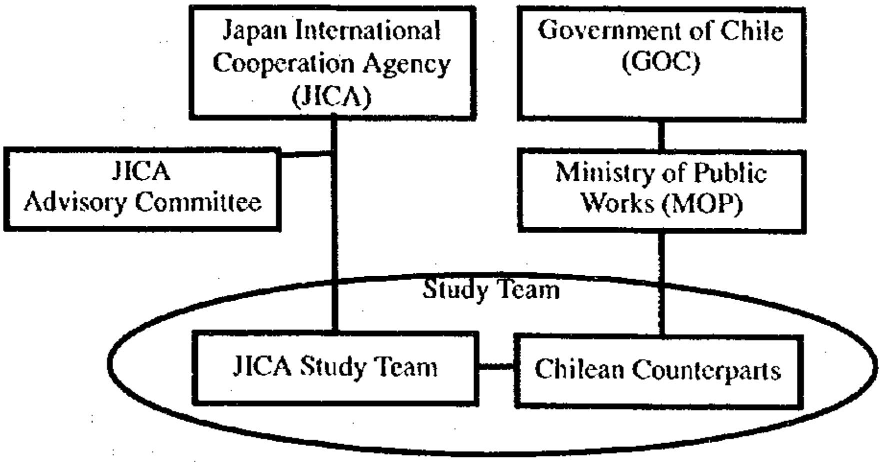


Figure 1.2 Study Organization

The member of the JICA Study Team (hereinafter simply called 'Study Team') is listed in **Table 1.1**.

Table 1.1 Member of the Study Team

Name	Assignment
Takashi Chujo	Team Leader/Bridge Planner
Tuyoshi Sasaki	Transport Planner
Kiminari Takahashi	Traffic Engineer
Toshio Kachi	Bridge Rehabilitation Planner
Torao Tokozumi	Bridge Engineer (Superstructure 1)
Jiro Koyama	Bridge Engineer (Superstructure 2)
Toshio Ueno	Bridge Engineer (Substructure)
Motoyoshi Yamada	Regional Planner
Akira Shikichi	Bridge Maintenance Planner
Masamitu Toriyama	Transport Economist
Hiroyuki Takano	Construction Planner/Cost Estimator
Hiroshi Tanaka	Environment Specialist
Tsuneo Kitagawa	Software Planner
Isamu Nishida	Software Designer (1)
Kunio Ohno	Software Designer (2)
Kazunori Tomita	Programmer (1)
Tateo Suzuki	Programmer (2)
Toyohide Tukii	Programmer (3)
Koichi Ishii	Project Coordinator

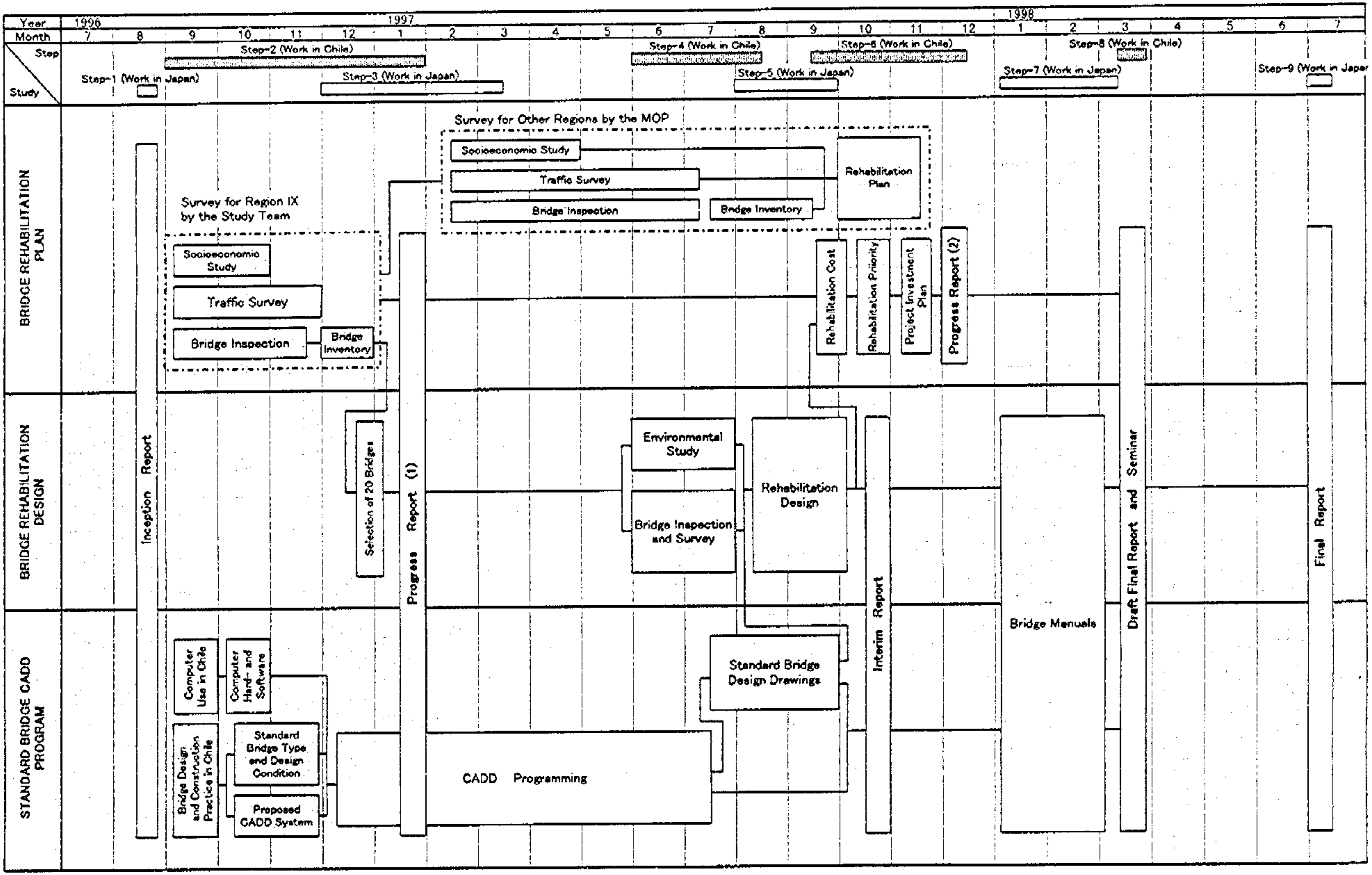


Figure 1.1 General Work Flowchart of the Study

CHAPTER 2

BRIDGE REHABILITATION PLAN

CHAPTER 2 BRIDGE REHABILITATION PLAN

2.1 CONCEPT OF BRIDGE REHABILITATION PLAN

2.1.1 Purpose of the Plan

The purpose of the bridge rehabilitation plan is to advise for the MOP in simple and practical manner to shape a rehabilitation plan for rural bridges but not to prepare individual bridge rehabilitation design.

Up to the present, the MOP has repaired bridges when damaged, and thus has not necessarily had a planned method of investment in rehabilitation. However, with a large number of bridges in deteriorated condition in rural regions, planned investment has become a necessity and ways in which effective use of a limited budget became an issue.

2.1.2 Bridges for the Plan

The MOP has been intending the rehabilitation of rural bridges. Therefore, the MOP would take the opportunity of the Study to adopt about 1000 bridges for the first phase of the rehabilitation of some 8000 rural bridges said to exist in the country.

The MOP selected 1000 bridges throughout the country according to the following three conditions:

- Bridge length not less than 10 m.
- Vehicle load limited to around 12 tons.
- Damaged or deteriorated severely.

2.1.3 Concept of the Plan

(1) Stratified Planning

The 1000 bridges are divided by regions to match up with the administration divisions of the MOP. The plan is first conducted in each region, and the results of each of the thirteen regions are totaled to make a nation wide plan. This concept of the stratified plan is illustrated in **Figure 2.1**.

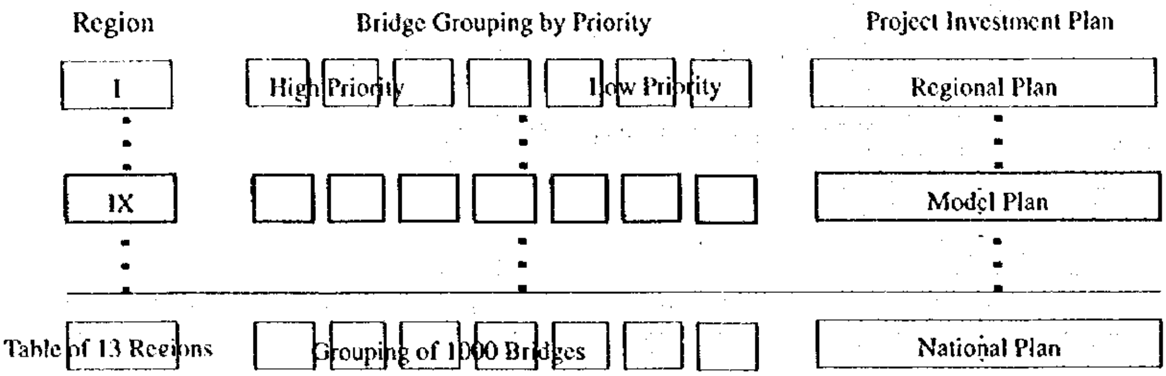


Figure 2.1 Regional and National Level Plans

Of the 1,000 bridges chosen nationwide, 110 bridges in Region IX were studied first as a model. The MOP then studied the remaining bridges in the twelve other regions based on this model. Region IX was chosen for model study as it was known to have a particularly large number of timber bridges.

(2) Evaluation Indices for Priorities

In order to fairly evaluate the priorities of rural bridges, many of which have low return of investment, bridge safety and social aspects were also taken into consideration. The three indices chosen for evaluation are representative of the MOP's project policy. See **Figure 2.2.**

Economic index	Ratio of rehabilitation cost to traffic volume (representing project benefit).
Safety index	Amount of bridge damage. Dangerous bridges take priority regardless of traffic volume or cost.
Social index	Based on ratio of local income to national average. Regions of lower income take priority in public investment.

The rate of priority is evaluated by calculating the three above indices and finding the total index figure after considering added weight of government policy.

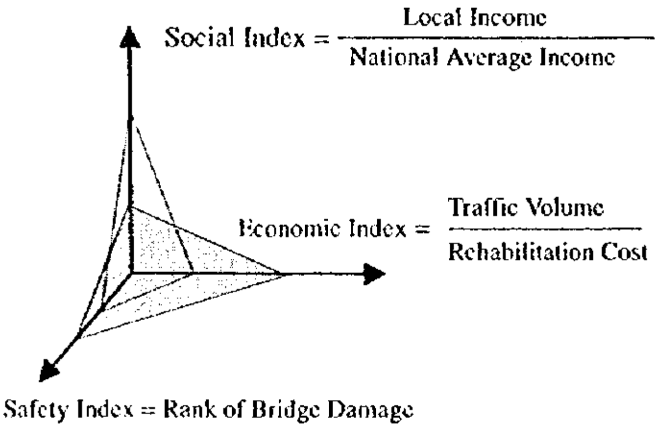


Figure 2.2 Indices for Rehabilitation Priority

(3) Grouping of Bridges by Road Link

In order that the bridge rehabilitation be effective, it is advised that subsequent bridges along the same route be rehabilitated in the same phase. The road segment, defined as a stretch between two major intersections having the same traffic volume, which contains project bridges, is called a "road link". Multiple numbers of bridges within the segment are to be treated as a group. See **Figure 2.3.**

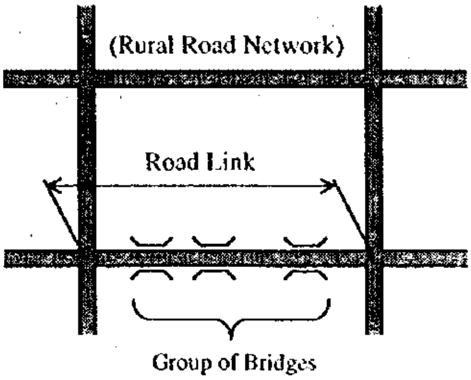


Figure 2.3 Grouping of Bridges

2.1.4 Process of the Plan

(1) Process

Bridge rehabilitation plan was worked for 1,000 selected bridges. First, bridge inventory (location and present condition of bridge) was made. In addition, socioeconomic data (population, income, traffic volume, etc.) was collected to measure the social and economic needs of the bridge. From the above data, rough estimates of rehabilitation cost and evaluation of priority were then made, and project investment plan was drawn up based on this information. See **Figure 2.4**.

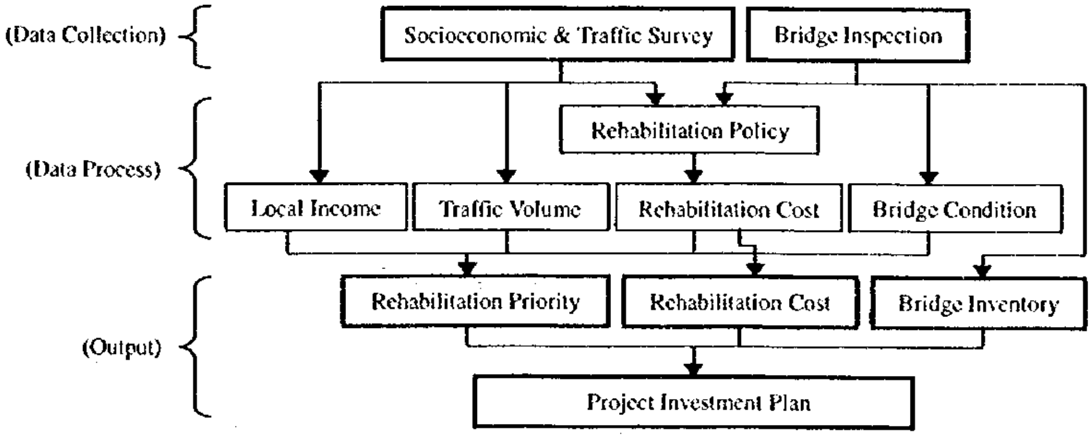


Figure 2.4 Process of Rehabilitation Plan

(2) Surveys and Data Collection

The purpose of surveys is to collect the site information attending to the bridges necessary for rehabilitation planning. The information includes:

- Bridge inventory and condition.
- Traffic volume on object bridges.
- Socio-economic data in regions.
- Rehabilitation criteria and approximate cost.

To collect the above information, the following surveys were carried out:

- Bridge inspection.
- Socio-economic data collection.
- Traffic survey.

The methods employed and the results of the above surveys the Study Team has conducted in the model region are reported in the succeeding **Chapters 2.2 through 2.4**.

2.2 BRIDGE INSPECTION

2.2.1 Selection of Bridges

The purpose of bridge inspection is to collect bridge inventory and condition data which are the basic information necessary for the bridge rehabilitation planning.

The MOP selected 1,000 bridges for the inspection throughout the country. The inspection work of the 1,000 bridges was shared between the Study Team and the MOP. The Study Team inspected 200 bridges in Regions VIII, IX and X and the MOP inspected the remaining 800 bridges in other regions. **Table 2.1** shows the number of bridges by regions the MOP selected.

Table 2.1 Number of Bridges Selected by Regions

Region	Capital	Number of Bridges	Inspected by the MOP	Inspected by the Study Team
I	Iquique	22	22	0
II	Anofagasta	16	16	0
III	Copiapo	62	62	0
IV	La Serena	100	100	0
V	Vakoarausi	100	100	0
VI	Rancagua	100	100	0
VII	Talca	100	100	0
VIII	Conception	95	55	40
IX	Temco	110	0	110
X	Puerto Montt	95	45	50
XII	Coihaique	50	50	0
XIII	Punta Arenas	100	100	0
RM	Santiago	50	50	0
Total		1,000	800	200

Of the 200 bridges inspected by the Study Team, the inspection results of 110 bridges in Region IX were used for the model study of rehabilitation plan.

2.2.2 Inspection Method

(1) Preparation of Inspection Form

An inspection form was designed keeping the following points in mind:

- to cover all the necessary data for the rehabilitation plan, and
- to be usable as a general bridge inventory system in the MOP.

The proposed inspection form consists of:

① bridge inventory form,
② bridge condition rating form, and
③ repair method and quantity form.

1) Inventory Form includes:

- general information of bridge such as name, construction year, location map, river condition and other administrative data,
- structural details including bridge type, major dimensions, profile and cross-sectional sketches, and
- photographs of side and front views and typical damages.

2) Condition Rating Form is to note kinds and magnitude of damages for each part of a bridge structure namely superstructure, substructure, and accessories (expansion joints and bearings), classifying each part into primary or secondary member according to structural importance.

3) Repair Method and Quantity Form is to note probable repair methods and approximate quantities proposed at site, in combination with the condition rating form by span and element.

Based on the above idea of inspection forms, the following nine (9) inspection sheets were derived.

1) Inventory Form

Sheet 1	General Information
Sheet 2	Structural Details
Sheet 3	Photographs

2) Bridge Condition Rating Form, and Repair Method and Quantity Form

Sheet 4	Condition Rating (Superstructure)
Sheet 5	Repair Method and Quantity (Superstructure)
Sheet 6	Condition Rating (Substructure)
Sheet 7	Repair Method and Quantity (Substructure)
Sheet 8	Condition Rating and Repair Method/Quantity (Accessories)
Sheet 9	Code Table of Damage Type, Degree/Rating, and Repair Type

The above inspection forms filled with a sample data and the guideline are presented in **Appendix I-1 (Volume 3/8)**.

(2) Inspection Method

Bridges were visually inspected and site information was collected in accordance with the inspection form. The inspection tools used were measure tapes, measure ropes with sinkers, binoculars, and cameras. Bridge condition was inspected span by span and element by element. Damages were noted on the form by prescribed damage codes to show damage types and by condition rating numbers to show degree of damages.

2.2.3 Rating System for Bridge Condition

(1) General Definition of Condition Rating

In order to standardize various condition-states of any bridge-element, a numerical rating system categorized into five ranks was recommended. See **Table 2.2**.

Table 2.2 Rating System for Bridge Condition

Rank	Definition
5	'Good, New or Like-new' condition, no sign of distress or deterioration. No repairs necessary.
4	'Functioning as Originally Designed'; insignificant deterioration or distress does not reduce the capacity of the elements under inspection nor their ability to function. For example, an expansion joint or bearing which is corroded but has not lost any effective strength and still permits the required movements. Minor repairs can be made to alleviate distress or eliminate deterioration.
3	'Not Functioning as Originally Designed'; serious deterioration (and/or distress), sufficient to reduce the element's structural capacity and or its ability to function as designed. When this rating applies to primary elements, the bridge must have the maximum design loading reduced accordingly. Immediate repairs must be made to return the structure to design capacity.
2	'Potentially Hazardous'; such a rating in primary members implies there is a danger of collapse under any further use of this structure and bridge should be closed to traffic immediately. When such rating applies to secondary elements, it can be cause of vehicular or pedestrian accidents and should be corrected immediately.
1	'Dangerous'; bridge already closed, conditions beyond repair, imminent danger of collapse or already collapsed. Structure to be demolished.

(2) How to Rate Bridge Condition

1) How to rate each element

Condition rating shall be practiced by visual inspection from close range (not just looking for a mere overview using binoculars from distance), span by span and element by element. Inspected damages are to be noted on the form by the prescribed damage codes to show damage types and by the condition rating numbers to show degree of damages. The guideline for rating bridge condition is given in **Appendix I-1 (Volume 3/8)**.

The condition rating of a span or an element shall be decided by taking the worst rating rank among the damages noted on the primary members of the span or the element.

2) How to rate a bridge totally

The condition rating of a bridge as a whole is determined as follows:

① Bridge structure is divided into primary members (such as structural elements of main beams, abutments/piers, etc.) and secondary members (such as pavement, expansion joints, paint, etc.). Concrete deck slab is generally considered to be primary member. However, timber deck slab is considered to be secondary, because it can be partially or totally replaced easily.

② The worst rating among the ratings of various damages in a primary member shall represent the rating rank of the span or the abutment/pier.

③ The worst rating rank among the ranks of all spans and abutments/piers of a bridge represents the rating rank of the bridge as a whole.

The total rating of a bridge would be used to calculate the safety index for appraising rehabilitation priority, and be a basis of deciding rehabilitation action of the bridge.

2.2.4 Results of Bridges Inspection

(1) Inspection Work

Bridge inspection for the 200 bridges was carried out by two teams in Regions VIII, IX and X from October 30 to December 5,1996. Each team consisted of two Japanese bridge engineers, a MOP engineer from respective region, and an English-Spanish interpreter.

(2) Inspection Procedures

The inspection work was carried out by taking the following procedures.

1) Bridge location and administrative data

Before going to site, location and administrative data of bridges ware obtained from the existing inventory of the MOP. Bridges location was plotted on the road map and grouped to prepare the inspection schedule.

2) Geographic and river condition

Topographic condition surrounding the bridge was observed and classified to be steep, hill or flat. River condition such as meandering, obstacles to flow, driftwood, riverbed and velocity of flow were inspected. River width was measured at the point of bridge. Past earthquake and flood water level ware inquired to local residents.

3) Bridge type

Bridge type was classified by material and structural type of major bridge components. The material types inspected were timber, concrete and steel. The superstructure type was defined by the kind of main beams like beam, truss or arch and by the supporting condition, simple or continuous. The substructure type was defined by the type of pier/abutment such as column, wall or frame. The foundation type was defined by spread footing or piles.

4) Dimensions of bridge structure

Tape measure was used for the measurement of bridge structures. For the bridge members where access was difficult, dimension was measured with the eye. Bridge length was measured for the distance between the front faces of back-wall of both abutments. The height of substructure was measured from bridge seat to ground level.

5) Damages

Damages were visually inspected from close range. Where access was difficult, binoculars was used. The kind and magnitude of damages were decided at the site by the engineer's judgement. To decide the rank of damage, the damage magnitude tables presented in **Division III of Bridge Manuals (Volume 6/8)** were used from time to time.

(3) Results of Inspection

The bridges inspected by the Study Team were 110 bridges in Region IX, 50 bridges in Region X, and 40 bridges in Region VIII, totally 200 bridges, but actually 193 bridges were inspected; 7 bridges did not exist.

The location of the inspected bridges are shown in **Figure 2.5**. The list of inspected bridges and the results of condition rating are attached in **Appendix I-2 (Volume 3/8)**. The results of the bridge condition rating in Region IX (model study) are summarised in **Table 2.3**.

Table 2.3 Summary of Bridge Condition Ratings in Region IX

(number of bridges)

Bridge Type	Condition Rating					Total
	1 (bad)	2	3	4	5 (good)	
Timber Bridge	6	50	25	6	10	97
Concrete Bridge	0	0	0	0	0	0
Steel Bridge	0	8	2	1	1	12
Total	6	58	27	7	11	109

The engineering examination of the inspected bridges is presented in the next **Chapter 2.2.5**.

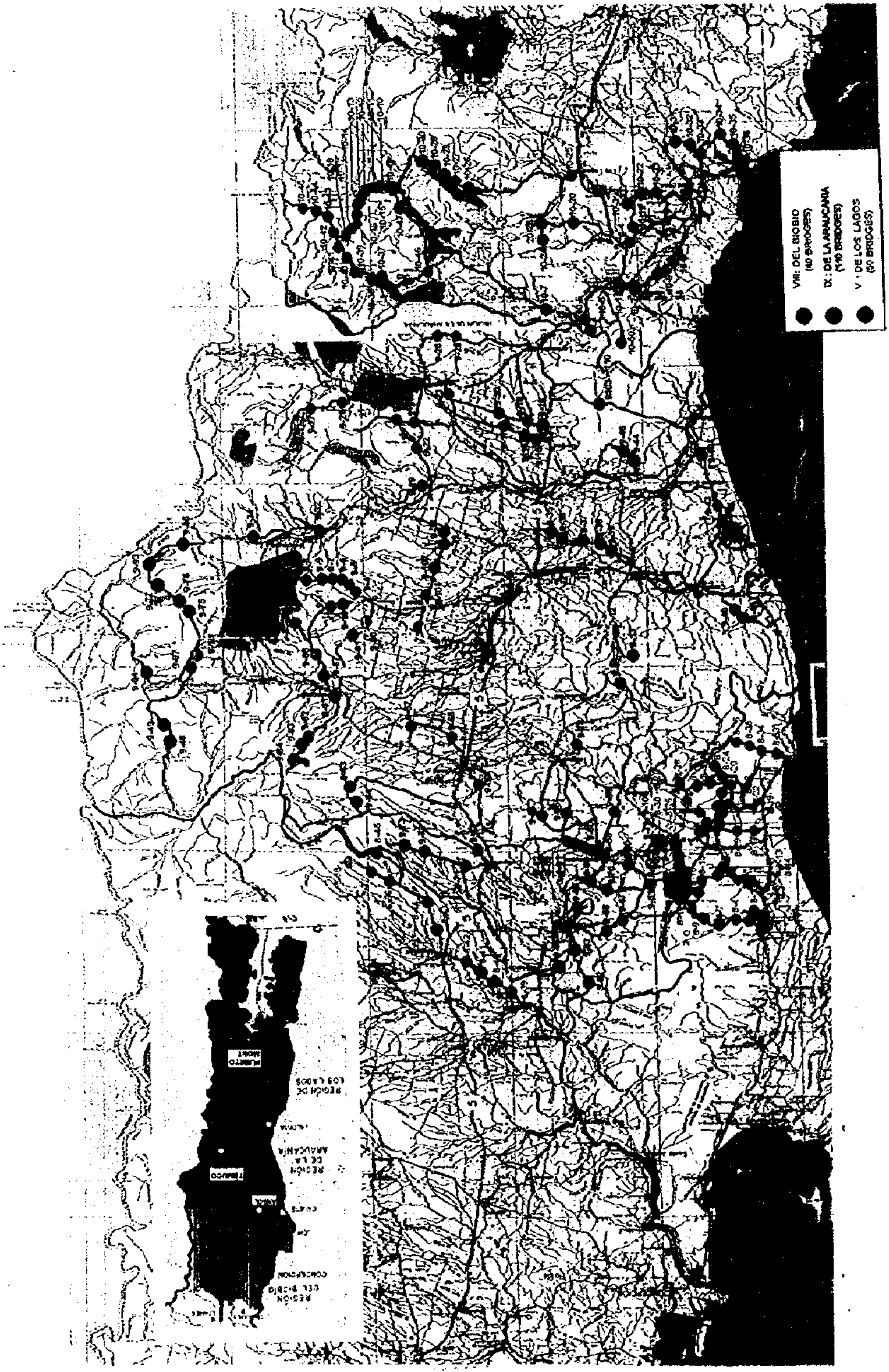


Figure 2.5 Location of Bridges for Rehabilitation Plan

2.2.5 Engineering Examination of Inspected Bridges

(1) Structure Type, Span/Length and Material

1) Structure type : The inspected bridges in Region VIII, IX and X are classified by the following material types of major elements:

Type	Deck Slab	Main Beam	Abutment/Pier	Percentage
1.	Timber	Timber	Timber	62 %
2.	Timber	Timber	Concrete or Steel(rail)	25 %
3.	Timber	Steel	Concrete	10 %
4.	Concrete	Concrete	Concrete	3 %
			Total	100 %

2) Roadway width : All bridges have only one-lane roadway varying between 2.0 and 5.5 m in curb-to-curb width.

3) Support condition : Most bridges are simply supported except six timber, three concrete and two steel bridges which are continuously or rigidly supported.

4) Span length : Span length ranges according to type and material as follows:

• Timber beam	$3 < L < 18$ m
• Timber beam (Fink type*)	$16 < L < 26$ m
• Timber beam (Rigid frame)	$30 < L < 35$ m
• Steel girder	$7 < L < 35$ m
• Concrete beam	$10 < L < 20$ m

* Timber beams reinforced with steel tie-bars (1.0-1.5 inch in diameter) like tension chord of truss under beam.

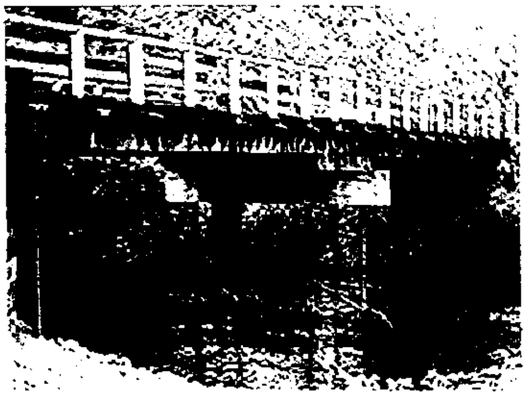
5) The longest bridges over 100m:

Region	Bridge No.	Bridge Name	Span & Length	Type
IX	32	Medina	6 @ 28.3 = 170.0 m	Steel simple I-beam
X	33	Naguilan	8 @ 20.0 = 160.0 m	Steel simple I-beam
X	25	Quinchilca	7 @ 20.1 = 141.0 m	Continuous concrete beam

6) The longest timber bridges:

Region	Bridge No.	Bridge Name	Span & Length	Type
X	16	Quilmo	10 @ 10.0 = 100.0 m	Simple beam
X	86	Malleco	10 @ 9.2 = 92.0 m	Simple beam
X	98	Lealtad	7@ 9.1 = 63.7 m	Simple beam

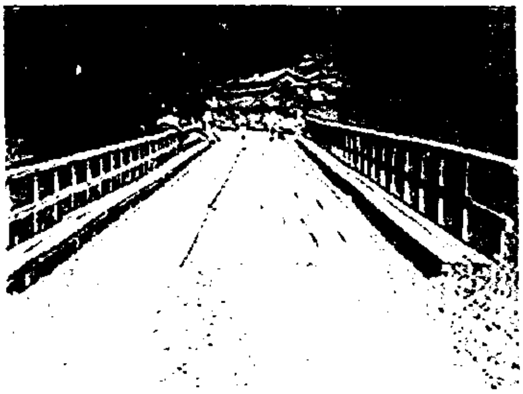
The following photographs show the typical bridges inspected.



① Timber bridge (No. IX-26 CRUCES)

② Steel beam with timber deck (No. IX-04 LLAMUCO)

③ Concrete Bridge (No. X-01 SAN JOSE N1)



④ Timber deck slab (No. X-5 QUILLEN)

(2) Timber Bridges

Timber bridges are the most common type on the rural roads in the central southern zone of Chile, and they have been constructed not only by regional MOP but also by private enterprises (lumber industry and farmland owners) who need roads to transport their commodities and products. Although the MOP has a simple standard design for timber bridges, construction of them has been not necessarily based on strict design but rather on experiences of technicians and availability of materials.

The timber bridges inspected are featured as follows:

Span length	3 ~ 18 m
Number of main beams	4 ~ 6 nos.
Depth of beam	30 ~ 40 cm
Thickness of deck slab	about 10 cm

Characteristics of the timber bridge work are:

- Construction and repair are based on experience and manpower, not on strict design and equipment.
- Major repair method is replacement of damaged or deteriorated timbers.
- For materials, Coigue and Oak are used for beams, deck slab and plank floor, and Eucalyptus is used for beams and pier columns.

There were decay caused by fungi or moss where timbers were in wet environment, especially substructure members, however no sign of attacks from insect of beetles and ants.

Typical timber bridge inspected is illustrated below:

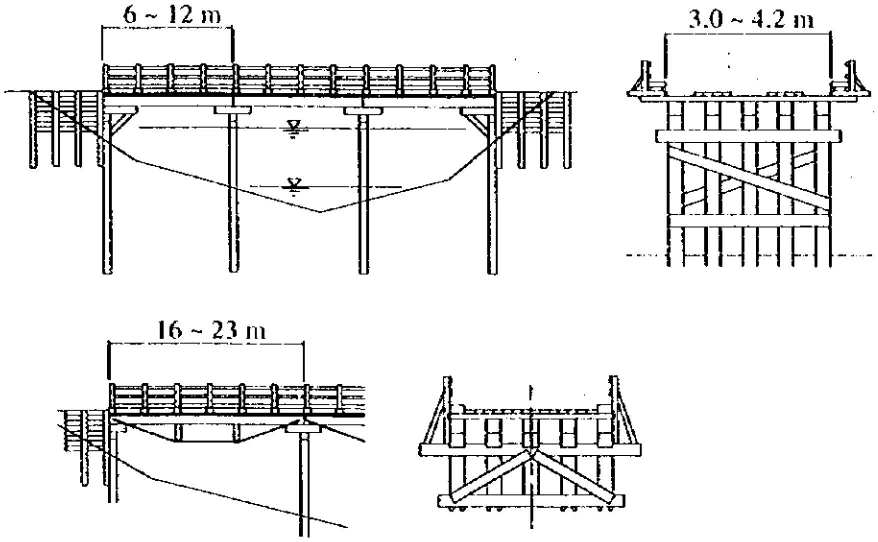


Figure 2.6 Typical Timber Bridge

(3) Load Limit

About 60 % of the bridges inspected had signboards to limit vehicle loads. According to the MOP engineers, that was an effort to guard old and less reliable bridges against heavy load traffic, and load limit was lowered as deterioration was getting worse. The load limits inspected in Region VIII, IX, and X are summarized in **Table 2.4**. The load limits of no signboard at site were acquired from the existing inventory.

Table 2.4 Load Limited Bridges

(number of bridges)

Load Limit	Timber Beam	Steel Beam	Concrete Beam	Total
2 ~ 6 ton	36	2	0	38
7 ~ 12 ton	126	11	0	137
13 ~ 18 ton	9	6	3	18
Total	171	19	3	193

The timber bridges of 2 ~ 6 ton load limit are those of already severely deteriorated, foundations scoured, bank eroded around abutments, or over 10m span length.

Traffic volume is few but truck percentage is high on rural roads. Lots of woods are produced from the forest of the central southern zone, consequently they are transported on the rural roads and forest roads are extended. Therefore, heavy vehicles such as trucks and semi-trailers loading lumber products and road construction equipment are passing the bridges even though there are signboards indicating less load limit.

When a heavy vehicle passed on timber bridge, abnormal deflection and lateral movement were often observed. The timber bridges of which span length was less than 8.0 m and had six beams were comparatively in good condition, and seemed to be stable up to 12 ton loading by our site inspection.

(4) General Problems of Bridges

The following problems are pointed out from the results of bridge inspection.

- Over loads promote more damage and deterioration of timber bridges.
- Lateral movement of timber bridges occurs when a vehicle passes due to insufficient diagonal bracing members and loose-joins of piers.
- Wooden handrails without diagonal supports threaten safety of pedestrians. Sufficient diagonal bracings shall be installed with bolts and nuts.
- An observed distance of 15 cm from beam edge to bearing seat edge of steel beams is considered insufficient against earthquake.
- Bridge bearings(roller or plate) for steel and concrete beams are severely rusted and do not work functionally.
- In many bridges, embedding depth of footing and piles(rails) are relatively shallow even in a rapid current. For this reason, foundation of piers and abutments are scoured to a considerable degree. These scoured parts shall be corrected and protected without delay by using wire mesh gabions, dumped stones or stone bags.
- River banks around some abutments are eroded. Especially, a portion where bridge beams

seats directly on a bank without abutment, are in a serious condition. This erosion can be controlled using rock/stone slopes, wire mesh gabions or timber plank piles.

- Debris and vegetation around piers of multiple short span bridge, may reduce the width of waterways considerably, then increased velocity leads to more scour near piers. Maintenance work to clear debris is occasionally required.

(5) Geography and River Condition

From west to east there are mountain area, flat or rolling area and Andes mountain range. The Pan-American Highway (Route 5) runs through longitudinal depressions between both mountain range. The terrain of rural roads is rolling and hilly to some extent. The rural roads are 4.0 to 4.5 meter wide and the surface of roads is covered with gravel/earth.

The rivers in the mountain areas flow in torrents through steep slope, and river beds are made of rock, boulder, gravel and lava stone layers. On the other hand, the rivers in flat/rolling area and coastal area, flow slowly and river are of sand or silty sand. All rivers are natural and not artificially controlled. There are no river training works.

The main industries in this zone are agriculture and forestry, and there are many resources of developing tourism in the lakes and mountain area in the east. Rural roads have served farmers of Mapuche Indians as means of transportation of lumbers and agricultural products, and tourists as an access to small scale resort spots.

2.2.6 Computerized Bridge Inventory System

(1) Purpose of the Inventory System

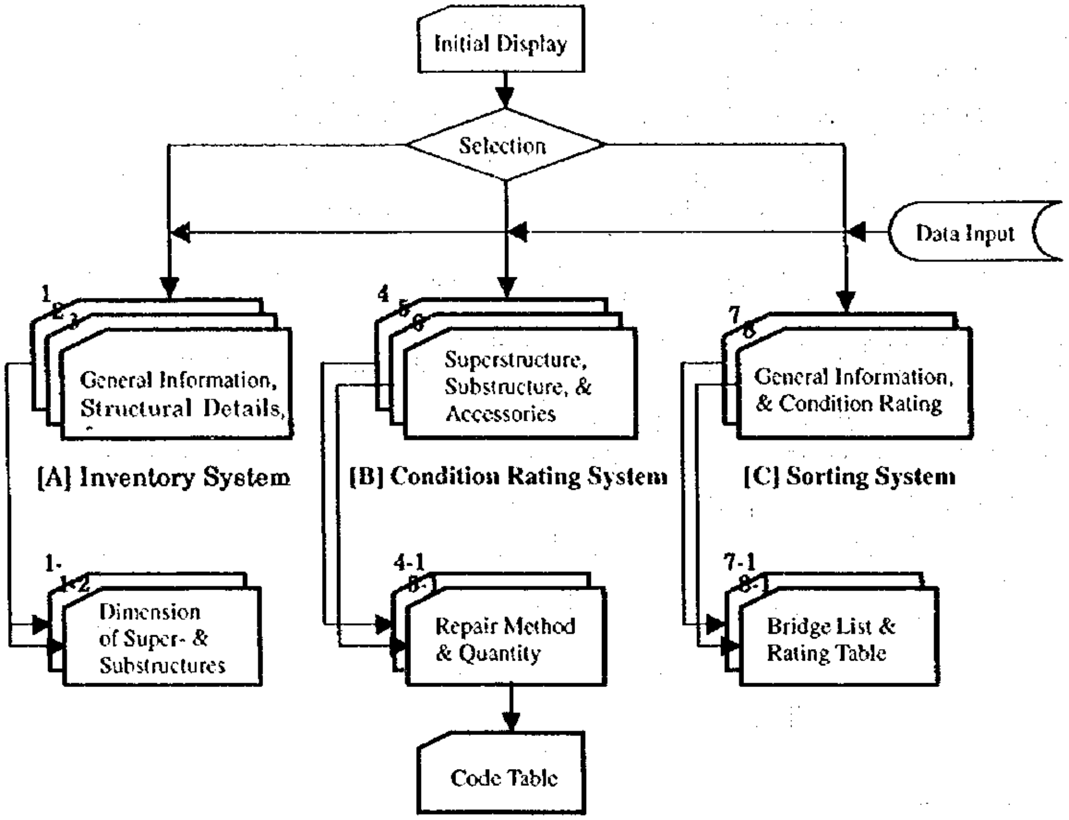
For the bridge rehabilitation planning, it is necessary at first to grasp the inventory and present condition of bridges. However, because the numbers of bridges to be rehabilitated are as many as over thousand, a computerized inventory system is proposed. The system was developed not only for the rehabilitation plan of the Study but also to take advantage of as a comprehensive bridge inventory system of the MOP.

(2) Program Design

The program, as shown in **Figure 2.7**, consists of the following three systems:

[A] Inventory System,
[B] Condition Rating System (including repair method and quantity), and
[C] Sorting System.

System [A] and [B] are based on the bridge inspection forms designed in the preceding **Chapter 2.2.2**.



[1]	General Information	[1]-1	Dimension of Superstructure
		[1]-2	Dimension of Substructure
[2]	Structural Details		
[3]	Photographs		
[4]	Condition Rating (Superstructure)	[4]-1	Repair Method and Quantity
[5]	Condition Rating (Substructure)	[5]-1	Repair Method and Quantity
[6]	Condition Rating (Accessories)		
[7]	Sorting for General Information	[7]-1	Bridge List
[8]	Sorting for Condition Rating	[8]-1	Rating Table
[9]	Code Table		

Figure 2.7 Concept of Inventory Program

System [C], sorting program was added for the compilation and analysis of inventory data. The program is made with data base system making possible all data input and searching by using data linkage function.

(3) Computer Hardware

The Study Team studied the current computer use in the MOP and decided a DOS/V computer. The following set of hardware was selected, all of which were available in Santiago.

IBM Apptiva L53 (Simm Memory – 32 MB, Hard Disk Memory – 2.0 GB)	
Cannon LBP 460 Printer	
Epson 1000 C Scanner:	to input bridge photographs and sketches into data base.
Zip Drive (100 MB):	to save data outside the computer hard disk.

(4) Application Software

The following application software was selected, all of which were available in Santiago.

- Microsoft-Windows 95 as operation system
- Microsoft-Office 7.0 Pro
- Microsoft-Access for Windows 95 including Visual Basic Application Edition

(5) Data Registration and Control System

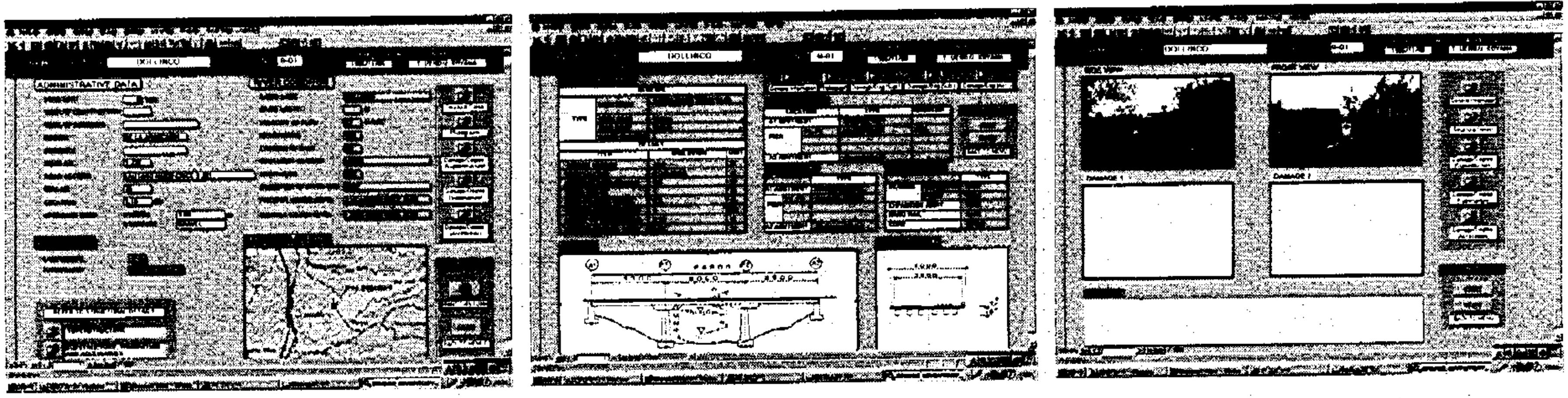
1) All inventory data area controlled by bridge No. which is required for every data sheets. Bridge No. is given first by the region No. and followed by the bridge No. For example, 'Bridge 9-19'means the bridge of No. 19 in Region IX (9).

2) Location map, photographs and sketches are input by using scanner or digital camera. The program recognizes most drawing application software on market.

3) Bridge data are inputted and saved separately by region. The data size of a bridge is about 1.0 MB including map and photographs. To save data for a region, use a zip disk of 200 MB after original capacity of 100 MB is expanded, considering maximum 150 – 200 bridges in a region.

(6) Inventory Program

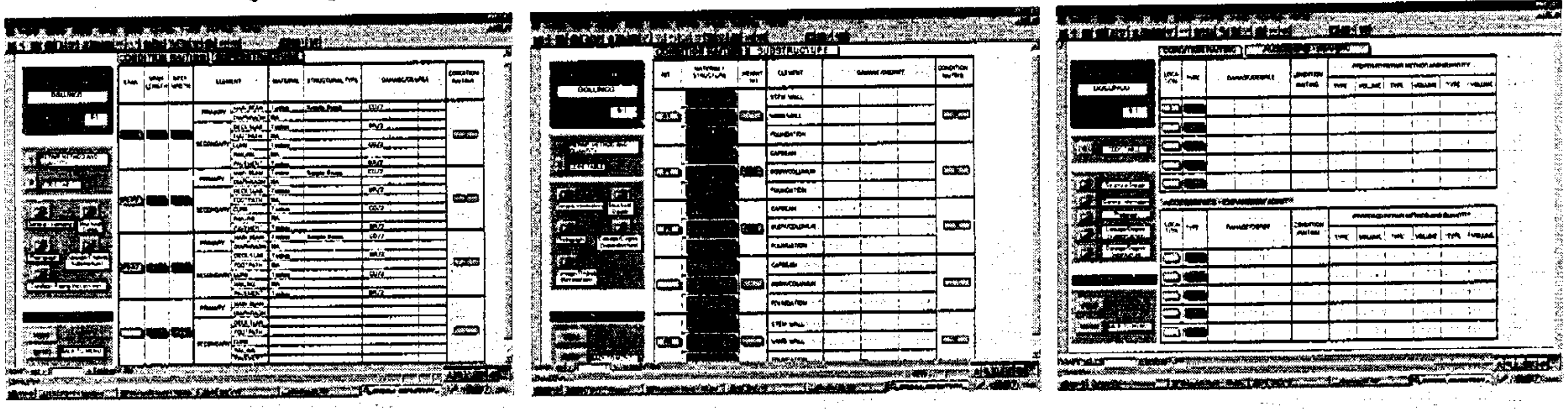
Figure 2.8 shows the major displays of the program developed, and the detail and operation sequence of the program are given in **Appendix I-3 (Volume 3/8)**.



1. General Information

2. Structural Details

3. Photographs

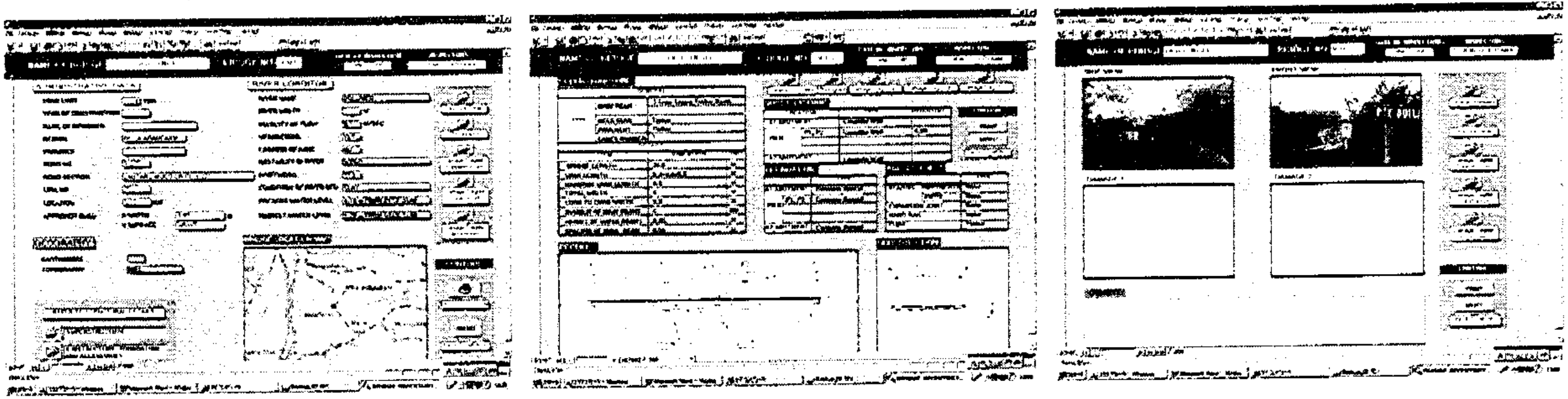


4. Condition Rating for Superstructure

5. Condition Rating for Substructure

6. Condition Rating for Accessories

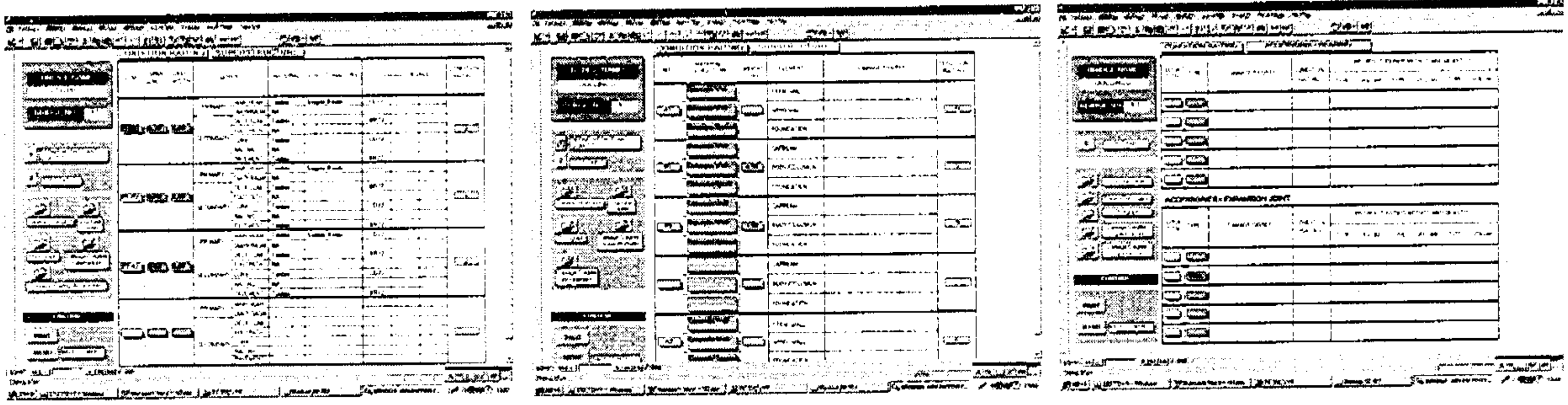
Figure 2.8 Major Displays of Inventory Program



1. General Information

2. Structural Details

3. Photographs



4. Condition Rating for Superstructure

5. Condition Rating for Substructure

6. Condition Rating for Accessories

Figure 2.8 Major Displays of Inventory Program

2.3 SOCIO-ECONOMIC STUDY

2.3.1 Socio-economic Framework

Forecasts shall be made of trends until 2010 in socio-economic indicators that are necessary for defining current traffic volumes, forecasting future traffic volumes on roads (bridges), and appraising rehabilitation priority, which is a objective of the rehabilitation plan, and in doing so a framework for the said trends shall be set.

The following three socio-economic indicators are forecast in both regional and communal levels:

- population
- regional gross domestic product (GDP)
- vehicle ownership number

2.3.2 Socio-economic Indices

(1) Population

Regarding population, because the Chile National Statistics Institute (INE: Instituto Nacional de Estadicas) has already compiled region-separate (region, province and commune) forecasts of population until 2005, so the work here shall be limited to forecasting in 2010.

Described below is the forecasting procedure of population in the year 2010 concerning the country, region, province and commune:

COUNTRY	to forecast, by time series trend, the Chilean national population in 2010,
REGION	to obtain the share of each region's time series trend value within the control total value which was forecast above as the national population, and to estimate the 2010 value for each region based on the said share,
PROVINCE	to obtain the share of each province's time series trend value within the control total value which was forecast above as the 2010 value for each region, and to estimate the 2010 value for each province based on the said share,
COMMUNE	to obtain the share of each commune's time series trend value within the control total value which was forecast above as the 2010 value for each province, and to estimate the 2010 value for each commune based on the said share.

The population forecasts by INE until 2005 and the population in 2010 obtained through the above procedure are indicated in Table (1) of **Appendix I-4 (Volume 3/8)**, where incidentally, only Region IX has commune-separate forecasts.

(2) Regional Gross Domestic Product

With regard to GDP, it was only possible to obtain the following materials during the course of the Study:

- Region-separate GDP materials for 1985-1992 (Source: Banco Central de Chile) in **Table 2.5.**
- Chile national GDP materials (Source: INE) for 1990-1995.

Table 2.5 Region Separate GDP (1985-1992)

Millones of pesos de 1986

REGION	1985	1986	1987	1988	1989(*)	1990(*)	1991(*)	1992(*)
I	107.082	112.375	114.582	117.273	126.108	124.828	131.198	141.620
II	208.681	212.376	212.099	229.753	269.505	271.778	289.155	303.012
III	49.560	50.071	54.810	58.272	67.767	61.161	70.939	79.994
IV	74.610	79.169	80.288	96.791	102.041	102.791	108.367	115.995
V	295.097	300.824	310.875	343.720	376.451	380.935	397.111	423.096
RM	1,206.461	1,298.403	1,403.961	1,497.188	1,660.442	1,736.198	1,853.863	2,080.761
VI	169.210	184.696	191.299	194.569	198.524	204.748	207.054	228.128
VII	121.992	131.445	136.445	148.823	154.058	161.150	185.353	211.066
VIII	335.024	344.175	358.891	386.724	399.363	409.815	429.243	457.223
IX	71.635	71.720	80.930	90.208	94.714	94.790	99.083	103.825
X	114.469	122.892	134.588	139.859	148.562	161.988	164.561	171.461
XI	15.268	16.391	17.787	18.310	18.966	19.171	20.974	21.792
XII	99.314	100.767	10.6642	105.489	117.937	117.493	116.391	114.999
GDP by Region	2,868.406	3,025.304	3,203.197	3,426.979	3,731.438	3,846.846	4,073.292	4,452.973
IVA,D^2,Taxes and others (**)	396.957	393.905	441.484	484.175	573.868	589.196	631.781	735.738
PIB País	3,238.003	3,419.209	3,644.681	3,911.154	4,308.306	4,436.012	4,705.073	5,188.711

Source: Banco Central de Chile
(*) Provisional Figures
(**) Otros corresponde a Servicios en el exterior del sector Administración Publica

Using the above materials, the region-separate GDP were estimated by the following procedure in 1996, 2000, 2005 and 2010:

National GDP

- As was mentioned before, the Chilean economy has displayed steady growth over the last ten years, with the GDP growing at an average of 7.4% per year in the five years between 1990 and 1995.

- Whether or not the economy can sustain this growth will in some part depend on trends in the world economy. However, according to figures published by the IMF, the capital formation vs. GDP ratio remained around the high level of 26% between 1990 and 1995 and the savings vs. GDP ratio, which supports the capital formation, also remained consistently high at above 22% over the same period. When the flow of foreign capital into the country is steady, it is considered that the economic environment in Chile is conducive to sure and continued growth in the future.

- This view was shared by an economic analyst of Naciones Unidas (Cepal) in an unofficial exchange of opinions. Therefore, based on this view, the future annual rate of growth of the Chilean economy has been estimated as follows:
  1996-2000 Upper limit 6.0% - Lower limit 4.0%
  2000-2010 Upper limit 5.0% - Lower limit 3.0%

- For the purposes of this study, the following intermediate points of the above figures shall be utilized as the future economic growth rates:
  1996-2000 5.0%
  2000-2010 4.0%

- Furthermore, regarding the growth rate in 1995-1996, the central forecast of 7.0% published by Banco Central de Chile has been adopted.

Regional GDP

- Regarding forecast of the regional distribution of GDP, because no materials relating to regional development and growth trends could be obtained, there is no choice but to assume that the development and growth that occurred between 1985 and 1992 will continue at the same pace. Thus, the future region-separate GDP was estimated by:

  ① first obtaining time series trend values between 1985-1992 for each region from the previously given Table 2.3.2 (region-separate GDP for 1985-1992),
  ② finding each region's share of that total trend value, and then
  ③ distributing the Chile national GDP figures forecast in ① above according to those regional shares.

The future region-separate GDP values that were forecast through this procedure are shown in Table (2) of **Appendix I-4 (Volume 3/8)**.

(3) Vehicle Ownership

Based on materials for the period between 1990 - 1995 provided by the INE, forecasts of the number of automobiles owned were carried out for the years 2000, 2005 and 2010 by the method described below classified by the four automobile types of ordinary car (automobil), freight automobile (camioneta), buses and other vehicles (otras).

National Future Forecast

1) Ordinary Cars (Automobil)

- Assuming that the ownership of ordinary cars correlates to GDP divided by population, i.e. the per capita regional GDP, actual data from 1990-1995 was used to set and analyze a correlation formula. As the result, a correlation coefficient of 0.9897 was confirmed.
- Then, by substituting the earlier forecast values for GDP and population into the correlation formula, the future level of ordinary car ownership was estimated.

Correlation formula: Yt = 4.0 x 10^5 (GDP t/Population t)$^{1.2633}$
where, $R^2 = 0.9897$
Yt = Automobil ownership in t year
GDP t: = GDP in t year
Population t: Population in t year

2) Freight Vehicles (Camioneta)

- Assuming that the ownership of freight automobiles correlates to GDP, actual data from 1990-1995 was used to set and analyze a correlation formula. As the result, a correlation coefficient of 0.9939 was confirmed.
- Then, by substituting the earlier forecast values for GDP into the correlation formula, the future level of freight automobile ownership was estimated.

Correlation formula: Yt = 0.0005 (GDP t)$^{1.3338}$
where, $R^2 = 0.9939$
Yt = Camioneta ownership in t year
GDP t = GDP in t year

3) Buses

- Assuming that the ownership of buses correlates to population, actual data from 1990-1995 was used to set and analyze a correlation formula. As the result, a correlation coefficient of 0.9803 was confirmed.
- Then, by substituting the earlier forecast values for population into the correlation formula, the future level of bus ownership was estimated.

Correlation formula: Yt = 8.0 x 10^{-41} (Population t)$^{6.2399}$
where, $R^2 = 0.9803$
Yt = Bus ownership in t year
Population t = Population in t year

4) Other Vehicles (Otros)

- Regarding other vehicles (motorcycles, etc.), future ownership was forecast by estimating a time series trend based on actual data from 1990 to 1995.

Region-separate Future Forecast:

- Regarding the forecast of the future ownership of all types of vehicles by region, hypothetical values were obtained for 2000, 2005 and 2010 by forecasting time series trends based on actual region-separate figures for 1990 to 1995, and the share of each region in each of those years was calculated.

- Following that, taking the aforementioned national forecasts of vehicle ownership to be a control total value, this was distributed among the regions according to the said share of each to estimate the region-separate forecast values.

Commune-separate Future Forecast:

- Regarding the further distribution of the regional forecasts between the communes, this was carried out by making estimates based on the share in terms of actual vehicle ownership of the communes within the regions in 1995. (This estimation was only carried out for IX region.)

- The forecast values of future vehicle ownership obtained through the above procedures are indicated in Table (3) and (4) of **Appendix I-4 (Volume 3/8)**.

2.4 TRAFFIC SURVEY

2.4.1 Procedure of the Survey

(1) Data Source

MOP has conducted traffic censuses every two years and the latest available traffic census data were those of 1994. A supplementary traffic survey was carried out by the Study Team to complement the above traffic censuses.

(2) Objective and Process of the Survey

Objectives of the survey are:

- to define Road Link for the traffic survey and for grouping neighboring bridges as a project unit of the rehabilitation plan,
- to estimate of traffic volume on each Road Link at present and in the future (target year 2005), and
- then, to work out a benefit-cost ratio indicator which is one of rehabilitation priority appraisal indices, where the estimated traffic volume represents a benefit.

The traffic of the rural road has the following characteristics :

- Traffic volume is small but fluctuates by season.
- Through traffic is rare and trip length is short.

Therefore, each region or commune is defined as an independent zone for traffic study. No in- and out-flow traffics from/to other zones are considered.

Process of the traffic survey is illustrated below.

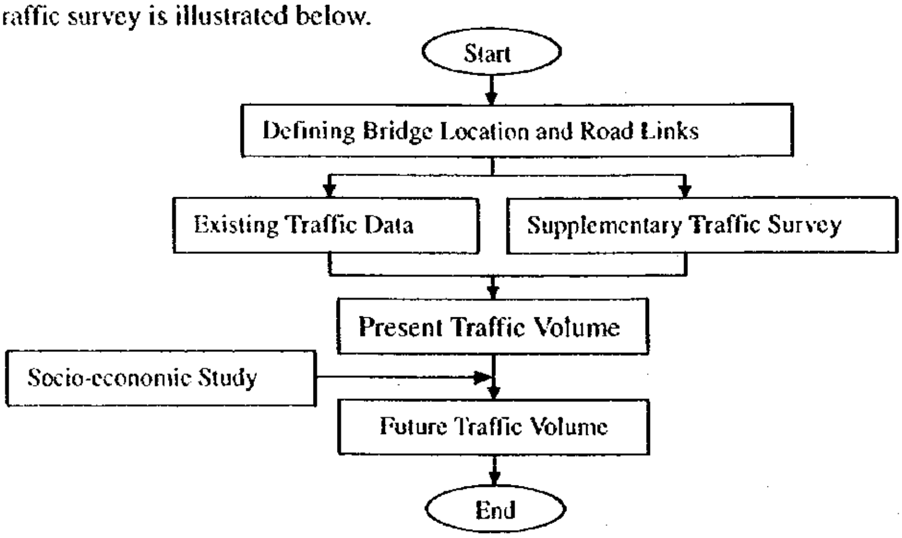


Figure 2.9 Process of Traffic Survey

(3) Defining of Bridge Location and Road Links

"Road Link" is defined as an elementary unit of road network between two adjacent intersections without any branch in it, where uniform traffic volume is assumed.

Bridge location and Road Links are defined in such procedure as follows:

Step 1	Prepare a MOP road map of a region(s = 1/250000).
Step 2	Plot bridge location on the map and define road links.
Step 3	Plot existing traffic(census 1994) data points and define the Road Links not covered by the census.
Step 4	Decide points for supplementary traffic survey.

Figure 2.10 shows the sample result of the above procedure practiced for the model survey in Region IX.

2.4.2 Estimate of Present Traffic Volume

(1) Existing Traffic Data

Existing and usable data are the traffic census in 1992 and 1994 conducted by the MOP. The census has been carried out in three seasons (summer, winter and spring) every two years at intersections of major roads nation wide in the country, by seven vehicle types of sedan, small truck, two-axle truck, over-two-axle truck, semi-trailer truck, full trailer truck, and bus/taxi-bus. The main parts of the census are 12-hour traffic data. 24-hour data and 12-to-24 hour traffic ratio are also given at several points in each region.

From the census, the following traffic data are collected:

- 12-hour traffic data of seven vehicle types in four seasons of 1994.
- 12-to-24 hour traffic ratio (hereinafter referred to as 12/24 ratio) in 1994.
- seasonal-to-annual average traffic ratio (hereinafter referred to as S/A ratio) in 1994.
- rate of traffic increase from 1992 to 1994.

The census traffic data of seven vehicle types are unified into three types of passenger cars, trucks and bus/taxi. The census traffic volumes of 1994 are converted into the present figures of 1996 by multiplying the rate of the past traffic increase from 1992 to 1994 of the census. 12-hour traffic data are modified to 24-hour (daily) traffic by multiplying 12/24 ratio to the 12-hour traffic. Daily (24-hour) traffic data in three seasons are averaged to convert to annual average daily traffic (hereinafter referred to as AADT).

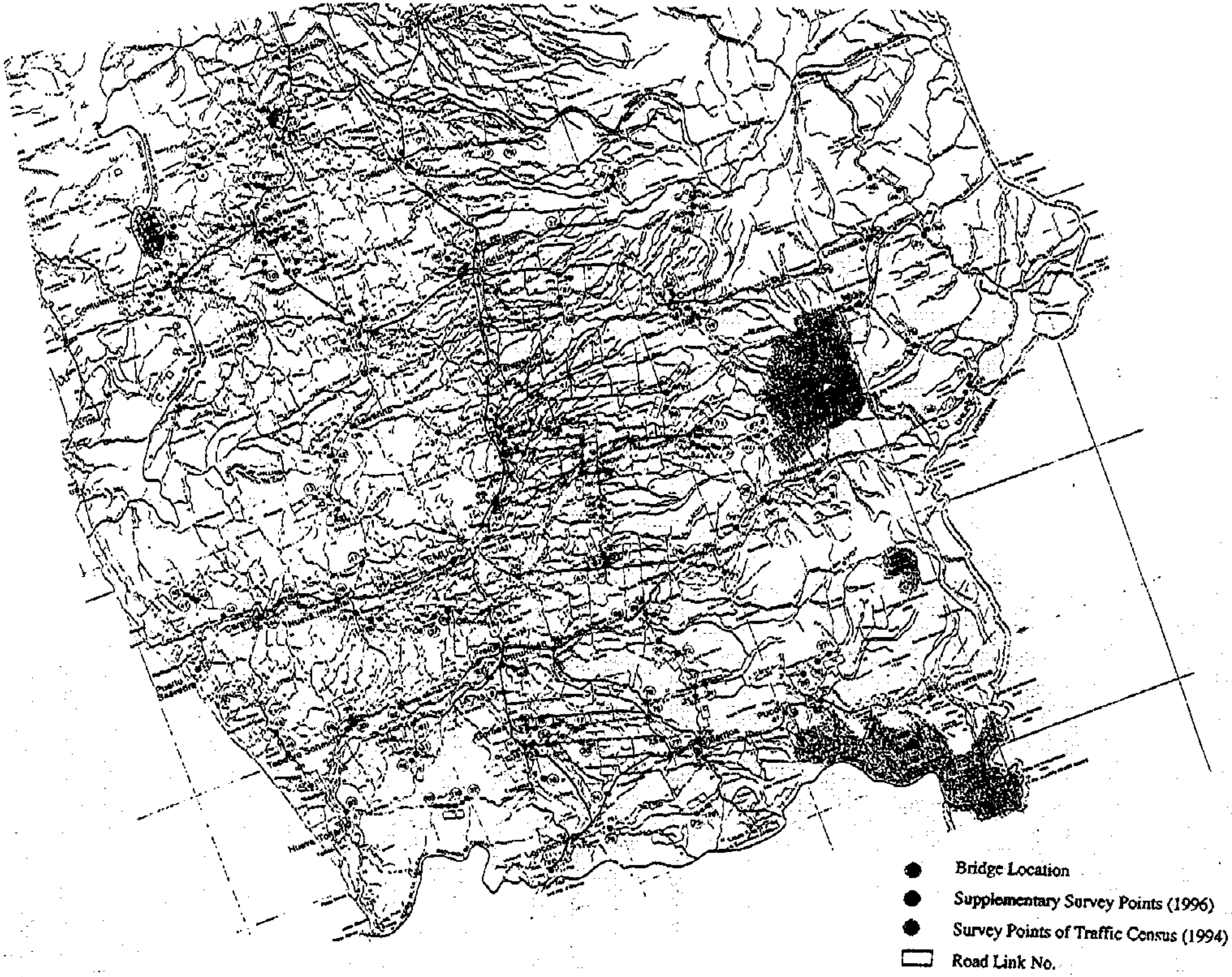


Figure 2.10 Location of Bridges, Road Links, Traffic Census and Survey Points

(2) Supplementary Traffic Survey

At the points defined in Step 4, supplementary traffic survey was carried out in the following way:

- Vehicle types are passenger car, truck and bus/taxi.
- 12-hour traffic be counted between 7:00 and 19:00 on week days.

The results of supplementary traffic survey (a seasonal and 12-hour data) are converted into AADT by applying the 12/24 ratio and S/A ratio in 1994 of the census.

(3) Summary of Present Traffic Volume

In **Table 2.6**, the present (1996) AADT in Region IX derived from both the traffic census (1994) and the supplementary traffic survey, is summarized.

Table 2.6 Present (1996) Traffic Volume in Region IX

Vehicle Types : A = Passenger Car, B = Truck, C = Bus/Taxi
Data Source : Cen.i = Census(1994) Point i, Sup.i = Supplementary Survey Point I
(number of vehicles)

Road Link No.	Bridge No.	12-Hour Traffic Volume				24-Hour Traffic Volume			AADT(1996)		
		A	B	C	Data Source	A	B	C	A	B	C
1	74	3	44	3	Sup.1	4	60	4	4	56	4
2	92	3	44	3	Sup.1	4	60	4	4	56	4
2	93										
3	86	3	44	3	Sup.1	4	60	4	4	56	4
4	98	1,626	245	189	Sup.2	2,309	333	253	2,168	313	238
5	67	3	27	4	Sup.3	4	37	5	4	34	5
5	68										
6	51	3	34	0	Sup.6	4	46	0	4	43	0
7	50	3	34	0	Sup.6	4	46	0	4	43	0
8	70	2	123	2	Sup.5	3	167	3	3	157	3
9	69	1	120	2	Sup.5	1	163	3	1	153	3
10	59	2	15	0	Sup.9	3	20	0	3	24	0
10	61										
10	62										
11	58	2	15	0	Sup.9	3	20	0	3	24	0
11	60										
12	79	4	46	3	Sup.7	6	63	4	7	75	5
13	52	4	46	3	Sup.7	6	63	4	13	146	9
13	53										
13	54										
13	55										
14	100	30	45	2	Cen.16				34	51	2
15	56	7	98	3	Sup.10	10	133	4	12	159	5
16	95	13	49	1	Cen.23				15	56	1
17	66	6	110	1	Sup.11	9	150	1	10	178	2
18	47	42	105	7	Cen.21				48	120	8
19	71	106	214	9	Cen.21				121	244	10
20	72	3	42	1	Sup.12	4	55	1	4	58	1
21	73	3	42	1	Sup.12	4	55	1	4	58	1
22	63	1	10	0	Sup.17	1	13	0	4	33	0
22	64										
23	80	22	29	0	Sup.14	31	38	0	24	30	0
24	65	2	24	11	Sup.15	3	31	14	5	57	24
25	57	8	95	13	Sup.16	11	125	16	20	224	29
26	81	6	97	0	Sup.18	8	127	0	9	142	0
27	82	0	4	0	Sup.46	0	5	0	0	6	0
27	83										
28	84	0	4	0	Sup.46	0	5	0	0	6	0
29	87	1	5	0	Sup.19	1	7	0	2	7	0
29	88										
30	89	1	5	0	Sup.19	1	7	0	2	7	0
31	78	10	119	2	Sup.13	14	156	2	74	830	13
32	45	58	100	8	Cen.36				67	114	10
33	13	58	100	8	Cen.36				67	114	10
34	12	58	100	8	Cen.36				67	114	10
35	1	5	110	5	Sup.22	8	127	5	16	272	11
35	2										
36	3	3	28	0	Sup.23	4	38	0	8	81	0
37	90	1	11	2	Sup.24	1	15	2	1	12	2
38	91	1	9	2	Sup.24	1	12	2	1	10	2
39	10	59	100	2	Cen.58				67	114	2
39	11										

40 40 40	4 5 6	22	61	0	Cen.58				25	70	0
41	7	1	5	0	Sup.41	1	7	0	1	7	0
42 42	8 9	1	5	0	Sup.41	1	7	0	1	7	0
43	101	33	59	3	Cen.56				38	67	3
44	102	2	32	2	Sup.26	2	43	2	2	31	2
45	31	1	10	0	Sup.27	1	14	0	1	10	0
46	30	1	17	1	Sup.27	1	23	1	1	16	1
47	35	63	139	20	Cen.8				72	158	23
48	36	10	123	11	Sup.29	13	167	13	11	143	11
49 49	37 38	4	48	8	Sup.29	5	65	9	4	56	8
50	39	10	108	13	Sup.28	13	146	15	11	125	13
51	99	8	80	6	Sup.31	13	121	14	24	221	25
52	43	7	99	7	Sup.45	11	90	6	11	95	7
53	42	8	96	4	Sup.45	9	111	7	10	118	8
54	44	8	80	6	Sup.31	11	108	4	21	210	8
55	46	12	129	11	Sup.31	11	90	6	21	175	12
56 56	15 16	3	35	0	Sup.35	16	145	12	14	129	10
57	17	4	45	4	Sup.35	5	54	5	5	48	5
58	18	12	144	9	Sup.33	16	173	12	14	154	11
59 59	19 20	7	89	1	Sup.34	9	107	1	8	95	1
60	29	50	75	6	Cen.69				57	86	7
61	22	2	37	2	Sup.36	3	44	3	6	101	6
62	24	10	119	20	Sup.37	14	143	26	31	324	60
63	21	14	161	24	Sup.37	19	194	32	43	438	72
64	32	3	46	5	Sup.39	4	55	7	6	87	10
65	34	3	36	0	Sup.40	4	43	0	6	68	0
66 66	33 85	3	25	1	Sup.47	4	30	1	6	47	2
67	77	2	14	0	Sup.47	3	17	0	26	161	0
68 68	75 76	2	14	0	Sup.47	3	17	0	26	161	0
69 69	96 97	3	34	0	Sup.20	4	41	0	39	391	0
70	94	11	103	1	Sup.21	15	124	1	142	1,185	13
71 71	48 49	11	103	1	Sup.21	15	124	1	142	1,185	13
72	23	78	99	17	Cen.77				89	113	19
73	28	6	65	0	Sup.38	8	78	0	39	372	0
74	27	6	65	0	Sup.38	8	78	0	39	372	0
75 75	25 26	45	141	10	Cen.75				51	161	11
76	103-110	3	28	2	Sup.32	4	34	3	4	36	3
77 77	40 41	18	242	6	Sup.44	24	291	8	38	450	12
78	14	2	34	0	Sup.25	3	41	0	3	48	0

2.4.3 Forecast of Future Traffic Volume

(1) Use of Socioeconomic Data (population and vehicle ownership number)

For the formulation of future traffic forecast, it is assumed that:

- The private and commercial traffic (passenger car and truck) demand will increase in proportion with the growth of the vehicle ownership numbers in a community, considering the characteristics of rural road traffic as mentioned above.
- The public traffic (bus/taxi) demand will increase in proportion with the growth of the population in a community.

Forecast was made based on the AADT (1996) estimated in the previous **Chapter 2.4.2**, by multiplying the ratio of increase of population and vehicle ownership number from 1996 to 2005.

The population and vehicle ownership number of 1996 and 2005 in each region are already given in **Chapter 2.3** of this report. Such data of commune or district level can be obtained by breaking down the regional data following the method explained in the chapter. A sample of breaking down the data into the commune level in the Region IX (model survey) was given.

The formula applied to forecast are:

For passenger car and truck

$$\text{AADT (2005)} = \text{AADT (1996)} \ \text{X} \ \frac{\text{Vehicle Ownership Number(2005)}}{\text{Vehicle Ownership Number(1996)}}$$

For bus/taxi

$$\text{AADT (2005)} = \text{AADT (1996)} \ \text{X} \ \frac{\text{Population (2005)}}{\text{Population (1996)}}$$

(2) Summary of Future Traffic Volume

In **Table 2.7**, the future (2005) AADT in Region IX is summarized. In the region, the increase of population in most communes is insignificant, so that the AADT (2005) of bus/taxi is actually assumed unchanged from the AADT (1996).

Table 2.7 Future (2005) Traffic Volume in Region IX

Vehicle Types : A = Passenger Car, B = Truck, C = Bus/Taxi (number of vehicles)

Road	Bridge	Vehicle Ownership Number (1996)			Vehicle Ownership Number (2005)			Ratio of Ownership Number	AADT (1996)			AADT (2005)		
Link No.	No.	A	B	A+B	A	B	A+B	2005 / 1996	A	B	C	A	B	C
1	74	13	17	30	19	27	46	1.52	4	56	4	6	86	4
2	92	22	17	39	35	30	65	1.64	4	56	4	7	92	4
2	93	22	17	39	35	30	65	1.64				0	0	
3	86	51	39	90	79	69	148	1.64	4	56	4	7	92	4
4	98	43	33	76	67	58	125	1.64	217	2,181	238	356	3,575	238
5	67	56	43	100	88	76	164	1.64	4	34	5	7	57	5
5	68	56	43	100	88	76	164	1.64				0	0	
6	51	37	50	87	55	84	139	1.61	4	43	0	6	70	0
7	50	97	131	228	145	221	366	1.61	4	43	0	6	70	0
8	70	23	31	55	35	53	88	1.61	3	157	3	4	252	3
9	69	47	63	110	70	106	176	1.61	1	153	3	2	246	3
10	59	13	17	30	19	29	49	1.61	3	24	0	5	39	0
10	61	13	17	30	19	29	49	1.61				0	0	
10	62	13	17	30	19	29	49	1.61				0	0	
11	58	36	49	85	54	83	137	1.61	3	24	0	5	39	0
11	60	36	49	85	54	83	137	1.61				0	0	
12	79	85	78	163	126	120	245	1.51	7	75	5	10	112	5
13	52	15	14	28	22	21	43	1.51	13	146	9	20	220	9
13	53	47	43	91	70	67	137	1.51				0	0	
13	54	47	43	91	70	67	137	1.51				0	0	
13	55	47	43	91	70	67	137	1.51				0	0	
14	100	11	11	22	17	16	33	1.51	34	51	2	52	77	2
15	56	17	23	39	25	38	63	1.61	12	159	5	19	255	5
16	95	5	7	12	8	12	19	1.61	15	56	1	24	90	1
17	66	5	7	12	8	12	19	1.61	10	178	2	16	286	2
18	47	40	49	90	57	78	135	1.51	48	120	8	72	180	8
19	71	36	44	81	51	70	121	1.51	121	244	10	182	367	10
20	72	28	34	62	40	54	94	1.51	4	58	1	7	88	1
21	73	14	17	31	20	27	47	1.51	4	58	1	7	88	1
22	63	28	25	53	39	42	81	1.52	4	33	0	5	50	0
22	64	8	10	18	12	16	28	1.51				0	0	
23	80	18	16	34	25	27	52	1.52	24	30	0	36	45	0
24	65	109	100	209	154	165	319	1.52	5	57	24	8	86	24
25	57	161	148	309	227	244	471	1.52	20	224	29	30	340	29
26	81	43	53	96	62	86	148	1.54	9	142	0	14	219	0
27	82	9	11	19	13	17	30	1.54	0	6	0	0	9	0
27	83	9	11	19	13	17	30	1.54				0	0	
28	84	9	11	19	13	17	30	1.54	0	6	0	0	9	0
29	87	18	22	40	26	35	61	1.54	2	7	0	2	11	0
29	88	18	22	40	26	35	61	1.54				0	0	
30	89	18	22	40	26	35	61	1.54	2	7	0	2	11	0
31	78	44	48	92	64	79	143	1.55	74	830	13	114	1,283	13
32	45	18	26	44	25	42	67	1.53	67	114	10	102	174	10
33	13	71	67	139	115	123	238	1.71	67	114	10	114	196	10
34	12	71	67	139	115	123	238	1.71	67	114	10	114	196	10
35	1	140	126	266	202	207	409	1.54	16	272	11	25	418	11
35	2	140	126	266	202	207	409	1.54				0	0	
36	3	49	45	94	70	68	139	1.47	8	81	0	11	119	0
37	90	12	11	23	18	18	36	1.54	1	12	2	1	18	2
38	91	12	11	23	18	18	36	1.54	1	10	2	1	15	2

39	10	19	17	36	27	26	52	1.47	67	114	2	99	168	2
39	11	19	17	36	27	26	52	1.47				0	0	
40	4	19	17	36	27	26	52	1.47	25	70	0	37	103	0
40	5	19	17	36	27	26	52	1.47				0	0	
40	6	19	17	36	27	26	52	1.47				0	0	
41	7	19	17	36	27	26	52	1.47	1	7	0	2	11	0
42	8	19	17	36	27	26	52	1.47	1	7	0	2	11	0
42	9	19	17	36	27	26	52	1.47				0	0	
43	101	73	66	139	104	101	204	1.47	38	67	3	55	99	3
44	102	46	42	88	66	64	130	1.47	2	31	2	2	45	2
45	31	46	42	88	66	64	130	1.47	1	10	0	1	14	0
46	30	21	19	40	30	31	61	1.51	1	16	1	1	25	1
47	35	111	114	225	157	179	337	1.49	72	158	23	107	237	23
48	36	111	114	225	157	179	337	1.49	11	143	11	16	213	11
49	37	100	96	196	155	168	323	1.65	4	56	8	7	92	8
49	38	100	96	196	155	168	323	1.65				0	0	
50	39	71	67	139	115	123	238	1.71	11	125	13	19	215	13
51	99	3	11	14	5	17	22	1.55	24	221	25	38	343	25
52	43	16	51	66	22	81	103	1.55	11	95	7	18	148	7
53	42	41	133	173	56	213	269	1.55	10	118	8	15	183	8
54	44	85	98	183	142	185	327	1.79	21	210	8	37	376	8
55	46	85	98	183	142	185	327	1.79	21	175	12	37	313	12
56	15	16	18	33	22	28	49	1.48	14	129	10	21	192	10
56	16	16	18	33	22	28	49	1.48				0	0	
57	17	35	41	76	49	63	113	1.48	5	48	5	7	72	5
58	18	66	75	141	92	118	210	1.48	14	154	11	21	229	11
59	19	66	75	141	92	118	210	1.48	8	95	1	13	142	1
59	20	12	14	26	17	21	38	1.48				0	0	
60	29	81	73	155	117	118	234	1.51	57	86	7	86	129	7
61	22	58	35	93	85	56	141	1.52	6	101	6	9	153	6
62	24	43	26	68	63	41	104	1.52	31	324	60	46	493	60
63	21	130	77	207	190	125	315	1.52	43	438	72	65	666	72
64	32	70	88	158	110	144	254	1.61	6	87	10	10	139	10
65	34	58	76	134	92	126	218	1.62	6	68	0	10	110	0
66	33	16	33	49	20	53	73	1.49	6	47	2	9	70	2
66	85	16	33	49	20	53	73	1.49				0	0	
67	77	16	33	49	20	53	73	1.49	26	161	0	39	240	0
68	75	24	51	75	31	81	112	1.49	26	161	0	39	240	0
68	76	24	51	75	31	81	112	1.49				0	0	
69	96	9	19	29	12	31	43	1.49	39	391	0	58	583	0
69	97	9	19	29	12	31	43	1.49				0	0	
70	94	5	10	15	6	16	22	1.49	142	1,185	13	212	1,767	13
71	48	9	19	27	11	29	41	1.49	142	1,185	13	212	1,767	13
71	49	9	19	27	11	29	41	1.49				0	0	
72	23	104	62	166	152	100	252	1.52	89	113	19	135	172	19
73	28	22	13	35	31	23	54	1.55	39	372	0	60	578	0
74	27	81	51	132	118	86	204	1.55	39	372	0	60	578	0
75	25	118	70	188	172	113	286	1.52	51	161	11	78	245	11
75	26	118	70	188	172	113	286	1.52				0	0	
76	103 - 110	20	24	44	29	38	67	1.50	4	36	3	6	54	3
77	40	28	45	73	40	74	114	1.55	38	450	12	58	697	12
77	41	28	45	73	40	74	114	1.55				0	0	
78	14	35	32	67	50	49	99	1.47	3	48	0	5	70	0

2.5 REHABILITATION COST

2.5.1 Rehabilitation Policy

(1) Definition of Bridge Management Action

To discuss the rehabilitation policy and criteria, it is necessary to define the following often used terms:

- *Maintenance*: refers to the work to preserve the intended load carrying capacity of the bridge and safety of the public using it.
- *Repair*: refers to the maintenance work of larger scale than maintenance, aiming at restoring the bridge to the service level it originally had or was intended to have.
- *Strengthening*: refers to improving the existing load carrying capacity and/or geometry of the bridge beyond the level it originally had. 'Grade-up load carrying capacity' and 'widening the deck' are included here.
- *Reconstruction*: refers to replacement of the whole bridge, since the cost and/or the extent of repair or strengthening may be beyond the acceptable economic or technical limits.

(2) Rehabilitation Policy

In principle, the rehabilitation decision (which may vary from no action, temporary action, strengthening, to an outright displacement) of a bridge could be reached through a cost-benefit analysis. However, this approach is too elaborate and so proves to be laborious for the rehabilitation of small-scale but large number of rural bridges. A simple criteria for decision-making was, therefore, recommended in this Study based on the bridge inventory data.

1) For existing timber bridges

The basic schemes are as follows:

- Maintain the existing structures with minimum cost for their life spans but do not try to do major repair or strengthening with expenses in order to prolong their lives.
- Then, within 10 years, reconstruct them with permanent structures but never with timber again.
- Avoid partial or staged replacement with permanent structures.

The countermeasures by condition ratings are:

- The bridges rated to '1-dangerous' shall be totally demolished and reconstructed to a permanent structure. The conditions of such bridges are beyond the repairing level.

- The bridges rated to '2-potentially hazardous' shall be closed to traffic to avoid possible failure. To resume traffic, such bridges need extensive repair or strengthening works and the repairing cost is usually so high. Therefore, the option of total reconstruction to a permanent structure may be economically feasible.

- The bridges rated to '3-not functioning as originally designed' shall be repaired without delay by replacing damaged elements to recover load carrying capacity, and maintained with minimum cost as long as until they have totally deteriorated. Then, reconstruct to a permanent structure. If repairing cost is required so high as more than about 40 % of the reconstruction cost, according to the practice in the MOP, reconstruction shall be carried out in earlier stage.

- The bridges rated to '4-functioning as originally designed' do not need major repairs but minor repairs may be required to eliminate local deterioration. The bridges shall be watched to maintain the present condition as long as possible with minimum cost.

- The bridges rated to '5-good, new or like-new' need no repair action now.

Even of the bridges rated to '4' or '5' now, in the next 10 to 15 years, timber bridges will inevitably deteriorate and have to be reconstructed. Therefore, for the rehabilitation plan of timber bridges, reconstruction scheme is considered as the long term solution regardless of the present condition.

2) For existing concrete and steel bridges

The basic schemes are as follows:

- Maintain the existing structures by repairing as far as they hold the current road function (width and load carrying capacity) to economize the rehabilitation cost.

- For the bridges insufficient of width and load carrying capacity, the reconstruction scheme is recommended rather than strengthening. The reconstruction of such bridges shall be carried out in priority from the bridges rated worse. Actually, the most existing concrete or steel bridges selected for the rehabilitation plan were old (about 40 to 50 years since construction), narrow (only one lane and less wider than 4.0 m), and uncertain of designed load carrying capacity.

The countermeasures by condition ratings are:

- The bridges rated to '1-dangerous' shall be demolished and replaced with a new structure. The conditions of such bridges are beyond the repairing level.

- The bridges rated to '2-potentially hazardous' shall be closed to traffic for high risk of failure. To resume traffic, the bridges need extensive repair or strengthening works but in many cases it will be a difficult and costly work to restore the original load carrying capacity. Therefore, the reconstruction scheme is recommendable for such bridges rather than difficult repair work.

- The bridges rated to '3-not functioning as originally designed' shall be repaired not to worsen the present condition and to recover load carrying capacity. However, in case that repair cost is estimated high and life expectancy of the repaired structure is not well expected longer than 10 to 15 years, the option of total reconstruction would be an economically logical choice. If the bridges do not have sufficient width and load carrying capacity, this tendency is more significant.

- The bridges rated to '4-functioning as originally designed' do not need major repairs but minor repairs may be required to eliminate local deterioration. Such bridges shall be watched to maintain the present condition as long as possible. If the width and load carrying capacity of such bridges are not sufficient for the today's traffic, reconstruction scheme is taken account into the future rehabilitation plan.

- The bridges rated to '5-good, new or like-new' need no repair action. Such like-new bridges shall be used for a while, even if the bridges do not have sufficient width and/or load carrying capacity, to avoid doubling rehabilitation cost.

For the rehabilitation of existing concrete and steel bridges, the following points shall be considered:

- Owing to the material durability, the service-life of concrete and steel bridges (it is said over 50 years depending on structure type and maintenance) is longer than that of timber bridges.

- During such long service life, the needs of rehabilitation arise not only from the structural deterioration but rather in many cases from the change of the socio-economic and environmental condition surrounding the bridge (such as growth of traffic demand, change of river condition, etc.).

- The function of the existing bridges (such as roadway width, load carrying capacity, under-bridge clearance, etc.) will be evaluated in the light of the standard design criteria for rural bridges established in the Study, refer to **Chapter 4.3** of this report.

2.5.2 Decision of Rehabilitation Method and Scale

Based on the rehabilitation policy discussed above, the criteria to decide rehabilitation method and scale was thought out as shown in **Table 2.8** considering the following points:

- Criteria shall be clear and simple for the MOP to deal with large number of bridges.
- All the determining factors of criteria shall be comprehensive through out the country in order to be easily collected from bridge inventory.
- The results of rehabilitation decision shall match up to the current bridge rehabilitation practices of the MOP.

This criteria was actually applied to the 110 bridges in Region IX and the result was as follows:

Number of bridges:	110 bridges
Reconstruction with one lane:	62 bridges
Reconstruction with two lanes:	47 bridges
Repair:	0
No action:	1 bridge

Most bridges in the Region IX resulted in to be reconstructed, because where 97 % of the bridges inspected were timber bridges.

Table 2.8 Criteria for Rehabilitation Method and Scale

Determining Factors					Rehabilitation Method and Scale
Traffic Volume (pcu/day)	Bridge Type	Bridge Condition (damage degree)	Bridge Roadway Width (m)	Load Carrying Capacity Limit (ton)	
1 ~ 499	Timber	-	-	-	Reconstruction (one lane)
	Conc./Steel	1 and 2	-	-	
		3 and 4	< 4.0	-	
			-	< 18.0	
			≥4.0	≥18.0	Repair
		5	-	-	No action
500 ~	Timber	-	-	-	Reconstruction (two lanes)
	Conc./Steel	1 and 2	-	-	
		3 and 4	< 7.0	-	
			-	< 18.0	
			≥7.0	≥18.0	Repair
		5	-	-	No action

Note: “ - “ means unconditional.

- The traffic volume of 500 pcu/day is a dividing line for number of roadway lanes (one or two) and width (4.0 or 7.0 m).
- The load limit of 18 tons is the rounded figure of standard design live load for rural bridges.

2.5.3 Rehabilitation Cost Estimate

Following the decision of rehabilitation method and scale, estimates of rehabilitation costs were divided into bridges to be reconstructed and those to be repaired. The costs referred to for estimation are those in Chile in 1996 and 1997. It is noted that the cost estimate for the rehabilitation plan is based on a rough and simple assumption with limited accuracy.

(1) Reconstruction Cost

1) Method of estimation

Reconstruction cost consists of the costs for construction of bridge, approach road, and bank protection.

The cost of bridge was calculated by multiplying surface area of bridge by construction unit cost per square meter. The construction unit cost was presumed assuming pre-stressed concrete bridge, based upon examples of the MOP's 1997 bridge construction orders, taking account of the results of cost estimates for the sample bridge rehabilitation design of the Study. The surface area of bride was calculated by multiplying standard bridge width (one or two lane) by existing bridge length.

For the cost of approach road and bank protection, a certain amount was set aside for 100 meters (single lane or double lane) of approach road and 50 meters of bank protection on both banks.

2) Unit reconstruction costs

The reconstruction unit costs adopted are summarized in **Table 2.9**. The breakdowns of unit bridge and approach road costs are presented in **Appendix I-5 (Volume 3/8)**.

Table 2.9 Reconstruction Unit Cost

	One lane	Two lane
Bridge cost	512,000 pesos/m^2	
Approach road cost	39,000,000 pesos/bridge	45,800,000 pesos/bridge
Bank protection cost	2,300,000 pesos/bridge	

3) Cost calculation

A simple "Excel" program was prepared to do cost calculation for a large number of bridges. **Table 2.10** shows a part of the cost calculation for the bridges in Region IX with the explanation of calculation process. Full calculation results for 110 bridges in the region are presented in **Appendix I-6 (Volume 3/8)**.

Table 2.10 Reconstruction Cost Calculation (Region IX)

1	2	3	4	5	6	7	8	9	10	11
Bridge				Bridge Length (m)	Number of Lanes	Bridge Cost		Approach Road Cost (x 1,000 pesos)	River Protection Cost (x 1,000 pesos)	Total Cost (x 1,000 pesos)
Link No.	Bridge No.	Comune Name	Bridge Name			Bridge Area (m2)	Cost (x 1,000 pesos)			
35	IX-001	LAUTARO	NIBLINTO	24.80	2	233.12	119,400	45,800	2,300	167,500
35	IX-002	LAUTARO	MUCOBAJO	34.50	2	324.30	166,000	45,800	2,300	214,100
36	IX-003	VILCUN	QUINTRILPE	10.00	1	60.00	30,700	39,000	2,300	72,000
40	IX-004	VILLARRICA	LLAMUCO	22.00	1		-	39,000	2,300	41,300
40	IX-005	VILLARRICA	PEDREGOSO	16.50	1	99.00	50,700	39,000	2,300	92,000
40	IX-006	VILLARRICA	CALBUCO	13.00	1		-	39,000	2,300	41,300
41	IX-007	VILLARRICA	ELTIGRE	19.50	1	117.00	59,900	39,000	2,300	101,200
42	IX-008	VILLARRICA	CHOME2	10.00	1		-	39,000	2,300	41,300
42	IX-009	VILLARRICA	ELSALTO	11.70	1	70.20	35,900	39,000	2,300	77,200
39	IX-010	VILLARRICA	LANI	21.80	2		-	45,800	2,300	48,100

Input ← → Output

Calculation Process

Input Data

Column 1: Road link No. where the bridge is

Column 2: Region No. first and followed by bridge No.

Column 3: Name of Comune where the bridge is.

Column 4: Name of the birdge.

Column 5: Existing bridge length from inventry.

Column 6: Number of roadway lanes according to the criteria for rehabilitation method and scale.

Output Data

Column 7: = Column:5 x Standard bridge width (6.0m for one lane and 9.4m for two lane)

Column 8: = Column:7 x Construction unit cost (512,000 pesos/m2)

Column 9: Fixed costs (39,000,000 pesos/bridge for one lane and 45,800,000 pesos/bridge for two lane)

Column 10: Fixed costs (2,300,000 pesos/bridge)

Column 11: = Column 8 + Column 9 + Column 10

(2) Repair Cost

1) Method of estimation

For repair costs, unit cost per square meter of repairing area according to type of damage was set and multiplied with damaged area ratio and surface area of super- and substructure. The damaged area ratio is defined as the percentage of damaged area requiring repair to total area of structure.

2) Unit repair costs

Unit repair cost was prepared for each damage type being divided into superstructure and substructure, and by the bridge material types namely concrete, steel and timber.

For the repair of concrete bridge, there are various repair methods for a damage, therefore to make it simple, average cost was computed for each damage type through the data obtained from the repair designs in **Chapter 3.4.2.** For timber bridge, the principal repair method is replacement of damaged members. Therefore, the timber repair cost was estimated from the costs provided by the Mop. For steel bridge, the principal repair method is repainting for rust.

Table 2.11 shows major unit repair costs thus estimated, and their breakdowns are presented in **Appendix I-5 (Volume 3/8)**.

Table 2.11 Repair Unit Costs by Damage Type

(pesos/m^2)

Damage Code	Kind of Damages	Superstructure			Substructure		
		Concrete	Steel	Timber	Concrete	Steel	Timber
BR	Breakage/Fallout	12,400	31,600	25,800	8,800	26,500	18,000
CO	Corrosion/Decay	9,900	13,600	25,800	9,300	12,400	18,000
CR	Crack	47,000	29,400	25,800	25,300	24,500	18,000
DH	Deformation		552,600			473,800	
ER	Erosion/Scouring					40,000	
FI	Fire			25,800			18,000
IN	Inclination				depend on site condition		
NF	Poor function	depend on site condition					
SC	Scaling	12,400			8,800		
SE	Settlement				depend on site condition		
SL	Sliding				depend on site condition		
SP	Spalling	9,300			6,500		
WE	Surface wearing	13,200			13,000		

4) Damaged area ratio

Damaged area ratio is required to be input together with damage code to compute repair cost for each superstructure and substructure. The repair cost is defined as the following formula:

Repair Cost = (Structure Area) x (Unit Cost) x (Damaged Area Ratio)
where, Structure Area = (Bridge Width) x (Span Length or Substructure Height)

5) Cost calculation

"Excel" program was prepared also for the calculation of repair cost. **Table 2.12** shows a part of the cost calculation for the bridges in Region IX with the explanation of calculation process. Full calculation results for 110 bridges in the region are presented in **Appendix I-6 (Volume 3/8)**.

However, the repair costs estimated for Region IX were not actually used for the rehabilitation planning, because no repair case was selected in the region.

Table 2.12 Repair Cost Calculation (Region IX)

Calculation Process

(1) Input Dimension Data

1	2	3	4	5							6
Bridge				Span Length and Substructure Height							Bridge Width (m)
Link No.	Bridge No.	Commune Name	Bridge Name	Abutment A1	A1-P1 Span	Pier P1	P1-P2 Span	Pier P2	P2-P3 Span	Abutment A2	
35	IX-001	LAUTARO	NIBLINTO	2.50	8.30	4.50	8.00	4.50	8.50	2.50	4.00
35	IX-002	LAUTARO	MUCOBAJO	4.50	7.20	9.00	20.00	9.00	7.30	4.50	4.15
36	IX-003	VILCUN	QUINTRILPE	5.00	10.00					5.00	3.60
40	IX-004	VILLARRICA	LLAMUCO	5.00	22.00					5.00	4.40
40	IX-005	VILLARRICA	PEDREGOSO	3.30	8.50		8.00			3.30	3.70
40	IX-006	VILLARRICA	CALBUCO	1.15	3.00	3.40	10.00			1.15	3.95

Column 1: Road link No. where the bridge is.
Column 2: Region No. first and followed by bridge No.
Column 3: Name of Commune where the bridge is.
Column 4: Name of the bridge.
Column 5: Span length and substructure height from inventory.
Column 6: Bridge width from inventory.

(2) Input of Damage Code and Damaged Area Ratio for Superstructure

1	2	7										
Bridge		Damage Code and Damaged Area Ratio of Superstructure										
Link No.	Bridge No.	A1-P1						P1-P2		P8-A2		
		Concrete	D. Ratio	Steel	D. Ratio	Timber	D. Ratio	Concrete	D. Ratio	D. Ratio	Timber	D. Ratio
35	IX-001		0.60		1.00	BR	0.40		0.60	0.40		0.40
35	IX-002		0.60		1.00	CO	0.40		0.60	0.40		0.40
36	IX-003		0.60		1.00	CO	0.40		0.60	0.40		0.40
40	IX-004		0.60	CO	1.00		0.40		0.60	0.40		0.40
40	IX-005		0.60		1.00	CO	0.40		0.60	0.40		0.40
40	IX-006		0.60		1.00	CO	0.40		0.60	0.40		0.40

Column 7: Damage code and damaged area ratio of superstructure from inspection.

(3) Unit Repair Cost for Superstructure

1	2	8										
Bridge		Unit Repair Cost for Damage of Superstructure										
Link No.	Bridge No.	A1-P1			P1-P2			P2-P3		P8-A2		
		Concrete	Steel	Timber	Concrete	Steel	Timber	Concrete	Steel	Concrete	Steel	Timber
35	IX-001	0	0	25,800	0	0	25,800	0	0	0	0	0
35	IX-002	0	0	25,800	0	0	25,800	0	0	0	0	0
36	IX-003	0	0	25,800	0	0	0	0	0	0	0	0
40	IX-004	0	13,600	0	0	0	0	0	0	0	0	0
40	IX-005	0	0	25,800	0	0	25,800	0	0	0	0	0
40	IX-006	0	0	25,800	0	0	25,800	0	0	0	0	0

Output
Column 8: Unit repair cost by damage.

(4) Output of Repair Cost for Superstructure

1	2	9										10
Bridge		Repair Cost of Superstructure										Total of Super-structure
Link No.	Bridge No.	A1-P1			P1-P2			P2-P3		P8-A2		
		Concrete	Steel	Timber	Concrete	Steel	Timber	Concrete	Steel	Steel	Timber	
35	IX-001	0	0	342,624	0	0	330,240	0	0	0	0	1,023,744
35	IX-002	0	0	308,362	0	0	856,560	0	0	0	0	1,477,566
36	IX-003	0	0	371,520	0	0	0	0	0	0	0	371,520
40	IX-004	0	1,316,480	0	0	0	0	0	0	0	0	1,316,480
40	IX-005	0	0	324,564	0	0	305,472	0	0	0	0	630,036
40	IX-006	0	0	122,292	0	0	407,640	0	0	0	0	529,932

Column 9: Repair cost for each span = Column 5 x Column 6 x Column 8 x Damage ratio(in Column7)
Column 10: Total repair cost for superstructure.

(5) Input of Damage Code and Damaged Area Ratio for Substructure

1	2	11										
Bridge		Damage Code and Damaged Area Ratio of Substructure										
Link No.	Bridge No.	A1						P1				
		Concrete	D. Ratio	Steel	D. Ratio	Timber	D. Ratio	Concrete	D. Ratio	Steel	Timber	D. Ratio
35	IX-001		0.005		1.0		0.4		0.005			0.4
35	IX-002		0.005		1.0		0.4	SP	0.005			0.4
36	IX-003		0.005		1.0	CO	0.4		0.005			0.4
40	IX-004		0.005		1.0		0.4		0.005		CO	0.4
40	IX-005		0.005		1.0		0.4		0.005		CO	0.4
40	IX-006		0.005		1.0		0.4		0.005			0.4

Column 11: Damage code and damaged area ratio of substructure from inspection.

(6) Unit Repair Cost for Substructure

1	2	12										
Bridge		Unit Repair Cost for Damage of Substructure										
Link No.	Bridge No.	A1			P1			P2			A2	
		Concrete	Steel	Timber	Concrete	Steel	Timber	Concrete	Steel	Timber	Steel	Timber
35	IX-001	0	0	0	0	0	0	0	0	0	0	0
35	IX-002	0	0	0	6,500	0	0	6,500	0	0	0	0
36	IX-003	0	0	18,000	0	0	0	0	0	0	0	0
40	IX-004	0	0	0	0	0	0	0	0	0	0	18,000
40	IX-005	0	0	0	0	0	18,000	0	0	0	0	18,000
40	IX-006	0	0	0	0	0	0	0	0	0	0	0

Output

Column 12: Unit repair cost by damage.

(7) Output of Repair Cost for Substructure, and Total Cost of Super-and Substructure

1	2	13									14	15
Bridge		Repair Cost of Substructure									Total of Sub-structure	Total of Repair Cost
Link No.	Bridge No.	A1			P1			P2				
		Concrete	Steel	Timber	Concrete	Steel	Timber	Concrete	Steel	Timber		
35	IX-001	0	0	0	0	0	0	0	0	0	0	1,023,744
35	IX-002	0	0	0	2,428	0	0	2,428	0	0	4,856	1,482,422
36	IX-003	0	0	129,600	0	0	0	0	0	0	129,600	501,120
40	IX-004	0	0	0	0	0	0	0	0	0	158,400	1,474,880
40	IX-005	0	0	0	0	0	0	0	0	0	87,912	717,948
40	IX-006	0	0	0	0	0	0	0	0	0	0	529,932

Column 13: Repair cost for each substructure = Column 5 x Column 6 x Column 12 x Damage ratio(in Column11).

Column 14: Total repair cost for substructure.

Column 15: Total of super-and substructure repair costs = Column 10 + Column 14