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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

SUMMARY

(VOLUME 1/8)

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.

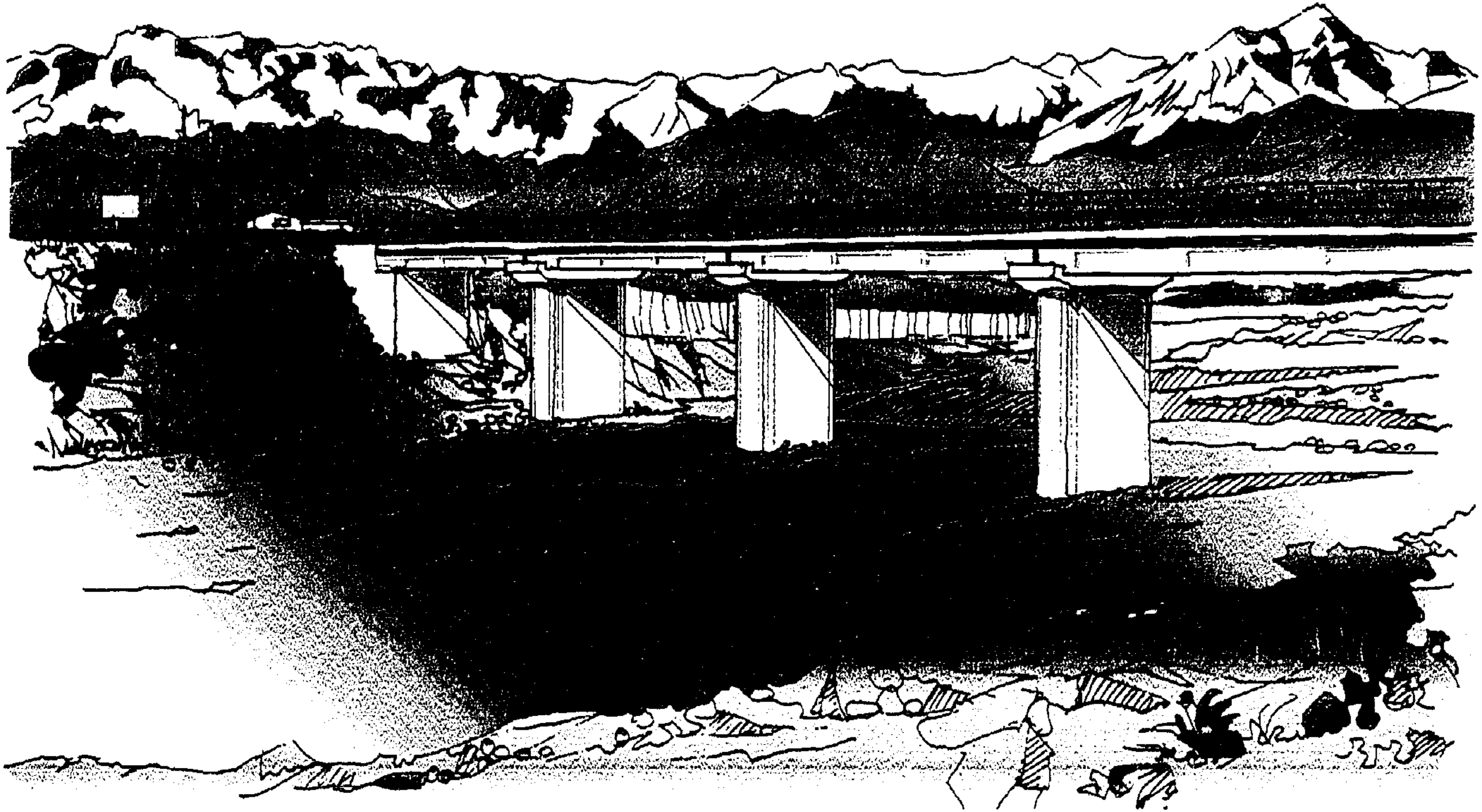
The study was carried out by Pacific Consultants International from September 1996 to March 1998 to work out rehabilitation plan, sample rehabilitation design, and standard bridge CADD program for the rural road bridges in Chile, based on the terms of references drawn up by the Japan International Cooperation 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.

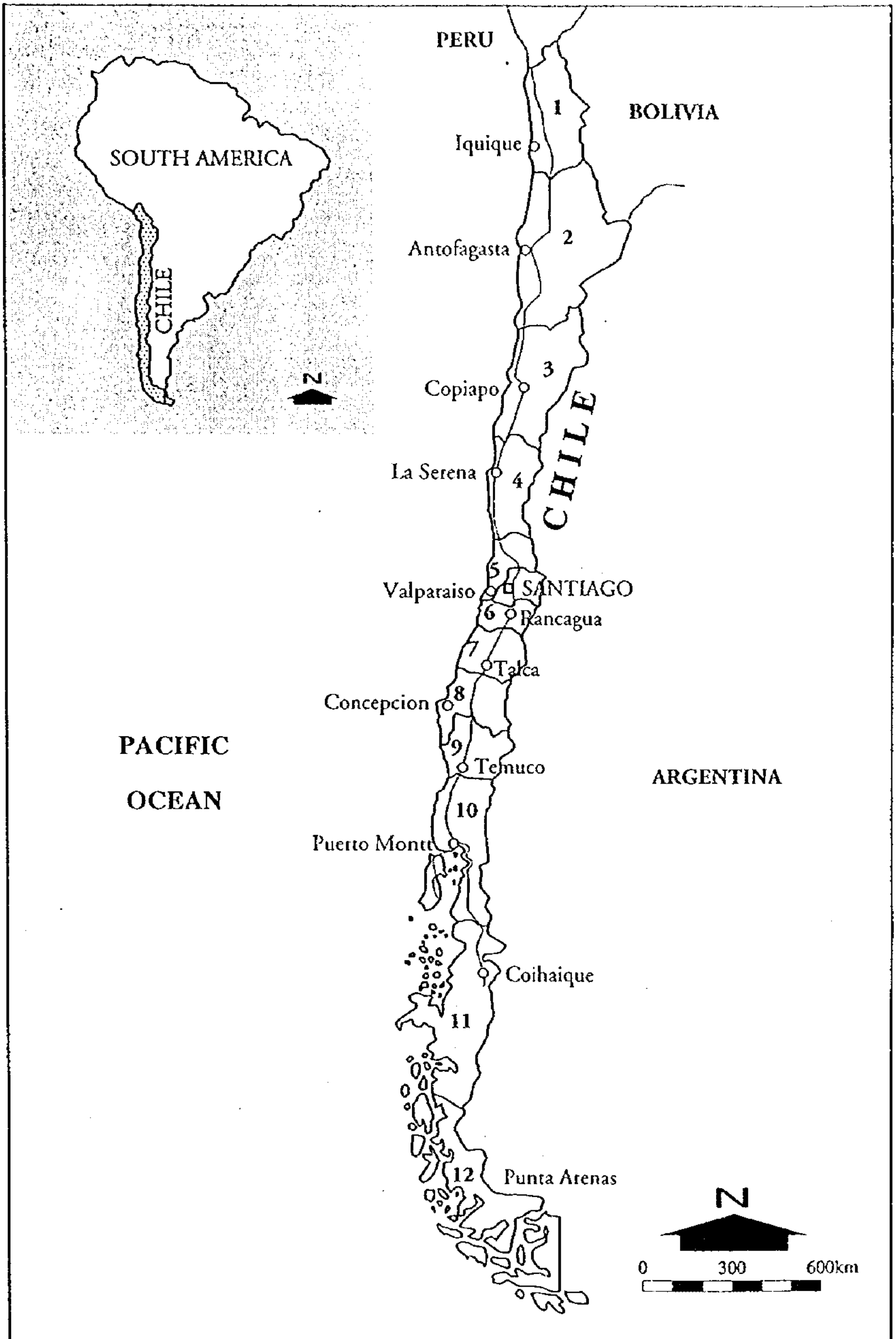
We wish to express our thanks to the JICA, the MOP, the Embassy of Japan in Chile for their cooperation given to us in the course of the study.

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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Puerto Montt
Coihaique
11
12
Punta Arenas
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MAP OF CHILE

VOLUME 1/8 SUMMARY

PREFACE

LOCATION MAP

CONTENTS

1. ESSENTIAL POINTS

1. ESSENTIAL POINTS

1. Circumstances of the Study

In response to the request of the Government of the Republic of Chile (hereinafter referred to as 'GOC'), the Government of Japan (hereinafter referred to as '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 GOC and GOJ in 1978. Based on this decision, the Japan International Cooperation Agency (hereinafter referred to as 'JICA') formed a survey team (hereinafter referred to as 'the Study Team') and commenced with the Study in August 1996. The team was sent to Chile in September the same year to discuss the Inception Report and presented this Final Report in July 1998 after four separate surveys in Chile.

2. Background of the Study

The bridges in the Study are categorized as rural bridges in Chile, and are mostly quite small in scale though great in number (about 8000). Most of them are heavily deteriorated timber bridges, especially in Regions VIII, IX and X. Very little traffic was surveyed at most bridge sites, but the ratio of heavy vehicles (lumber and mining transport) was quite high on the roads, and safety is being guarded by the fixing of load limits on the bridges. The MOP (Ministry of Public Works) intends to gradually replace about 1000 bridges of higher urgency with permanent bridges (concrete or steel) as the first phase.

3. Purpose of the Study

The Study is intended as a form of technical cooperation with the MOP for the rehabilitation of the 1000 bridges mentioned above. The purposes of the Study were:

(1) To establish rehabilitation plan for 1000 bridges on rural roads,

(2) To prepare sample rehabilitation designs for 20 bridges, and

(3) To develop standard bridge CADD (computer aided design and drafting) program and design drawings.

4. Scope of the Study

Scope of the Study included the followings:

(1) Rehabilitation plan

Through a survey of Region IX, the procedure of rehabilitation planning was determined and made known to the concerned person in the MOP. The contents of the planning procedure include the following surveys:

- Bridge inspection and inventory preparation.
- Traffic survey and socioeconomic indices (GDP, population, etc.).
- Bridge rehabilitation cost estimates.
- Bridge rehabilitation priority and investment plan.

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) Rehabilitation design

Twenty rehabilitation designs are prepared as examples of site technology needed for the MOP personnel in charge of actually inspecting and deciding the rehabilitation method for the project bridges. The twenty bridges were selected in cooperation with the MOP counterparts, and damage inspection and analysis as well as rehabilitation design were conducted. IEE(Initial Environmental Examination) for the area of each bridge to be rehabilitated was also carried out.

(3) Standard bridge CADD program and design drawings

The development of the standard bridge CADD program and compilation of design plans will assist the MOP to save labors in preparing basic designs for as many as 8000 bridges in the country. The bridge CADD programs developed for the Study is based on the specifications of AASHTO which are usually applied by the MOP. The representative bridge types to be developed as well as computer hardware and software were selected according to bridge design, bridge construction, and computer use in Chile.

The types of program developed are shown below.

Superstructure:
- Pre-tensioned PC beam
- Post-tensioned PC beam
- Steel rolled H beam
- Steel plate girder

All the girders above are composite types with concrete deck.

Substructure:
- Inverted T abutment with spread foundation
- Wall-type pier with spread foundation

The standard drawings were prepared for the bridges of one and two lanes with span length between 14 and 36 m.

5. Conclusion and Recommendation

Conclusions and recommendations are divided into the three particular issues of the Study.

(1) Rehabilitation plan

Conclusion

- The bridge rehabilitation plan consists of three systems: bridge inventory, rehabilitation cost estimates, and prioritizing; upon which the rehabilitation investment plan will be based. By the model study, an amount of about 14750 million pesos (price in 1997) was estimated for the 10 year plan in Region IX.
- The bridge inventory system was developed as a general system that can be applied to all types of bridges in the MOP road network.
- In the case of evaluating priority of the many rural bridges with low returns of investment, bridge safety and socioeconomic investment must be considered, with less emphasis on purely economic feasibility alone. In this light, the three indices of economic feasibility (traffic volume/ rehabilitation cost), safety (level of bridge damage), and social value (rectification of regional imbalance of income) were defined.

1. ESSENTIAL POINTS

Recommendation

- There was no consideration of the bridges' relation with the road network made, thus, coordination between road development plans and bridge rehabilitation plans must be worked out.
- As the economic situation and traffic demand of rural roads in Chile are likely to change within the next ten years, the results of the rehabilitation process of the first five years should be carefully reviewed before proceeding with the next five-year phase.
- As the bridges included in the second five-year phase must wait a long while for rehabilitation, there will be need for temporary repairs in the meantime. Such costs should be allocated from the MOP's yearly maintenance budget and not included in the rehabilitation project investment cost estimated in the plan.

(2) Rehabilitation design

Conclusion

- Twenty actual bridges were selected and studied for damage for which sample rehabilitation designs were prepared. This includes five timber bridges, seven concrete beam bridges, and eight steel girder bridges. Among these, eight samples of bridge replacement (seven PC beams and one steel girder) and eleven samples of bridge repairs are included.
- Among the rural bridges are many wooden bridges which are deteriorated, too narrow and not strong enough to bear heavy loads. The MOP intends to extend the life of such bridges with repairs while replacing them in order. Therefore, more common smaller-scale repair methods are established rather than large-scale technically difficult ones.
- As a result of discussion with the MOP Department of the Environment regarding the need of environmental considerations, the standardized environmental examination (IEE and Pre-EIA) are prepared.

Recommendation

- The construction of new wooden bridges has become difficult both economically and environmentally; however, as such bridges tend to be more easily maintained, it is recommended that the MOP retain the importance of their maintenance technology as long as such bridges remain rather than discarding it.
- It is recommended that concrete bridges to be built from now on in rural areas adopt pre-stressed concrete structure. Quality of concrete construction in bridges is a very important matter in constructed bridges which are expected to last well into the future.
- The suggested Standard Environmental Survey form is simplified and can be filled out in survey with minimum time and effort. Therefore, regardless of the scale of impact of environmental impact, it is advisable that all bridge projects be surveyed in this manner.

(3) Standard bridge CADD program and design drawings

Conclusion

- The CADD program is for standard-type width composition (symmetrical) and right-angle straight bridges and not applicable for curved or skewed bridges.
- Due to the fact that AASHTO standards are not specific regarding high-strength bolt connections for steel girders or positioning of post-tensioned cables, design technology normally applied in Japan was interposed following discussion on technological matters with the MOP.

Recommendation

- The program was developed so that the user can compile the output according to his/her purpose. It is possible to use the program out of the scope of its original specifications to some extent depending upon the user's creative capacity.
- Existing computer applications were used in the development of the program. Therefore, there will be need in the future to upgrade to newer versions of software and/or hardware used in this program. In conjunction with this, it will be necessary to upgrade the program itself to meet with revisions of design standards, etc.
- It is recommended that the program be widely used in the country. The technical staff of the MOP would use the program in planning the bridge size. The bridge designers both in the MOP and in private firms, would use it in professional application to their design works within the capacity of the program.

2. INTRODUCTION

2. INTRODUCTION

1. Background of Request for the Study

The improving of the national road network and developing regional economies is an important issue in the Chilean government's policy to resolve the problem of poverty. However, in the rural area, about 70 % of the nation's 8000 bridges are made of wood, signs of deterioration, and are not functioning properly. In order to fulfill the government's objective, the rehabilitation of such bridges is an urgent matter. In order to cope with a large number of bridges, the MOP needs to strengthen its bridge rehabilitation and management technique. Survey and repair work carried out by the MOP for rural bridges is required to be more efficient and systematic.

In view of this situation, the Government of Chile requested the Government of Japan for a development survey for a master plan of bridge rehabilitation and a standard bridge design system making use of computer, for 1000 bridges along regional roads throughout the country.

2. Situation of Rural Bridges in Chile

The bridges for the Study are categorized in rural bridges and characterized as follows:

- They are small in scale though great in number.
- Most of them are deteriorated and made of wood (especially in Region VIII, IX and X).
- There is little traffic but the ratio of heavy vehicles (for lumber and mining transport) is high, consequently traffic load is limited (about 12 tons) on most bridges.
- Timber bridge needs frequent member replacement for maintenance. The MOP has experienced minor replacement in about 5 years and major replacement in 10 years.

3. Rehabilitation Policy of the MOP

Timber bridges so far widely used in Chile have become difficult to be maintained, for the disadvantages specific to timbers have become conspicuous such as the government policy of forest conservation, rise of timber cost and need of frequent maintenance. Therefore, the MOP intends to gradually replace timber bridges with permanent concrete or steel bridges.

4. Purpose of the Study

The Study aimed the technical cooperation to the MOP on the following three objectives for the rehabilitation of rural bridges:

(1) Establishment of bridges rehabilitation planning method,

(2) Preparation of sample bridge rehabilitation designs, and

(3) Development of standard bridge CADD program and design drawings.

The relation between the process of rehabilitation of rural bridges and the technical cooperation is shown in **Figure 1**.

5. Organization for the Study

The Study was conducted by the organization shown in the **Figure 2**. The Study Team consisted of Pacific Consultants International with JICA, and local counterpart staff from the Bridge Department of the MOP. Furthermore, as a supervisor for the Study, an advisory committee was set up obtaining cooperation from the Japanese Ministry of Construction's Civil Engineering Research Institute.

6. Schedule of the Study

The Study was commenced in August 1996. The Study Team was sent to Chile in September the same year to discuss the Inception Report and presented this Final Report in July 1998 after four separate surveys in Chile. The Schedule of the overall Study is shown in **Figure 3.**

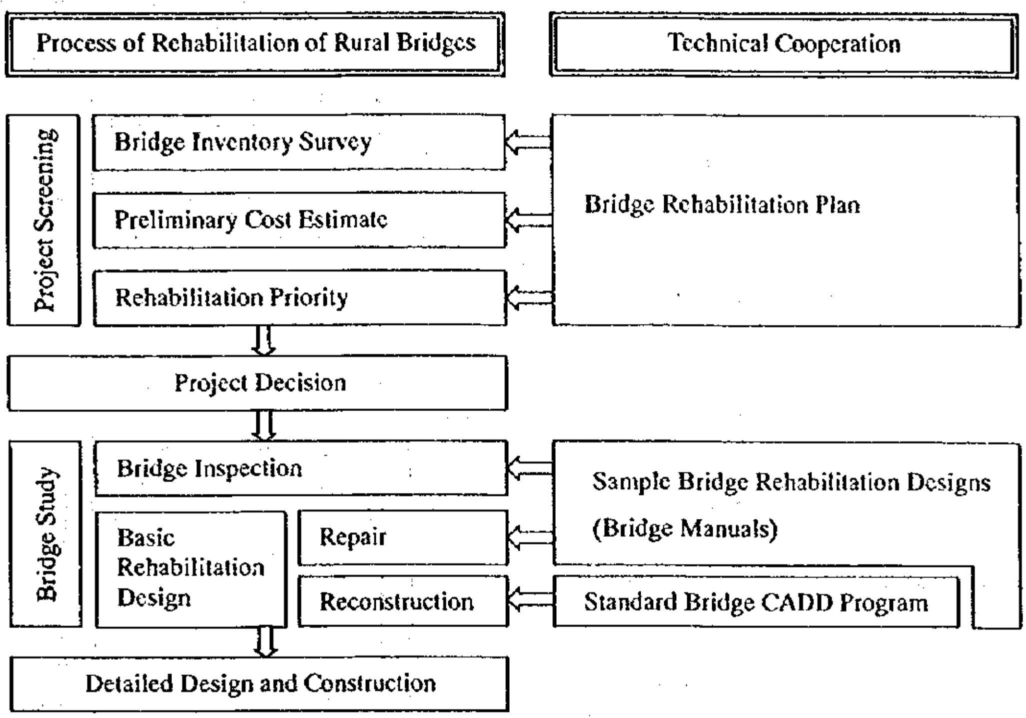


Figure 1 Relation of Bridge Rehabilitation Process and Technical Cooperation

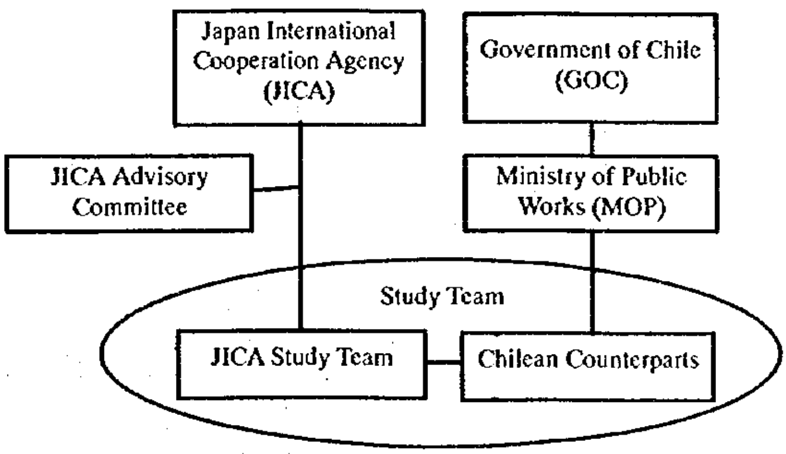


Figure 2 Organization of the Study

2. INTRODUCTION

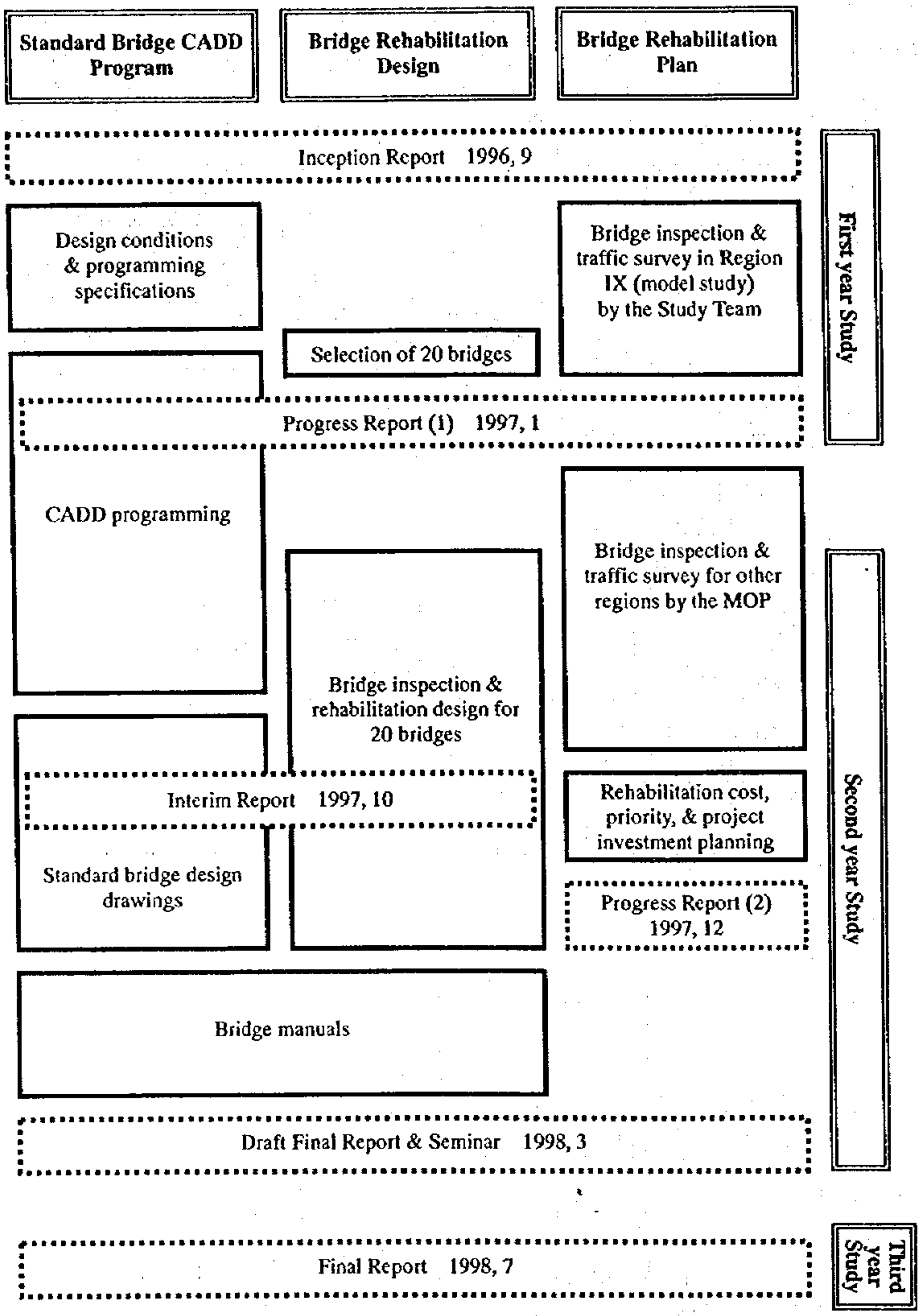


Figure 3 Schedule of the Study

3. BRIDGE REHABILITATION PLAN

1. Process of Rehabilitation Plan

Bridge rehabilitation plan was worked for 1000 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 rehabilitation project plan was drawn up based on this information (see **Figure** 4).

2. Selection of 1000 Bridges

To select rural bridges in need of rehabilitation from about 8000 bridges said to exist in Chile, (1) bridges of more than 10 m in length, (2)bridges with load limitations, and (3)bridges with conspicuous damage were the main conditions for selection of the 1000 bridges as part of the MOP's first phase plan.

3. Plans for National and Regional Level, and Model Study Region

The plan is first conducted in each region, and the results of each of the thirteen regions are totaled to make a nationwide plan(see **Figure** 5). Of the 1000 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.

4. Evaluation Indices for Prioritization of Rehabilitation

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** 6).

- 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.

5. Grouping of Bridges by Road Link

In order that the bridge rehabilitation be effective, it is most advisable 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, will be called a "road link". Multiple numbers of bridges within the segment are to be treated as a group (see **Figure** 7).

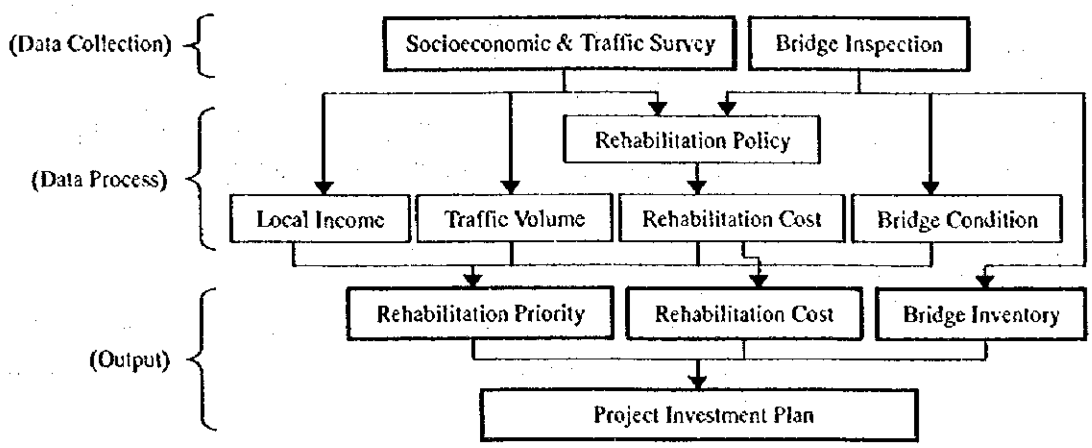


Figure 4 Process of Rehabilitation Plan

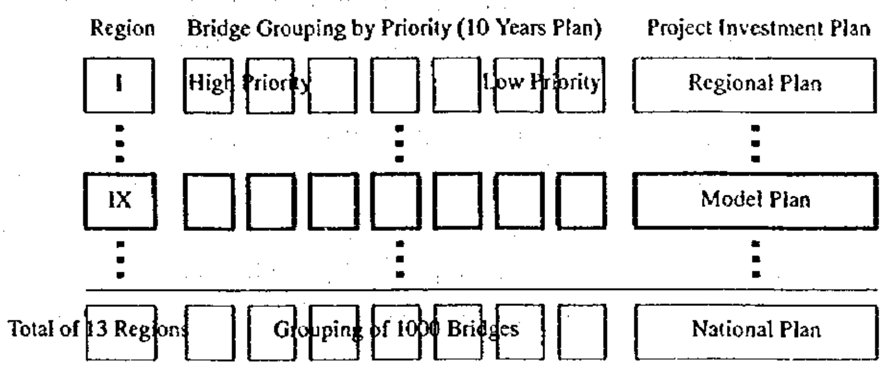


Figure 5 Regional and National Level Plans

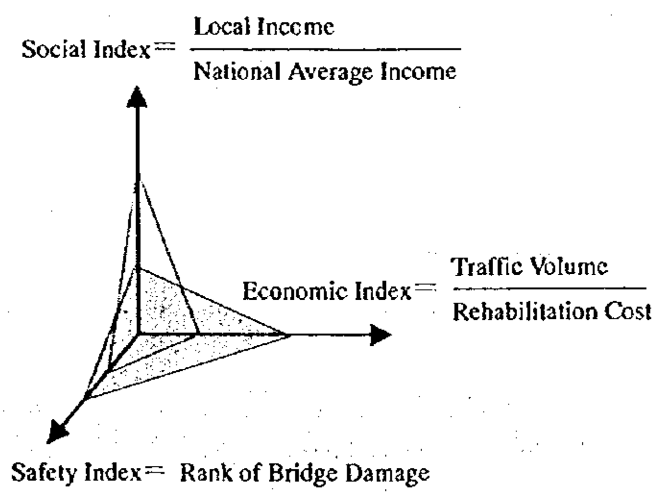


Figure 6 Indices for Rehabilitation Priority

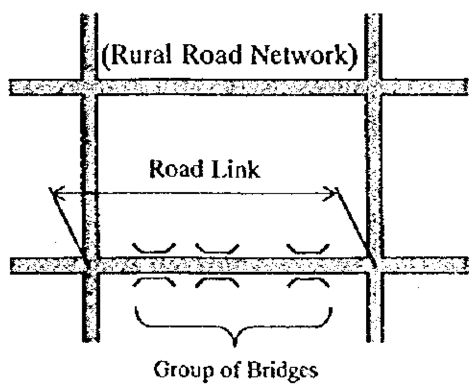


Figure 7 Grouping of Bridges

1. Bridges to be Inspected

Bridge inspection was conducted to collect bridge inventory and condition data for bridge rehabilitation planning. The Study Team inspected first 200 bridges in Regions VIII, IX and X, and then the MOP inspected 800 bridges in the other regions. 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. Method of Inspection

An inspection form was so devised as to cover inspection items necessary for rehabilitation planning as well as to be usable for a general bridge inventory of the MOP. The inspection form is divided into three systems and includes the following items:

(1) "Inventory Form" includes general information such as bridge name, location map, river condition, etc. and structural details including bridge type, major dimensions, profile/cross-sectional sketches, and photographs of side and front views and of typical damages.

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

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

Bridges were visually inspected and site information was collected in accordance with the inspection form. 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.

3. Rating System for Bridge Condition

(1) Numerical Rating System

In order to standardize various condition-states of any bridge element, a numerical rating system categorized into five ranks was recommended (see **Table 1**). Damage ranks were rated according to location, pattern, depth and extent of damages referring to the "Bridge Inspection Guidelines (Proposal in1988)" by the Civil Engineering Research Institute of Japan's Ministry of Construction.

(2) How to Rate Bridge Condition

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

The total condition rating of a bridge was decided by taking the worst rating number among the rating results of every spans and elements of the bridge.

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

4. Results of Inspection

In Region IX, 109 bridges were inspected but a bridge did not exist. The inspection results of condition ratings are summarised in **Table 2** by bridge types. The bridge types inspected are classified in **Table 3**: about 90 % of the bridges inspected were timber bridges. Most bridges had only one-lane width (2.0 to 5.5 m), and were simply supported except several bridges which were supported continuously. Many bridges had signboards to limit vehicle loads. According to the MOP, limited loads were lowered as deterioration was getting worse. The limited loads inspected in Region VIII, IX, and X are summarized in **Table 4**.

Table 1 Rating System for Bridge Condition

Rank	Definition
1	'Dangerous'; bridge already closed, conditions beyond repair, imminent danger of collapse or already collapsed.
2	'Potentially Hazardous'; such a rating in primary members implies there is a danger of collapse for further use and bridge should be closed to traffic immediately.
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.
4	'Functioning as Originally Designed'; insignificant deterioration or distress does not reduce the capacity of the elements under inspection nor their ability to function.
5	'Good, New or Like-new' condition, no sign of distress or deterioration. No repairs necessary.

Table 2 Condition Ratings Inspected in Region IX (number of bridges)

Bridge Type	Condition Rating Rank					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

Table 3 Bridge Types Inspected in Regions VIII, IX & X

Bridge 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 %

Table 4 Load Limits Inspected in Regions VIII, IX & X (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

1. Computerized Inventory Program

For more efficient administration of bridge management and maintenance, as well as rehabilitation planning, the compiling of bridge inventory is to be a computerized system. The inventory program consists of three systems namely [A] Inventory System, [B] Condition Rating System, and [C] Sorting System(see **Figure 8**). The systems [A] and [B] are developed based on the inspection forms designed for bridge Inspection. The system [C] was added as a tool to compile and analyze inventory data.

The program is made with data base system making possible all data input and searching by using data linkage function. The hard- and software employed were a set of DOS/V computer, Microsoft-Windows 95 and Access including Visual Basic, which were popular and available in Chile. Major displays of the program are shown in **Figure 9**.

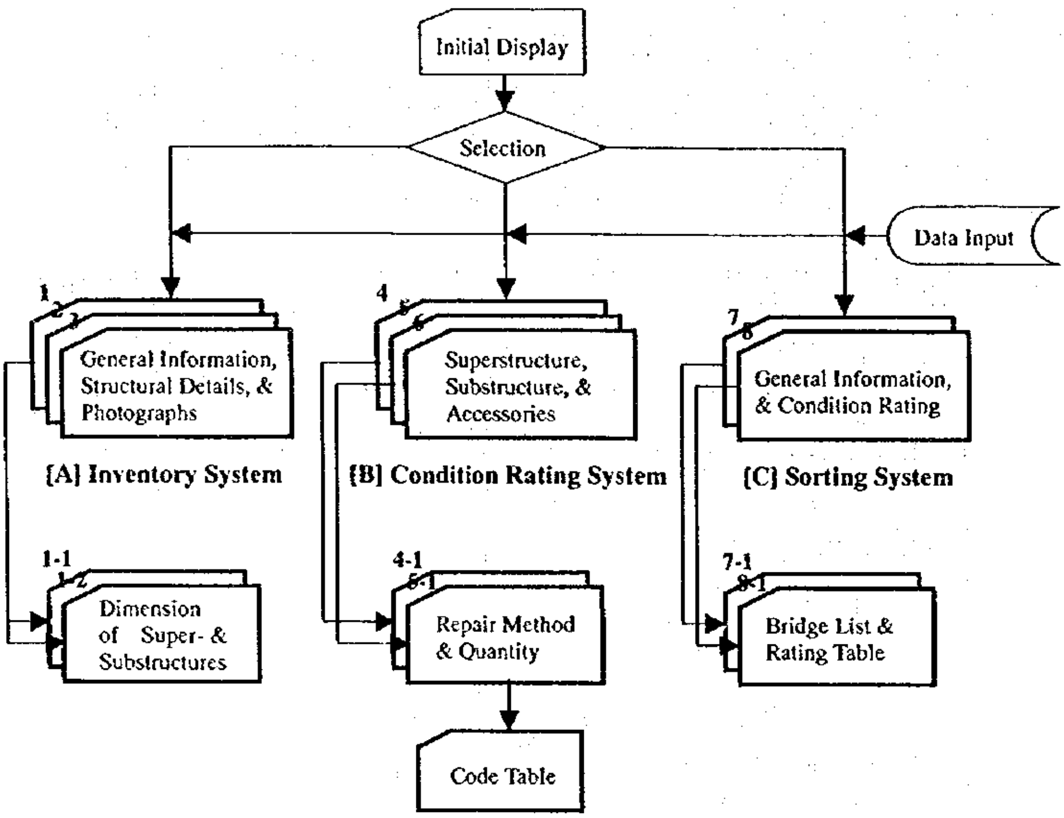
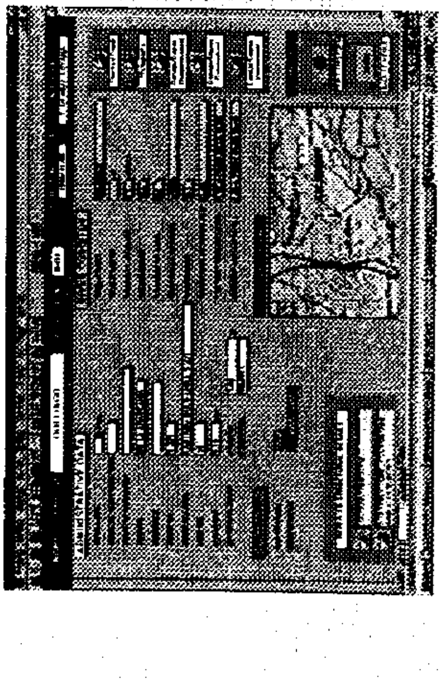
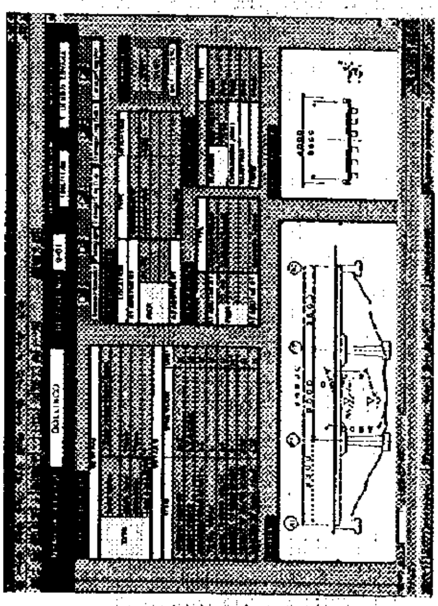


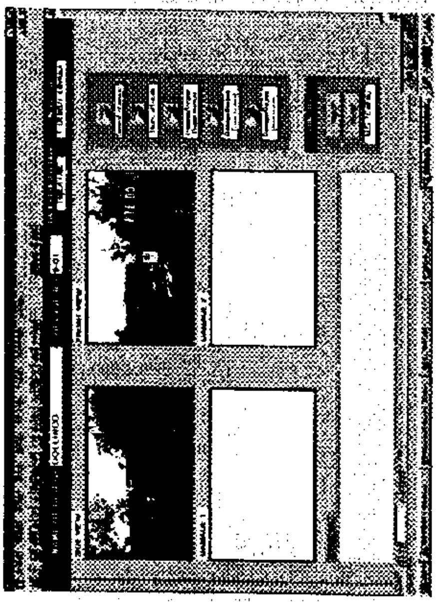
Figure 8 Bridge Inventory Program



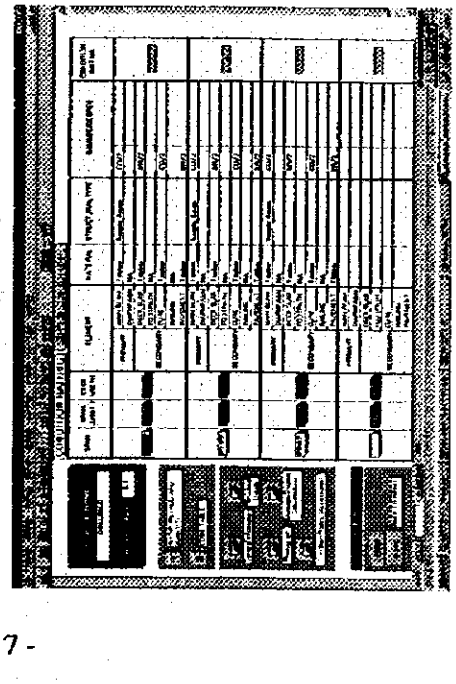
1. General Information



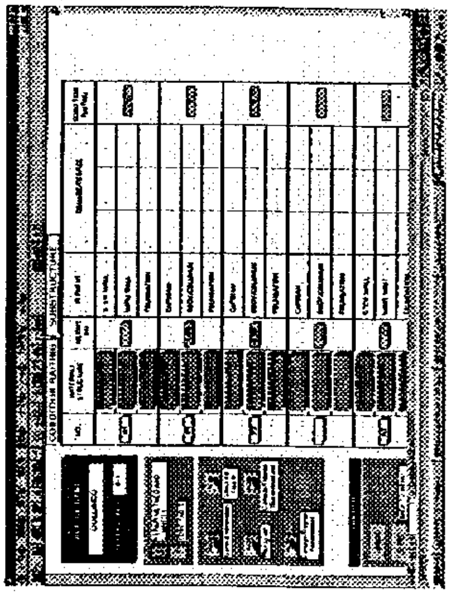
2. Structural Details



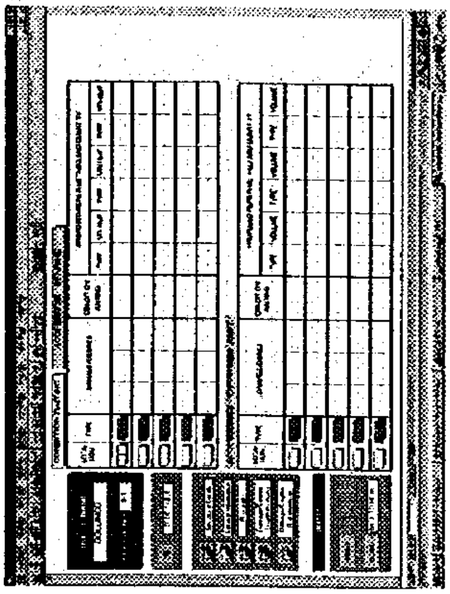
3. Photographs



4. Condition Rating for Superstructure



5. Condition Rating for Substructure



6. Condition Rating for Accessories

Figure 9 Major Displays of Inventory Program

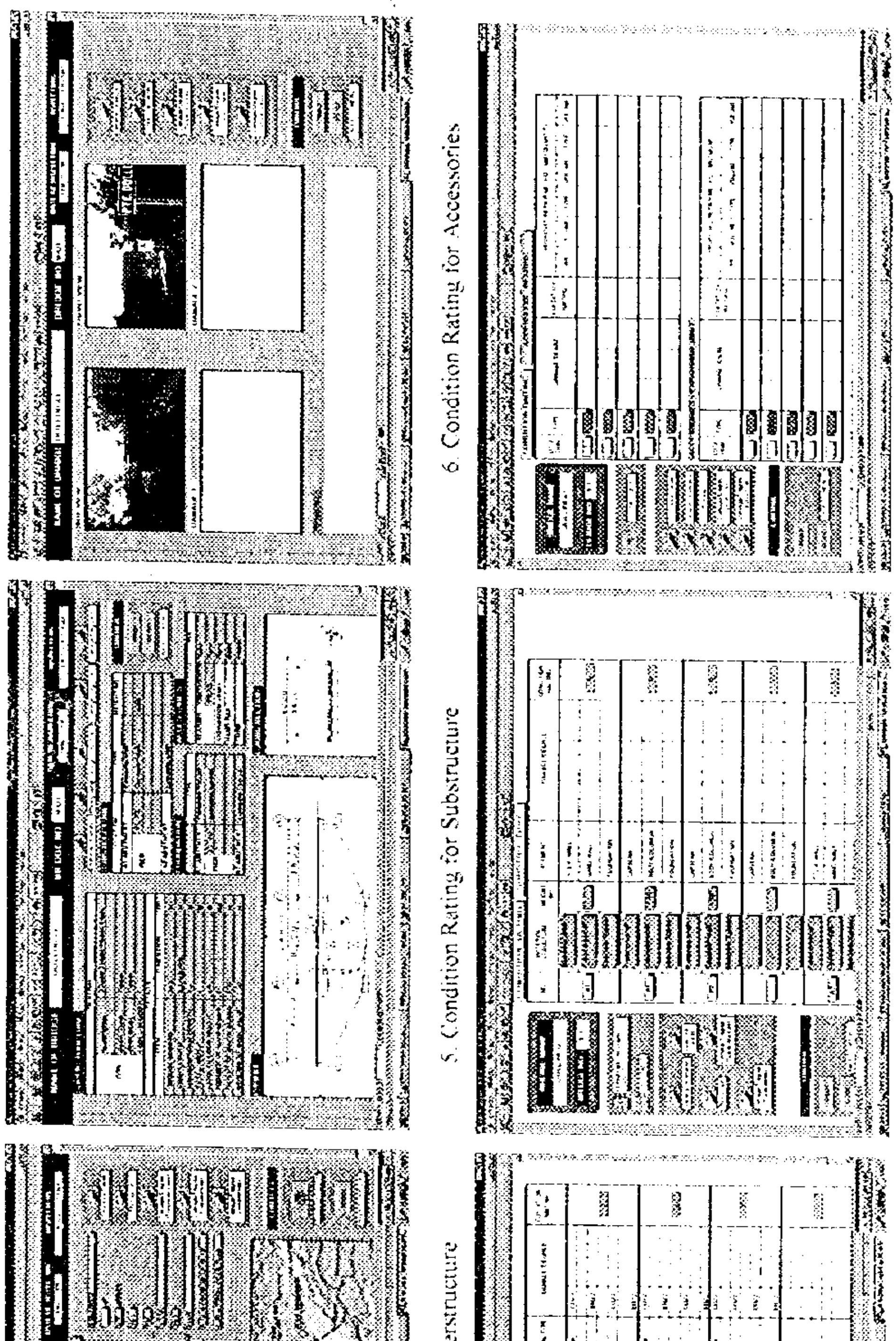


Figure 9 Major Displays of Inventory Program

1. Study of Socioeconomic Indices

As indices to measure the socioeconomic need of the bridges, predicted growth in population, regional gross domestic product (GDP), and vehicle ownership to the year 2010 were figured. Population and vehicle ownership are indicators of future traffic volume, while the GDP is used as a socioeconomic index in calculating the priority evaluation of bridge rehabilitation.

2. Traffic Study

The traffic study was conducted with the purpose of defining road links and forecasting traffic volume for the year 2005. Future traffic volume is necessary for calculation of socioeconomic index of rehabilitation priority. The MOP has conducted traffic censuses every two years and the traffic census data for 1992 and the latest edition of 1994 were used as reference. A supplementary traffic survey was carried out by the Study Team to complement the above traffic censuses.

(1) Fixing of "road link"

The location of project bridges were plotted on the 1:250000 scale MOP road maps and road links were fixed. Following that, locations covered by the 1994 traffic census were plotted and links lacking census data were found. **Figure 10** shows the traffic study map of Region IX.

(2) Traffic volume forecast

Present traffic volume (1996)

Made up with the 1994 traffic census data translated into the 1996 figures and results of the supplementary traffic survey. The average annual daily traffic volume (AADT) was calculated by using seasonal change ratio, 12/24 hour conversion rate, 1992-94 growth rate which were obtained from the traffic census data.

Future traffic volume (2005)

Forecasted based on the 1996 AADT by applying the equation below.

Automobiles, Trucks: $$AADT(2005) = AADT(1996) \times \frac{\text{vehicle ownership (2005)}}{\text{vehicle ownership (1996)}}$$

Buses, Taxis: $$AADT(2005) = AADT(1996) \times \frac{\text{population (2005)}}{\text{population (1996)}}$$

In the model study of Region IX, no remarkable population growth was predicted between 1996 and 2005, so the AADT figures remained the same. **Table 5** shows a part of results of the traffic study in Region IX.

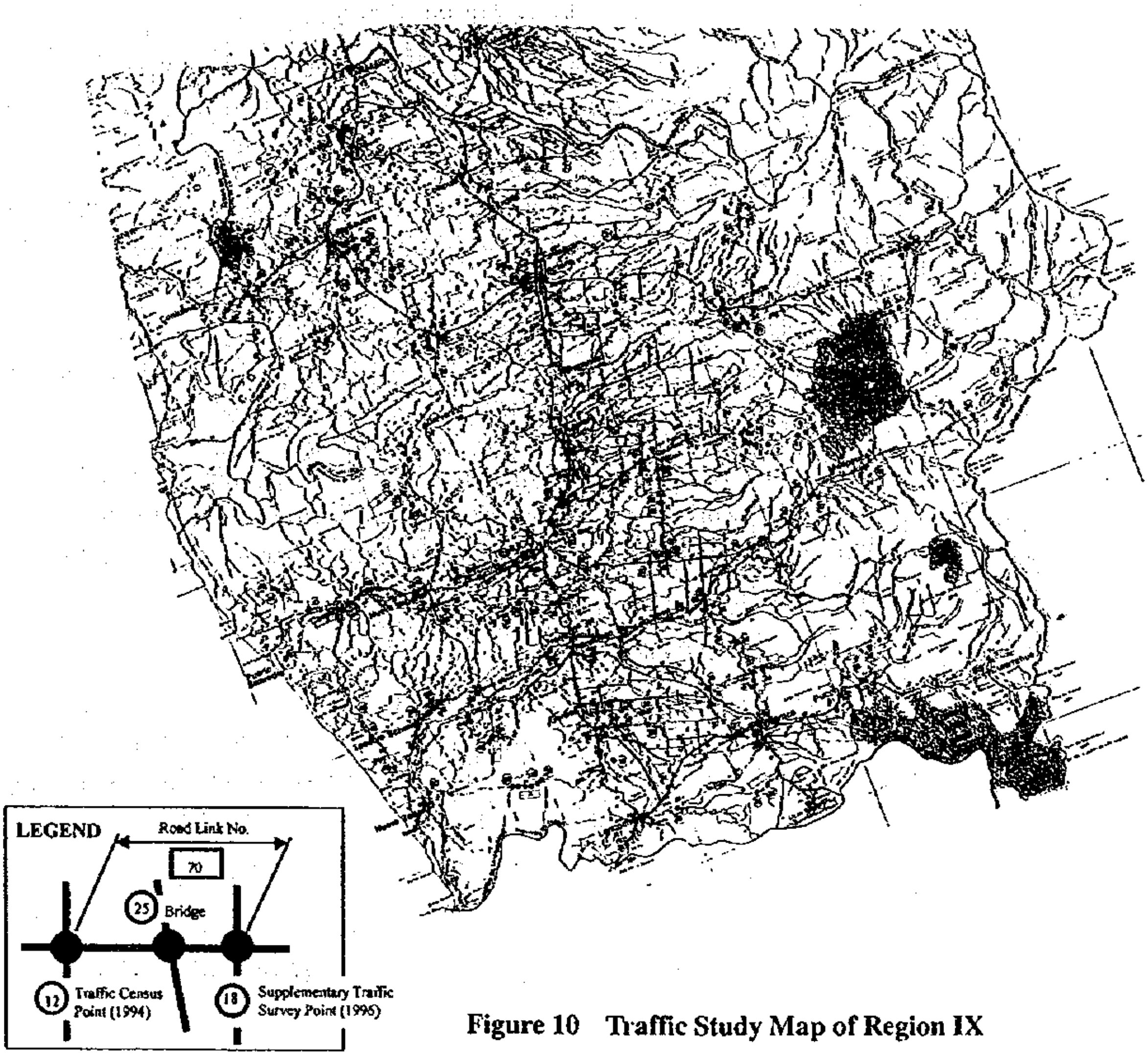


Figure 10 Traffic Study Map of Region IX

Table 5 Traffic Volume of Region IX

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

Road Link No.	Bridge No.	Vehicle Ownership (1996)			Vehicle Ownership (2005)			Ratio of Ownership	AADT (1996)			AADT (2005)		
		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

1. Rehabilitation Policy

In principle, rehabilitation decisions can be reached through cost-benefit analysis. However, this approach is too elaborate and laborious for the rehabilitation plan of a large number of small-scale bridges. Here, simple criteria are recommended based on the following rehabilitation policy.

(1) For many bridges are already old and deteriorated, and so their width and load capacity are insufficient against the today's traffic burden. Therefore, it is recommended for such aged bridges to be replaced with new structures rather than to be repaired.

(2) It is recommended for timber bridges, for their short durable years and frequent maintenance required, to be replaced with permanent (concrete or steel) structures in around 10 years regardless of present condition, but never with timber again.

(3) It is recommended for concrete or steel bridges to be maintained by repairing as far as they hold adequate width and load capacity to economize rehabilitation cost. However, for the bridges insufficient of width and load capacity, replacement scheme is recommended rather than widening and strengthening.

2. Decision of Rehabilitation Method and Scale

The criteria to decide rehabilitation method and scale were settled based upon the above rehabilitation policy (see **Table 6**). In the table, the traffic volume of 500 vehicles per day is the dividing line for number of roadway lanes (one or two) and width (4.0 or 7.0 m), respectively. The load limit of 18 tons is the rounded figure of standard design live load for rural bridges.

3. Bridge Rehabilitation Cost Estimate

Following the decision of rehabilitation method and scale, estimates of rehabilitation costs were divided into bridges to be repaired and those to be replaced. The costs referred to for estimation are those in Chile in 1996 and 1997.

(1) Reconstruction Cost

Reconstruction cost consists of the costs for construction of bridge, approach road, and bank protection (see **Table 7**).

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 bridge 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) Repair Cost

For repair costs, unit cost per square meter of repairing area according to the types of damage was set (see **Table 8**), 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.

Table 6 Criteria for Rehabilitation Method and Scale

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

Note: " – " means unconditional.

Table 7 Reconstruction Unit Cost

	One lane	Two lane
Bridge cost	512 000 pesos/m2	
Approach road cost	39 000 000 pesos/bridge	45 800 000 pesos/bridge
Bank protection	2 300 000 pesos/bridge	

Table 8 Repair Unit Costs

(pesos/m2)

Kind of Damages	Superstructure			Substructure		
	Concrete	Steel	Timber	Concrete	Steel	Timber
Breakage/Fallout	12 400	31 600	25 800	8 800	26 500	18 000
Corrosion/Decay	9 900	13 600	25 800	9 300	12 400	18 000
Crack	47 000	29 400	25 800	25 300	24 500	18 000
Deformation		552 600			473 800	
Erosion/Scouring				40 000		
Fire			25 800			18 000
Inclination				depend on site condition		
Poor function	depend on site condition					
Scaling	12 400			8 800		
Settlement				depend on site condition		
Sliding				depend on site condition		
Spalling	9 300			6 500		
Surface wearing	13 200			13 000		

1. Period of Plan

The period for the rehabilitation plan is set for 10 years based on the basic plan of the MOP, beginning in 1998 and lasting until 2007. The national level total rehabilitation cost for the 1000 bridges was estimated around 134 000 million pesos based on the model study of Region IX. Evaluating this amount from the financial condition and construction ability of the MOP, the 10 year plan was concluded practicable.

2. Appraisal Method of Rehabilitation Priority

Due to the regional and social characteristics of rural bridges, priority evaluation cannot be made based on economic internal rate of return (EIRR), as in the case of bridges along major routes. It is necessary to consider other social factors besides purely economic ones when making decisions regarding the rehabilitation of such bridges (see **Table 9**). From this viewpoint, nine items of socioeconomic effects expected to the rehabilitation of rural bridges were laid out, and which were summarized in the three indices (economic, safety, and social) given below considering constraints of the study involving number of bridges, difficulty in collection of proper data, etc. within a limited time frame.

Expected rehabilitation effects	Priority index	Definition
-Increase of income -Increase of productivity -Development of resources	Economic Index	= (Traffic volume/Rehabilitation cost) x Weight
-Dissolution of detour time -Shortening of river crossing time -Safeguarding of lives and properties	Safety Index	= (Rank of bridge damage) x Weight
-Deterring of regional population outflow -Rectification of regional income differences -Mitigation of regional isolation	Social Index	= (National average income/ Regional average income) x Weight
	Total Index	= Economic Index +Safety Index +Social Index

3. Process of Rehabilitation Priority Appraisal and Project Planning

The process of rehabilitation priority appraisal and project planning was conducted as follows:

(1) Each index is calculated for each bridge, and the sum of the weighted indices made.

(2) The maximum index value among the bridges belonging to the same road link represents that link. A list of bridges and their rehabilitation costs by road links is made in an order of the index (priority) for each region.

(3) According to the priority, budget is allocated to road links to be rehabilitated for each fiscal year. Allocation is made so that budget for each fiscal year is roughly the same amount.

The rehabilitation project list of Region IX resulted by model study is shown in **Table 10**.

In the table, A = Priority index for individual bridge
B = Priority index for road link (representative index value of grouped bridges)
C = Rehabilitation cost

Table 9 Regional and Social Characteristics of Rural Bridges

- Length of bridges is short (24 m in Region IX), therefore savings in running cost are small.
- Number of bridges is high, and bridges are widely dispersed.
- Rehabilitation cost per bridge is small (134 million pesos/bridge in Region IX).
- Traffic volume is small; most traffic is local (200 vehicles/day in Region IX).
- Few bridges can be considered "economically feasible", and both "feasible" and "unfeasible" exist.
- Due to few socioeconomic data, it is difficult to evaluate economical return of investment.
- Despite low economical return of investment, many bridges function to connect social institutions such as hospitals and schools; therefore it is difficult to measure bridge's value solely in economic terms.

Table 10 Rehabilitation Project List of Region IX

Priority Order	Bridge Location: Link No.	Comuna Name	Bridge No.	Bridge Name	Priority Index: Individual Bridge A	Grouped Bridges B	Existing Bridge Data: Bridge Type	Length (m)	Width (m)	Load Limit (t)	Damag. Rank	Bridge Rehabilitation Data: Traffic (pcu)	Rehabili. Method	Number of Lanes	Rehabilitation Cost (million peso) C	Bridge No.	Link No.
	1st Year: 1998																
1	71	LONQUIMAY	IX-049	ÑIRECO	2.651	2.651	Timber	8.20	3.70	10	2	4660	Reconst.	2	87.6	IX-049	71
2	71	LONQUIMAY	IX-048	ÑANCUREO	2.458	2.651	Timber	10.00	3.00	6	2	4660	Reconst.	2	96.2	IX-048	71
3	70	LONQUIMAY	IX-094	LOLEN	1.000	1.000	Timber	67.00	2.60	4	2	4660	Reconst.	2	370.6	IX-094	70
4	4	ANGOL	IX-098	LEALTAD	0.994	0.994	Timber	63.70	3.50	10	2	9887	Reconst.	2	354.7	IX-098	4
5	51	TEODO.SCHMIDT	IX-099	POCULON	0.942	0.942	Timber	31.00	1.85	0	1	958	Reconst.	2	197.3	IX-099	51
6	74	PUCON	IX-027	EL CRISTO	0.755	0.755	Timber	26.00	3.50	6	1	1504	Reconst.	2	173.2	IX-027	74
7	31	TRAIGUEN	IX-078	HUIÑILHUE	0.726	0.726	Timber	33.30	4.20	-	2	3356	Reconst.	2	208.4	IX-078	31
					Indicator over	0.720								Total Cost	1488.0	million peso	
	2nd Year: 1999																
8	77	CARAHUE	IX-040	SAN JUAN	0.714	0.714	Timber	31.60	4.00	10	2	1830	Reconst.	2	200.2	IX-040	77
9	77	CARAHUE	IX-041	LONCOMAYO	0.444	0.714	Timber	18.00	3.94	12	3	1830	Reconst.	2	134.7	IX-041	77
10	12	PUREN	IX-079	LA ISLA	0.707	0.707	Timber	36.70	3.50	1	1	303	Reconst.	1	154.0	IX-079	12
11	38	LAUTARO	IX-091	COLLIN	0.577	0.577	Timber	21.80	3.76	-	1	43	Reconst.	1	108.3	IX-091	38
12	66	LONQUIMAY	IX-085	HUILLINCO	0.572	0.572	Timber	16.80	4.10	10	2	190	Reconst.	1	92.9	IX-085	66
13	66	LONQUIMAY	IX-033	ICALMA	0.569	0.572	Timber	17.90	3.70	10	2	190	Reconst.	1	96.3	IX-033	66
14	19	COLLIPULLI	IX-071	CALLIN	0.562	0.562	Timber	13.60	4.00	12	2	1126	Reconst.	2	113.6	IX-071	19
15	65	MELIPEUCO	IX-034	ALLIPEN	0.542	0.542	Timber	58.00	3.82	4	2	286	Reconst.	1	219.5	IX-034	65
16	52	TEODO. SCHMIDT	IX-043	ALLLIPEN	0.532	0.532	Timber	9.10	4.05	10	2	404	Reconst.	1	69.3	IX-043	52
17	33	NUEVA IMPERIAL	IX-013	HUAMAQUI	0.526	0.526	Timber	19.10	4.00	8	2	628	Reconst.	2	140.0	IX-013	33
18	8	LOS SAUCES	IX-070	LA OBRA	0.500	0.500	Timber	10.40	3.40	5	2	641	Reconst.	2	98.2	IX-070	8
					Indicator over	0.500								Total Cost	1427.0	million peso	
	3rd Year: 2000																
19	34	NUEVA IMPERIAL	IX-012	HUECHUCON	0.475	0.475	Timber	30.60	4.10	-	2	628	Reconst.	2	195.4	IX-012	34
21	63	VILLARRICA	IX-021	PEDREGOSO	0.458	0.458	Steel	38.00	3.85	12	2	1909	Reconst.	2	231.0	IX-021	63
20	22	VICTORIA	IX-063	MALLECO	0.458	0.458	Timber	32.20	3.70	4	1	131	Reconst.	1	140.2	IX-063	22
22	22	VICTORIA	IX-064	LOS SOLDADOS	0.007	0.458	Timber	33.50	3.80	8	2	130	Reconst.	1	144.2	IX-064	22
23	13	PUREN	IX-055	VILUCO	0.451	0.451	Timber	8.30	3.90	10	2	594	Reconst.	2	88.0	IX-055	13
24	13	PUREN	IX-054	CHACRE	0.344	0.451	Timber	20.10	3.70	10	2	594	Reconst.	2	144.8	IX-054	13
25	13	PUREN	IX-053	ÑATO	-0.142	0.451	Timber	28.40	3.80	12	3	594	Reconst.	2	184.8	IX-053	13
26	13	PUREN	IX-052	PINOUIDAHUE	-0.934	0.451	Timber	11.00	3.40	12	5	594	Reconst.	2	101.0	IX-052	13
27	14	PUREN	IX-100	LAS MINAS	0.442	0.442	Timber	12.50	3.70	10	2	251	Reconst.	1	79.7	IX-100	14
28	18	COLLIPULLI	IX-047	LAS TOSCAS	0.379	0.379	Timber	10.80	3.85	6	2	543	Reconst.	2	100.1	IX-047	18
					Indicator over	0.360								Total Cost	1409.2	million peso	
	4th Year: 2001																
29	35	LAUTARO	IX-001	NIBLINTO	0.377	0.377	Timber	24.80	3.60	8	2	1098	Reconst.	2	167.5	IX-001	35
30	35	LAUTARO	IX-002	MUCOBAJO	0.319	0.377	Timber	34.50	3.70	6	2	1098	Reconst.	2	214.1	IX-002	35
31	17	LOS SAUCES	IX-066	QUINQUEN	0.370	0.370	Timber	36.10	3.80	6	2	736	Reconst.	2	221.8	IX-066	17
32	69	LONQUIMAY	IX-097	PUNTA NEGRA 2	0.369	0.369	Timber	28.80	3.55	18	3	1516	Reconst.	2	186.7	IX-097	69
33	69	LONQUIMAY	IX-096	PUNTA NEGRA 1	-0.529	0.369	Timber	28.60	3.50	18	5	1516	Reconst.	2	185.7	IX-096	69
34	62	VILLARRICA	IX-024	SALVA TU ALMA	0.360	0.360	Steel	40.70	3.77	15	2	1427	Reconst.	2	244.0	IX-024	62
35	9	LOS SAUCES	IX-069	MIRAFLORES	0.332	0.332	Timber	44.40	3.60	10	2	624	Reconst.	2	261.8	IX-069	9
					Indicator over	0.330								Total Cost	1481.6	million peso	
	5th Year: 2002																
36	16	LOS SAUCES	IX-095	REÑICO	0.332	0.332	Timber	20.70	3.40	8	2	251	Reconst.	1	104.9	IX-095	16
37	68	LONQUIMAY	IX-075	LOS SOLDADOS	0.309	0.309	Timber	10.00	3.35	8	3	639	Reconst.	2	96.2	IX-075	68
38	68	LONQUIMAY	IX-076	MIRAFLORES	-0.229	0.309	Timber	19.70	3.90	6	4	639	Reconst.	2	142.9	IX-076	68
39	7	LOS SAUCES	IX-050	HUADABA	0.307	0.307	Timber	19.90	3.60	10	2	181	Reconst.	1	102.4	IX-050	7
40	10	LOS SAUCES	IX-059	NAPAÑIR	0.291	0.291	Timber	11.10	3.10	8	2	103	Reconst.	1	75.4	IX-059	10
41	10	LOS SAUCES	IX-062	PELEHUITO	0.279	0.291	Timber	17.80	2.80	8	2	103	Reconst.	1	96.0	IX-062	10
42	10	LOS SAUCES	IX-061	CATALINA N°1	0.275	0.291	Timber	20.40	4.00	8	2	103	Reconst.	1	104.0	IX-061	10
43	47	FREIRE	IX-035	NEGRO	0.256	0.286	Steel	20.70	3.85	8	2	755	Reconst.	2	147.7	IX-035	47
44	11	LOS SAUCES	IX-060	CATALINA N°2	0.267	0.267	Timber	28.90	3.75	8	2	103	Reconst.	1	130.1	IX-060	11
45	11	LOS SAUCES	IX-058	REHUE	0.266	0.267	Timber	30.50	3.80	8	2	103	Reconst.	1	135.0	IX-058	11
46	20	COLLIPULLI	IX-072	MININCO	0.261	0.261	Timber	16.30	4.30	10	2	229	Reconst.	1	91.4	IX-072	20
47	40	VILLARRICA	IX-005	PEDREGOSO	0.252	0.252	Timber	16.50	3.20	-	2	293	Reconst.	1	92.0	IX-005	40
48	40	VILLARRICA	IX-006	CALBUCO	-0.631	0.252	Timber	13.00	3.55	8	4	293	Reconst.	1	81.2	IX-006	40
49	40	VILLARRICA	IX-004	LLAMUCO	-0.668	0.252	Steel	22.00	4.00	12	4	293	Reconst.	1	108.9	IX-004	40
					Indicator over	0.250								Total Cost	1509.1	million peso	

	6th Year: 2003																
50	59	GORBEA	IX-020	RINCO	0.237	0.237	Steel	12.20	3.85	12	2	370	Reconst.	1	78.8	IX-020	59
51	59	GORBEA	IX-019	DONGIL	0.131	0.237	Timber	44.10	4.00	12	2	370	Reconst.	1	176.8	IX-019	59
52	29	CURACAUTIN	IX-087	TRAHUILCO	0.235	0.235	Timber	39.70	3.80	12	1	31	Reconst.	1	163.3	IX-087	29
53	29	CURACAUTIN	IX-088	CAUTIN	-0.215	0.235	Steel	39.40	3.85	12	2	31	Reconst.	1	162.3	IX-088	29
54	67	LONQUIMAY	IX-077	RUCANUCO	0.204	0.204	Timber	22.80	3.60	4	3	639	Reconst.	2	157.8	IX-077	67
55	56	GORBEA	IX-015	CHARLEO	0.192	0.192	Timber	20.40	3.90	8	2	527	Reconst.	2	146.3	IX-015	56
56	56	GORBEA	IX-016	LAS LUMAS	-1.112	0.192	Timber	13.20	3.90	6	5	527	Reconst.	2	111.6	IX-016	56
57	49	FREIRE	IX-037	CHUCAUCO	0.188	0.188	Timber	17.50	3.97	8	2	257	Reconst.	1	95.1	IX-037	49
58	49	FREIRE	IX-038	FIN FIN	-0.677	0.188	Timber	10.00	4.00	8	4	257	Reconst.	1	72.0	IX-038	49
59	36	VILCUN	IX-003	QUINTRILPE	0.182	0.182	Timber	10.00	2.90	8	2	309	Reconst.	1	72.0	IX-003	36
60	58	GORBEA	IX-018	PUYEHUE	0.171	0.171	Timber	32.10	4.00	10	2	621	Reconst.	2	202.6	IX-018	58
					Indicator over	0.170								Total Cost	1438.6	million peso	
	7th Year: 2004																
61	54	PITRUFQUEN	IX-044	QUINQUE	0.144	0.144	Timber	24.80	4.12	8	2	997	Reconst.	2	167.5	IX-044	54
62	53	TEODO. SCHMIDT	IX-042	PUYEHUE	0.143	0.143	Timber	8.40	4.00	10	3	492	Reconst.	1	67.1	IX-042	53
63	76	GORBEA	IX-105	PLANCHADO 3	0.137	0.137	Timber	8.00	2.65	12	2	147	Reconst.	1	65.9	IX-105	76
64	76	GORBEA	IX-110	PLANCHADO 8	0.120	0.137	Timber	12.80	4.00	12	2	147	Reconst.	1	80.6	IX-110	76
65	76	GORBEA	IX-103	PLANCHADO 1	-0.309	0.137	Timber	7.00	4.00	12	3	147	Reconst.	1	62.8	IX-103	76
66	76	GORBEA	IX-108	PLANCHADO 6	-0.317	0.137	Timber	8.90	3.95	12	3	147	Reconst.	1	68.6	IX-108	76
67	76	GORBEA	IX-104	PLANCHADO 2	-0.319	0.137	Timber	9.60	4.00	12	3	147	Reconst.	1	70.8	IX-104	76
68	76	GORBEA	IX-107	PLANCHADO 5	-0.321	0.137	Timber	10.00	2.70	12	3	147	Reconst.	1	72.0	IX-107	76
69	76	GORBEA	IX-106	PLANCHADO 4	-0.325	0.137	Timber	11.30	2.84	12	3	147	Reconst.	1	76.0	IX-106	76
70	76	GORBEA	IX-109	PLANCHADO 7	-0.335	0.137	Timber	14.80	3.50	12	3	147	Reconst.	1	86.8	IX-109	76
71	41	VILLARRICA	IX-007	EL TIGRE	0.134	0.134	Timber	19.50	3.75	8	2	29	Reconst.	1	101.2	IX-007	41
72	37	LAUTARO	IX-090	EL TRUENO	0.123	0.123	Timber	43.80	3.55	-	2	51	Reconst.	1	175.9	IX-090	37
73	57	GORBEA	IX-017	POLUL I	0.119	0.119	Timber	22.70	3.90	10	2	198	Reconst.	1	111.0	IX-017	57
74	50	NUEVA IMPERIAL	IX-039	BOROA	0.086	0.086	Timber	15.90	3.75	12	3	588	Reconst.	2	124.6	IX-039	50
75	78	VILCUN	IX-014	PUMALAL	0.060	0.060	Timber	32.20	4.20	2	2	180	Reconst.	1	140.2	IX-014	78
					Indicator over	0.060								Total Cost	1471.0	million peso	
	8th Year: 2005																
76	23	VICTORIA	IX-080	DUMO	0.013	0.013	Timber	32.90	3.97	12	2	149	Reconst.	1	142.4	IX-080	23
77	15	LOS SAUCES	IX-056	RANQUILEO	0.008	0.008	Timber	15.30	3.60	10	3	669	Reconst.	2	121.7	IX-056	15
78	75	VILLARRICA	IX-025	COLLICO	-0.019	-0.019	Timber	9.60	4.04	4	3	718	Reconst.	2	94.3	IX-025	75
79	75	VILLARRICA	IX-026	CRUCES	-0.126	-0.019	Timber	20.00	5.70	8	3	718	Reconst.	2	144.4	IX-026	75
80	2	ANGOL	IX-093	PELLOMENCO	-0.021	-0.021	Timber	14.10	4.20	10	2	246	Reconst.	1	84.6	IX-093	2
81	2	ANGOL	IX-092	LAS ANIMAS	-0.054	-0.021	Timber	24.70	4.20	15	2	246	Reconst.	1	117.2	IX-092	2
82	60	CUNCO	IX-029	LA BASTILLA	-0.060	-0.060	Timber	74.10	3.97	6	2	427	Reconst.	1	268.9	IX-029	60
83	26	CURACAUTIN	IX-081	AMANTIBLE	-0.068	-0.068	Timber	18.20	3.50	12	2	563	Reconst.	2	135.7	IX-081	26
84	1	RENAICO	IX-074	TOLPAN	-0.092	-0.092	Steel	93.40	3.20	10	2	229	Reconst.	1	328.2	IX-074	1
					Indicator over	-0.090								Total Cost	1437.4	million peso	
	9th Year: 2006																
85	73	PUCON	IX-028	CARHUELLO	-0.100	-0.100	Timber	21.90	3.91	8	3	1504	Reconst.	2	153.5	IX-028	73
86	3	ANGOL	IX-066	MALLECO	-0.103	-0.103	Timber	92.00	3.60	8	2	246	Reconst.	1	323.9	IX-066	3
87	6	LOS SAUCES	IX-051	AGUA SANTA	-0.132	-0.132	Timber	15.50	3.80	12	3	181	Reconst.	1	88.9	IX-051	6
88	61	VILLARRICA	IX-022	LONG LONG	-0.136	-0.136	Timber	14.60	3.95	10	3	407	Reconst.	1	86.2	IX-022	61
89	48	FREIRE	IX-036	PELALES	-0.183	-0.183	Timber	15.80	3.92	8	3	576	Reconst.	2	124.1	IX-036	48
90	30	CURACAUTIN	IX-089	COLORADO	-0.211	-0.211	Timber	21.50	3.75	3	2	31	Reconst.	1	107.3	IX-089	30
91	27	CURACAUTIN	IX-082	CORCOLUDO	-0.226	-0.226	Timber	13.80	3.70	8	2	23	Reconst.	1	83.7	IX-082	27
92	27	CURACAUTIN	IX-083	SANTA RITA	-0.675	-0.226	Timber	11.70	3.80	8	3	23	Reconst.	1	77.2	IX-083	27
93	42	VILLARRICA	IX-009	EL SALTO	-0.313	-0.313	Timber	11.70	3.50	6	3	29	Reconst.	1	77.2	IX-009	42
94	42	VILLARRICA	IX-008	CHOME 2	-0.762	-0.313	Timber	10.00	3.20	12	4	29	Reconst.	1	72.0	IX-008	42
95	55	PITRUFQUEN	IX-046	MAHUIDANCHE	-0.393	-0.393	Timber	36.40	4.00	10	3	851	Reconst.	2	223.3	IX-046	55
96	5	ANGOL	IX-067	VEGAS BLANCAS	-0.490	-0.490	Timber	8.00	3.40	10	3	160	Reconst.	1	65.9	IX-067	5
97	5	ANGOL	IX-068	EL MANZANO	-0.515	-0.490	Timber	15.40	4.00	10	3	160	Reconst.	1	88.6	IX-068	5
					Indicator over	-0.490								Total Cost	1571.8	million peso	
	10th Year: 2007																
98	39	VILLARRICA	IX-011	LAN2	-0.542	-0.542	Timber	8.80	3.55	8	4	525	Reconst.	2	90.5	IX-011	39
99	39	VILLARRICA	IX-010	LAN1	-0.638	-0.542	Timber	21.80	3.60	10	4	525	Reconst.	2	153.0	IX-010	39
100	64	CUNCO	IX-032	MEDINA	-0.547	-0.547	Steel	170.00	3.97	8	3	354	Reconst.	1	563.5	IX-032	64
101	28	CURACAUTIN	IX-084	DILLO	-0.674	-0.674	Timber	10.00	4.60	8	3	23	Reconst.	1	72.0	IX-084	28
102	25	VICTORIA	IX-057	HUILLINLEBU	-0.986	-0.986	Timber	10.40	4.20	12	5	953	Reconst.	2	98.2	IX-057	25
103	43	VILLARRICA	IX-101	MALLA	-1.052	-1.062	Timber	10.00	4.00	12	5	312	Reconst.	1	72.0	IX-101	43
104	21	COLLIPULLI	IX-073	ÑANCO	-1.082	-1.082	Timber	14.40	4.20	10	5	229	Reconst.	1	85.5	IX-073	21
105	44	VILLARRICA	IX-102	PUELLO	-1.171	-1.171	Timber	14.50	3.50	6	5	119	Reconst.	1	85.8	IX-102	44
106	45	VILLARRICA	IX-031	HUICAHUE	-1.218	-1.218	Timber	33.00	3.70	10	5	36	Reconst.	1	142.7	IX-031	45
107	24	VICTORIA	IX-065		-1.233	-1.233	Timber	12.00	3.50	8	5	283	Reconst.	1	78.2	IX-065	24
108	46	CUNCO	IX-030	CODULTO	-1.440	-1.440	Timber	10.80	4.00	8	5	65	Reconst.	1	74.5	IX-030	46
					Indicator over	-1.440								Total Cost	1515.9	million peso	
														Grand Total Cost	14748.6	million peso	
	No Action																
109	32	GALVARINO	IX-045	AILLINCO	-10.000	-10.000	NoBridge				0	562	NoAction	-	0.0	IX-045	32
110	72	VILLARRICA	IX-023	QUEBRADA HONDA	-10.000	-10.000	Steel	18.00	3.52	12	5	613	NoAction	-	0.0	IX-023	72

4. Appraisal of Feasibility of Investment

The overall cost for the ten-year bridge improvement plan (110 bridges) in Region IX amounts to 14 750 million Chilean Pesos. For this amount, attempts were made to appraise feasibility of investment by economic internal rate of return (EIRR); however, there were problems encountered with the estimation of project benefits such as mentioned below and its dependability was questionable.

- It was not possible to ascertain the data regarding detour route, distance, and road conditions necessary for the calculating of benefits of savings in running time and running cost. Roads were excluded in this Study from the aspect of cost-efficiency because there was a very large number of rural bridges and the scale of each was small; therefore bridges became the sole focal point of survey. As the total bridge length in Region IX of 110 bridges was only 2.64 kilometers, to calculate savings in running time and running cost judged on the bridges alone would result in a negligible figure. In addition, rural traffic volume is small and the added productivity of saved time is not great.
- In the case of replacing a timber bridge with a permanent concrete bridge, maintenance costs for timber bridges are no longer involved and savings benefit in capital occurs. In the case that a timber bridge is not replaced, it is assumed that the same bridge is rebuilt every ten years. However, the higher the cost of the timber bridge, the greater the benefits; therefore the EIRR fluctuates considerably.

It is therefore difficult to evaluate the feasibility of investment for the improvement of rural bridges by economical analysis, but as one part of the road is improved as a result, the nine socioeconomic effects such as mentioned in "2. Appraisal Method of Rehabilitation Priority" can be anticipated. Such effects include the alleviation of poverty and rectification of regional imbalance in income, which are policy objectives of the Chilean government. Roads are a fundamental public facility for the use of local inhabitants, and when passage is deterred, unfavorable effects come about in the economy and lives of local inhabitants. In view of the social policies at hand, the MOP has reconstructed deteriorated and hazardous timber bridges over cycles of five to ten years. However, due to the rising costs of timber bridges and increase of heavier vehicle load in recent years, it has been decided that all bridges be replaced with permanent concrete bridges. This decision was made based on the judgment that concrete bridges have greater advantage in technical and economic aspects in regards to future maintenance.

4. BRIDGE REHABILITATION DESIGN

1. Scope of Rehabilitation Design

The purpose of the rehabilitation design is to transfer technical skills of inspection and rehabilitation of bridges to the MOP personnel in charge for bridge maintenance, while reflecting the obtained technical information on the Bridge Inspection & Rehabilitation Manual and the Bridge Rehabilitation Plan drawn up as part of the Study. The design covered the following works:

- Inspection of bridge condition.
- Topographic and geological survey for reconstruction design.
- Inspection of damages for repair design.
- Rehabilitation design and cost estimate both of repair and reconstruction.
- Environmental study on bridge site.

2. Process of Rehabilitation Design

General inspection was carried out to collect the general bridge data as well as to evaluate adequacy of the existing bridge condition. Through this inspection, the basic rehabilitation scheme (reconstruction or repair) was decided for each bridge. After that, for the bridges judged to be reconstructed, topographic and soil-boring surveys were carried out, and for the bridges judged to be repaired, damages were inspected in detail. Collecting all the site information inspected and surveyed, sample rehabilitation designs and cost estimates for the selected 20 bridges were prepared. In parallel with the inspection of bridge, environmental study was conducted to assess the effect which rehabilitation of bridge might have on its surroundings. See the flowchart in **Figure 11**.

3. Selection of 20 Bridges

Twenty bridges for the rehabilitation design were selected considering the following points (see **Table 11**):

- Bridges of various structural types and for rehabilitation methods be selected.
- Bridges under various geological and geographical conditions be selected.
- Bridges which the MOP needs urgent rehabilitation be selected.

Common bridge types in Chile such as simply supported timber, concrete and steel beams were selected, but special types such as continuous beams, suspension bridges, arches, etc. were excluded.

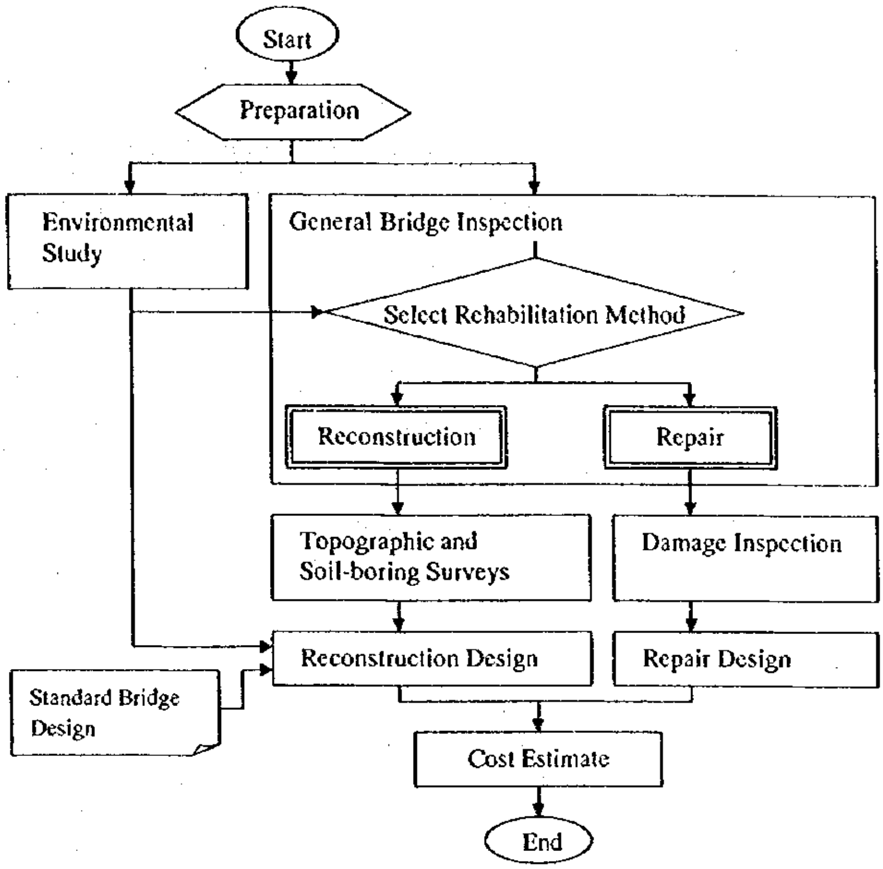


Figure 11 Process of Bridge Rehabilitation Design

Table 11 Twenty Bridges for Rehabilitation Design

No.	Bridge Name	Region	Bridge Type	Length (m)	No.	Bridge Name	Region	Bridge Type	Length (m)
1	Confluencia	IV	ST	113.10	11	El Indio	IX	ST	21.10
2	David Garcia	V	RC	93.05	12	Quillen	IX	TM	25.90
3	Granallas	V	ST	49.85	13	Poculon	IX	TM	31.00
4	Ventanas	V	RC	30.00	14	Malleco	IX	TM	92.00
5	San Jose	RM	RC	16.10	15	Miraflores	IX	TM	44.40
6	Puangue	RM	RC	105.10	16	San Juan	IX	TM	31.60
7	San Jose de Marchiue	VI	ST	120.00	17	Medina	IX	ST	170.00
8	Antivero No.2	VI	RC	102.90	18	Cautin	IX	ST	39.40
9	Los Cardos	VI	ST	73.55	19	Salva Tu Alma	IX	ST	40.70
10	Cautin	IX	RC	140.00	20	Quinchilca	X	RC	140.00

Notes: RM = Region metropolitan
RC = Reinforced concrete beam bridge
ST = Steel beam bridge
TM = Timber beam bridge

1. General Bridge Inspection

(1) Joint Inspection

Bridge sites were at first inspected jointly by the MOP and the Study Team engineers in order to have common understandings of bridge condition between us. Through the joint inspection, not only visible bridge damages but also other invisible problems such as construction year, past repair, design load, river flow at flood, traffic condition, etc., were collected by hearing from the regional MOP staff and the local people using the bridge. Basic plans of location and alignment for the reconstruction bridges as well as topographic and soil-boring survey area, were agreed with the MOP during the inspection.

(2) Inspection of Damages and Defects

Damages and defects of the bridges were visually inspected span by span in close proximity as far as access was safe. Major damages and defects were taken by photographs and evaluated by five ranks of I (dangerous) through V (good). Most inspected were rated at II or III.

An example of inspected bridge and its damages are shown in **Figure 12** and **Table 12**.

2. Rehabilitation Method

(1) Rehabilitation Policy

On deciding rehabilitation method whether to be repaired or reconstructed, opinion and request from the MOP were taken as an important factor together with the technical judgment according to the results of inspection. The MOP has such policy for the rehabilitation of rural bridges as follows.

Many bridges in rural area have already aged and deteriorated, and their width and loading capacity have become insufficient against the today's traffic. For such old bridges, the reconstruction scheme with a new bridge is preferably adopted rather than repairing or strengthening the existing one.

- Existing timber bridges, for their short durable years and frequent maintenance required, should be replaced with permanent (concrete or steel) structures.
- Existing concrete or steel bridges, for economy of the rehabilitation, should be maintained by repairing as far as they hold adequate width and loading capacity. However, the bridges insufficient of width and loading capacity, should be reconstructed with the latest design standard Widening or strengthening the existing structure be avoided.

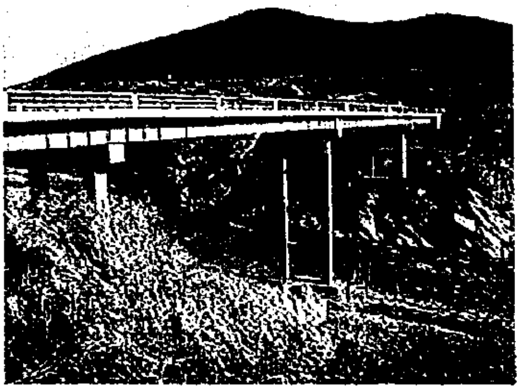
(2) Selection of Rehabilitation Method

Rehabilitation method was studied for each bridge based on the results of inspection and considering the rehabilitation policy of the MOP, and concluded that eight bridges were for reconstruction design and twelve for repair.

The technical and social reasons why reconstruction scheme is adopted, are explained in **Table 13** by taking an example of No.2 David Garcia Bridge.

For the repair design, simple and small scale of repair methods suitable for the maintenance of old bridges until reconstruction, were adopted. In the repair design, loading capacity could not be justified.

BRIDGE NAME: CONFLUENCIA



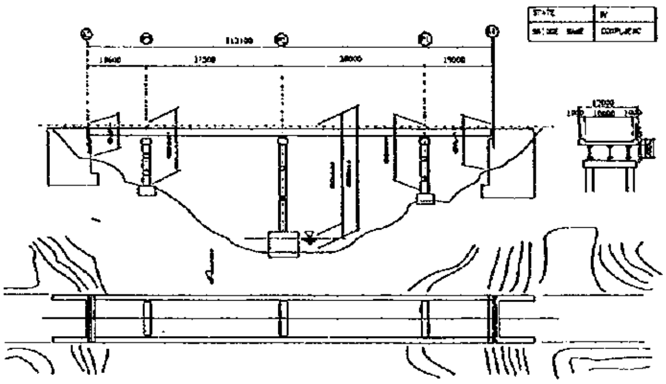
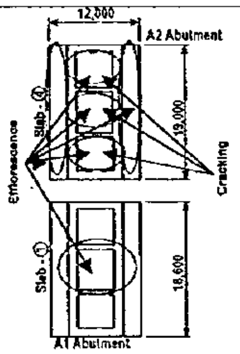
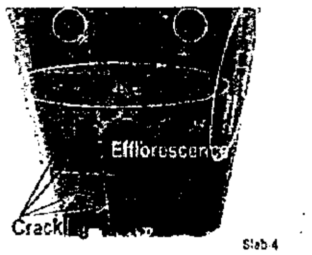
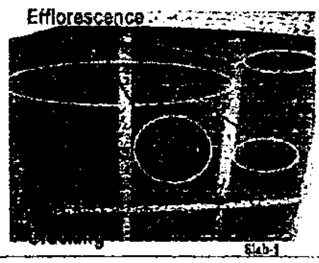
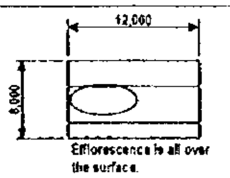
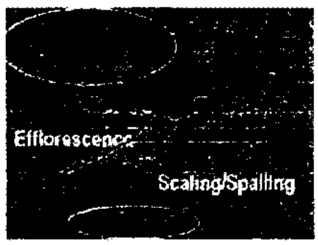


Figure 12 General View Drawing of Inspected Bridge

Table 12 Damage Table

Bridge Component	Location of Damage	Damage	Evaluation of Damage	Damage Rank	Picture
Slab	 Cracking X: one direction 0.3mm<Y<0.2mm Z: less 50cm Efflorescence Z: over 0.1m2	Cracking	X / Y / Z / All member: Large / Large / Large: II Large / Large / Small: II Large / Medium / Large: II Large / Medium / Small: III Large / Small / Large: III Large / Small / Small: IV Small / Large / Large: III Small / Large / Small: III Small / Medium / Large: (shaded) Small / Medium / Small: IV Small / Small / Large: IV Small / Small / Small: IV Damage was observed, but rehabilitation is not needed. Follow-up inspection must be executed.	III	
		Efflorescense	Z / Main Member / Secondary Member: Large: (shaded) / II Small: III / IV Degree of damage was large so that rehabilitation must be needed.	II	
A1 Abutment	 Scaling/Spalling Y: no exposed reinforcement bar Z: less 1.0m2 Efflorescence Z: over 1.0m2	Scaling/Spalling Efflorescence	Scaling/Spalling Y / Z / Main Member / Secondary Member: Large / Large: [illegible] / [illegible] Large / Small: [illegible] / IV Small / Large: [illegible] / IV Small / Small: (shaded) / IV Damage was observed, the degree must be recorded. Efflorescence Z / Main Member / Secondary Member: Large: (shaded) / II Small: III / IV Degree of damage is large, so that rehabilitation must be needed.	Scaling/ Spalling IV Efflorescence II	

3. Topographic and Soil-Boring Surveys

At the eight bridge sites selected for reconstruction design, topographic and soil-boring surveys were carried out and then topographic maps for the new bridge designs were prepared. The area and location surveyed are illustrated in **Figure 13.** In total, 14.4 ha of topographic survey and 135 m of soil-boring (44 m for fine soil and 91 m for gravel) survey were conducted.

4. Damage Inspection

The major damages shown in **Table 14** observed in general inspection, were inspected more in detail for repair designs using non-destructive test instrument.

Table 14 Typical Damages

Material Type	Concrete	Steel	Timber
Typical Damages	Cracking Scaling/Spalling Delamination Honeycomb Efflorescence Wear Breakage	Aging Coat Rusting Loosening Falling off Deformation Cracking	Decay Split/Check Sagging Loosening

Nondestructive test (NDT) can detect inside of bridge element and assess deficiencies that may not be visible. The following NDTs were performed for where the situation permitted:

Table 15 Nondestructive Tests

Material Type	Test Equipment	Objectives of Test
Concrete	Schmidt Hammer (NR-4)	Strength of concrete
	Paco-Meter 3D Type	Location and diameter of reinforcing bars
	Phenolphthalein Liquid	Neutralization of concrete
Steel	Ultrasonic Thickness Meter	Thickness of steel plate
	Dye Penetrant	Detecting cracks

The results of damage inspection are briefed as follows:

(1) Concrete member

Large amount of cracks, spalling, isolated lime and honeycomb etc. are observed indicating problems in quality of concrete. Remarkable carbonation was not observed.

(2) Steel member

Very large amounts of rust and coat deterioration. However, such damage did not penetrate the cross-section and thus did not present problems in structural parts.

(3) Wooden member

More than half suffers from rot resulting from age and traffic rather than from insects or fungi.

Table 13 Example of Reasons of Reconstruction

Bridge Name: David Garcia

Technical Reasons	Social Reasons
1. Built in 1930s, the concrete bridge looks seriously deteriorated from the color and the external appearance. 2. Judging from a neutralization test conducted by spraying a phenolphthalein solution, it is supposed that the concrete has been already neutralized to some extent and the re-bars may be corroded through the neutralization. 3. While a heavy vehicle is passing the bridge, a considerable vibration is felt. It is possible that the vibration comes from some defects of the foundation, because reasonable rigidities of both the superstructure and the substructure are supposedly secured. 4. An isolated lime blots the bottom of the concrete slab, and from the fact the depth of cracks in the concrete can be guessed. 5. At the bridge seat of the abutment, so wide crack as 1 cm was found. 6. Squatters used to live and make a fire under the bridge. As the result the bottom of the bridge has changed to black by the soot. It is probable for the bridge to be affected adversely. 7. The concrete is scaled off and the re-bars are exposed on the pier.	1. Los Andes is the nearest city from the bridge having a population of 55,000. 2. The bridge is located on E-85, an important trunk road, which connects Los Andes, San Felipe and Santa Maria. 3. The traffic volume of the bridge is as much as 6,000 vehicles a day. The width of 6 m is not enough for that traffic volume.
Conclusion In addition to the age and deterioration, the foundation is very likely unstable due to scouring. Furthermore, the roadway is required to be widened. Thus, reconstruction was proposed.	

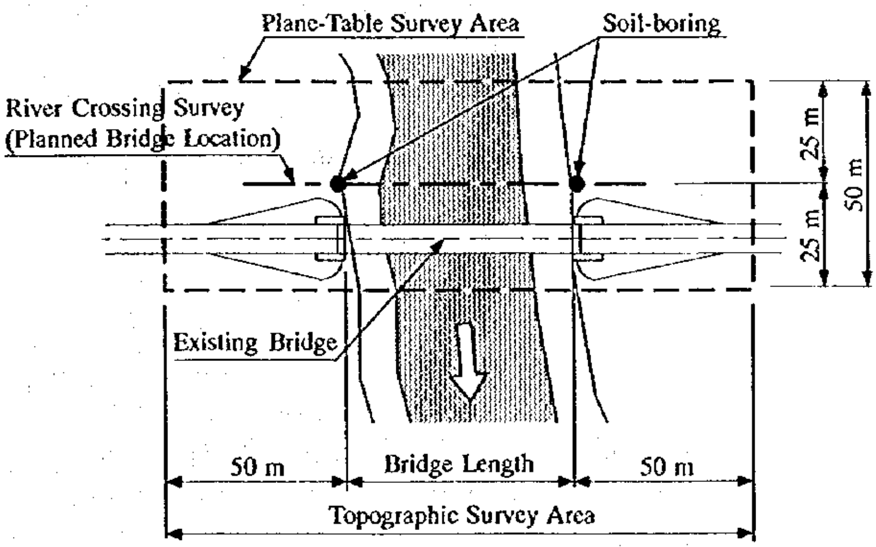


Figure 13 Area and Location for Surveys

1. Reconstruction Design

(1) Process of Design Work

The bridges were planned based on the topographic maps and the ground conditions surveyed, to select bridge type, size and location, considering function and capacity of bridge, geological and geographical condition, and environmental impacts. Basic plans for location and alignment of reconstruction had been agreed with the MOP during the general inspection. After the bridge plan, design drawings were prepared by the CADD (Computer Aided Design and Drafting) programs developed in the Study.

(2) Design Condition

Major design conditions adopted are as follows:

- Design method: CADD Program (allowable stress method)
- Design specifications: AASHTO (1992)
- Live loads: HS 20-44 loading
- Earthquake load: Acceleration coefficient A = 0.15 (Category B by single mode spectral method)

(3) Bridge Design

Bridges were designed taking account of the following technical points:

- Span length was selected from the economical span range of 20 to 30 m.
- In case of the reconstruction parallel and adjacent to the existing, the location of new piers was so determined as to come on the direction of flow from the existing piers in order not to disturb flow.
- Judging from the construction market in Chile, PC (pre-stressed concrete) beam bridge was generally designed. However, for the span over 30 m and terrain of site was mountainous, steel beam was selected considering ease of erection work although it was costly compared to PC beam.
- For floating debris, a minimum freeboard of 1.0 m between high-water-level and the lowest point of superstructure was adopted.
- For scouring, a minimum depth of 2.0 m was taken from riverbed down to top of footing.

The main features of bridge designs are summarized in **Table 16.** A sample design of general view drawing is shown in **Figure 14.**

2. Repair Design

(1) Selection of Repair Method

Based on the damage data collected by inspection, repairs were designed for the methods which were common and often practiced in the MOP as listed in **Table 17.** To select the most suitable repair method, relation charts of damage types and repair methods were recommended for major damages. A sample chart for crack repair is shown in **Figure 15.**

As for the repair of timber bridges, the only method was replacement of damaged timbers, therefore no drawing was required to interpret such method.

(2) Repair Design

Table 18 summarizes the repair designs for each bridge.

Figure 16 shows a sample drawing of repair plan in which the following design data are given for each damage to be repaired:

① Damage Location
② Kind of Damage
③ Repair Method
④ Material for Repair
⑤ Quantity

The details of repair methods are presented in **Division III of Bridge Manuals (Volume 6/8).**

Table 16 Summary of Reconstruction Bridge Designs

No.	Bridge Name	Type of Superstructure	Span/Bridge Length	Bridge Width (Roadway/Sidewalk)	Location of New Bridge
2	David Garcia	Post-tension PC beam	4 @ 26 = 104 m	10 + 2 @ 1.5 = 13.0 m	Same location
3	Granallas	Post-tension PC beam	2 @ 28 = 56 m	7 + 2 @ 1.2 = 9.4 m	Same location
5	San Jose	Post-tension PC beam	3 @ 28 = 84 m	10 + 2 @ 1.0 = 12.0 m	Down-stream
6	Puangue	Post-tension PC beam	4 @ 30 = 120 m	10 + 2 @ 1.2 = 12.4 m	Up-stream
7	San Jose de Marchiue	Post-tension PC beam	6 @ 27 = 162 m	7 + 2 @ 1.0 = 9.0 m	Up-stream
8	Antivero No. 2	Post-tension PC beam	4 @ 29 = 116 m	9 + 2 @ 1.2 = 11.4 m	Same location
13	Poculon	Pre-tension PC beam	2 @ 20 = 40 m	7 + 2 @ 1.0 = 9.0 m	Down-stream
16	San Juan	Steel plate girder	1 @ 34 = 34 m	8 + 2 @ 1.2 = 10.4 m	Same location

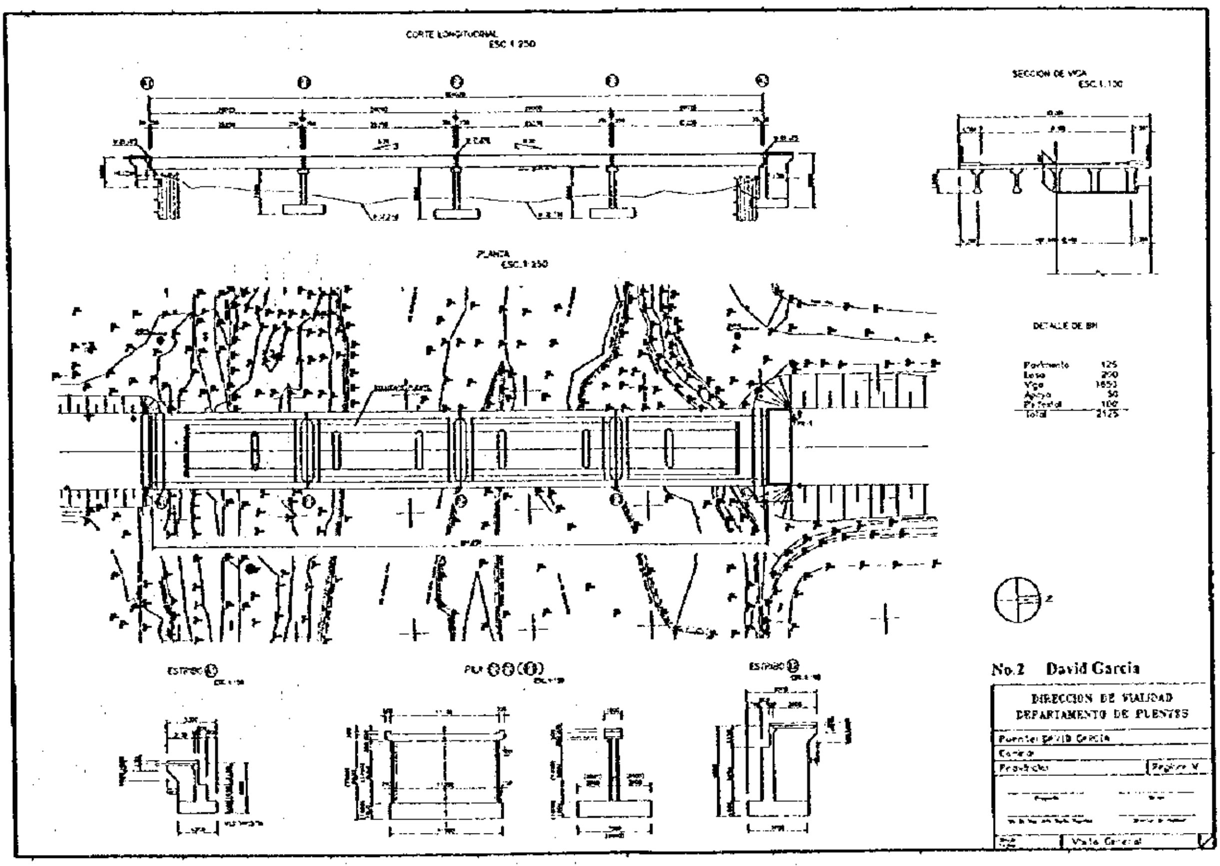


Figure 14 General View Drawing for Reconstruction Design

Table 17 Proposed Repair Methods

Type of Material	Repair Methods
Concrete	Injection, Caulking, Grinding, Coating, Resurfacing, Pre-packing, Dry-packing, Shotcrete/Gunite, Patching, Overlay, Replacement
Steel	Repainting

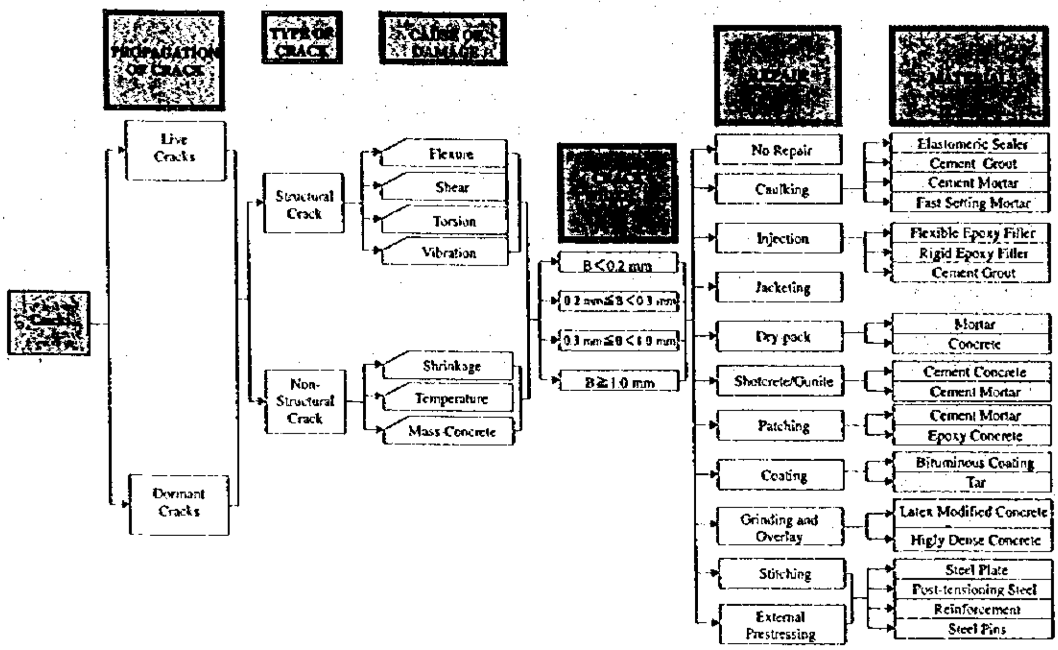


Figure 15 Damage-Repair Method Chart for Cracks

Table 17 Proposed Repair Methods

Type of Material	Repair Methods
Concrete	Injection, Caulking, Grinding, Coating, Resurfacing, Pre-packing, Dry-packing, Shotcrete/Gunite, Patching, Overlay, Replacement
Steel	Repainting

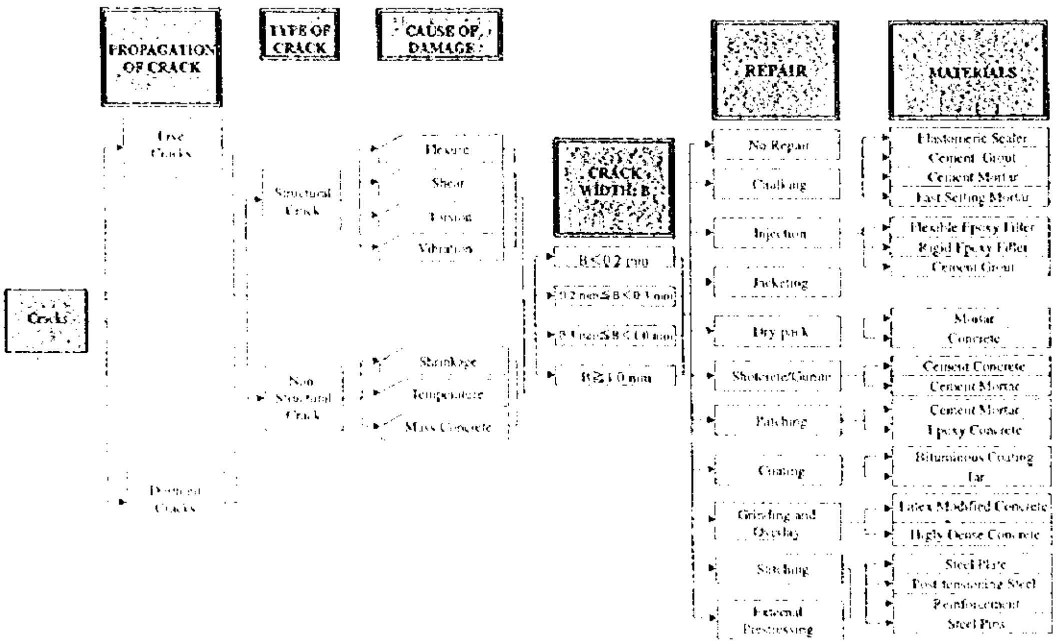


Figure 15 Damage-Repair Method Chart for Cracks

Table 18 Summary of Repair Bridge Designs

No.	Bridge Name	Bridge Type	Bridge Length (m)	Proposed Major Repairs
1	Confluencia	ST	113.10	Repair of concrete Repainting of steel beams
2	David Garcia	RC	93.05	Repair of concrete
3	Granallas	ST	49.85	Repair of concrete Repainting of steel beams
4	Ventanas	RC	30.00	Repair of concrete Replacement of expansion joints
10	Cautin	RC	140.00	Repair of concrete
11	El Indio	ST	21.10	Repair of concrete
14	Malleco	TM	92.00	Repair of concrete (abutment only)
17	Medina	ST	170.00	Repair of concrete (abutment only) Repainting of steel beams
18	Cautin (88)	ST	39.40	Repair of concrete (abutment only) Repainting of steel beams
19	Salva Tu Alma	ST	40.70	Repair of concrete (abutment only) Repainting of steel beams and pier column
20	Quinchilca	RC	140.00	Repair of concrete

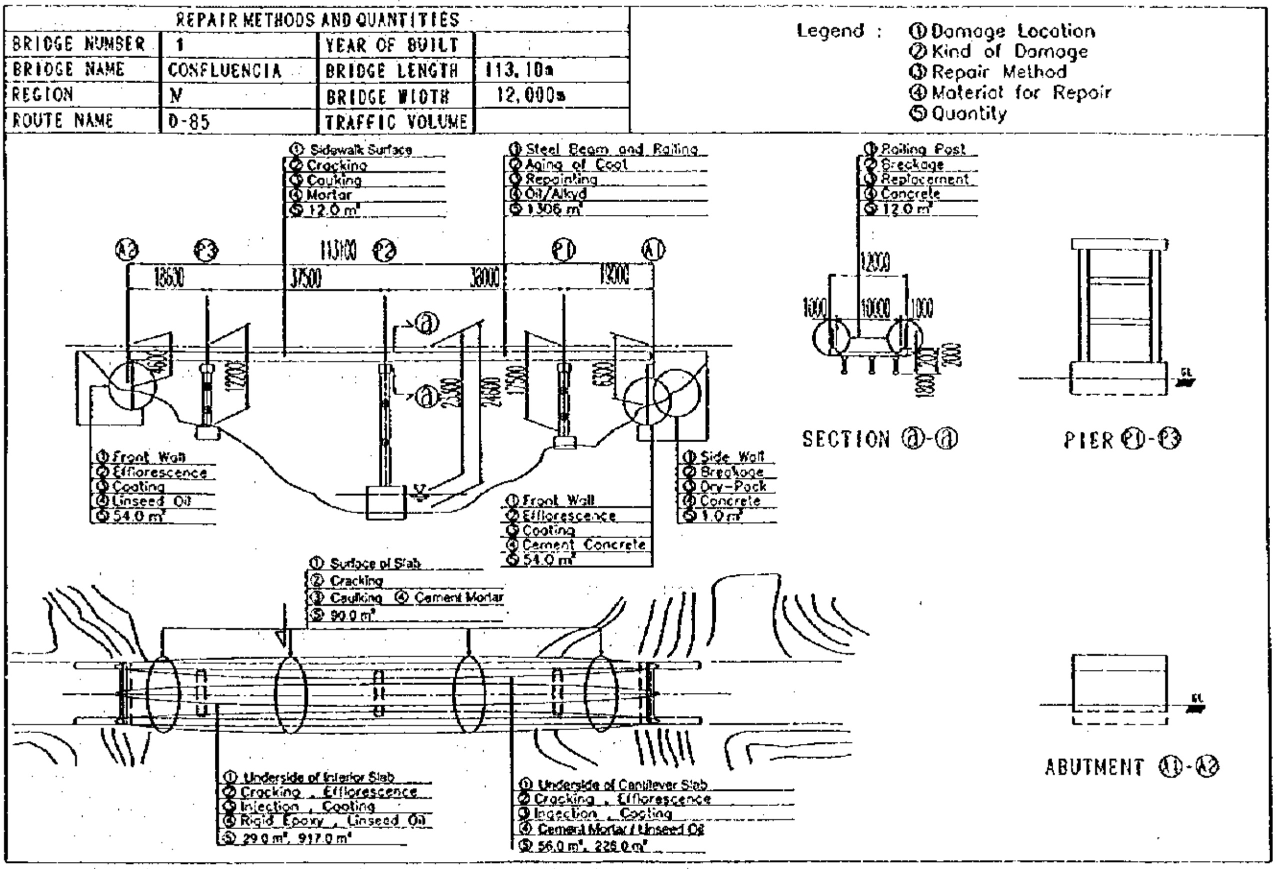


Figure 16 Repair Plan Drawing

1. Purpose of Environmental Study

Chile established the General Fundamental Law of Environment in March 1994 and the Environmental Impact Assessment Standard in April 1997. MOP is examining the possibilities of requiring such assessment for bridge construction in addition to road construction due to effects on the natural environment and land use.

This environmental study covered comprehension of present environmental condition and project activity, initial environmental evaluation (IEE), and preliminary environmental impact assessment (Pre-EIA). Views were exchanged with the MOP's Environment Department on the necessity of environmental study for rehabilitation of rural bridges, and in conclusion a standardized study process and form were recommended based on the JICA Environmental Study Guideline.

2. Environmental Study Process and Standard Form

Many common environmental problems are observed in rural bridges relating to geographical condition and due to construction activity. Therefore, a standard form was employed in the survey of the 20 bridges which were selected for rehabilitation design. The items of this form were chosen through scoping and screening survey on site.

The process of standardized environmental study is shown in **Figure 17**, and the standard forms filled with the actual data of David Garcia Bridge are given in **Table 19**.

3. Assessment Methods

In the IEE evaluation column of Form 3, negative impact is marked by "yes" and no negative impact by "no". Where applicable, "temporary" or "slight" impact is also recorded as such. In the case that there is a "yes" and/or a number of "temporary" or "slight" marks, proceed to the Pre-EIA assessment and record the cause and effects.

The Form 4 of Pre-EIA matrix evaluation is conducted in conjunction with the filling in of the Pre-EIA evaluation column in Form 3. In the matrix evaluation, the impact assessment mark (see below) is filled in according to the project activity items in pre-construction, under construction and post-construction stages.

- P: Possibilities of highly negative environmental impact are noted, but a solution has already been found.
- A: High possibilities of negative impact, but data obtained to predict the extent is insufficient.
- X: Remaining notable negative impact is perceived.
- E: Notable improvement of environment is perceived.

4. Results of Environmental Study of 20 Bridges

Many of the 20 bridges studied in detail are apart from settlements; and impacts which project activities may render are small and/or temporary. Furthermore, there are no historical sites or cultural institutions in their vicinities. The ecological environment of all the bridges is general riparian and the existence of endangered species of plants or animals is not reported.

Out of the 20 bridges, 12 bridges were only to be repaired; therefore it was judged that negative socioeconomic, ecological, or pollution-oriented impact in these areas is not significant.

As for the 8 bridges which were to be replaced, there were perceived some negative effects resulting from bridge replacement construction activities. Problems anticipated were resettlement of local inhabitants and land acquisition in case of construction on private land, also traffic congestion due to detouring during construction.

Negative ecological impacts include those on water quality, aquatic life, etc., resulting from soil erosion which is in itself also a negative impact. Earthwork carried out in the dry summer period will result in the raising of dust which will effect air quality. In cases near ranches, etc., where livestock are kept; noise produced from construction machinery will have some negative effects. However, the bridge replacement spots are located within the river banks away from settlements and ranches, so it is considered that polluting effects will be small.

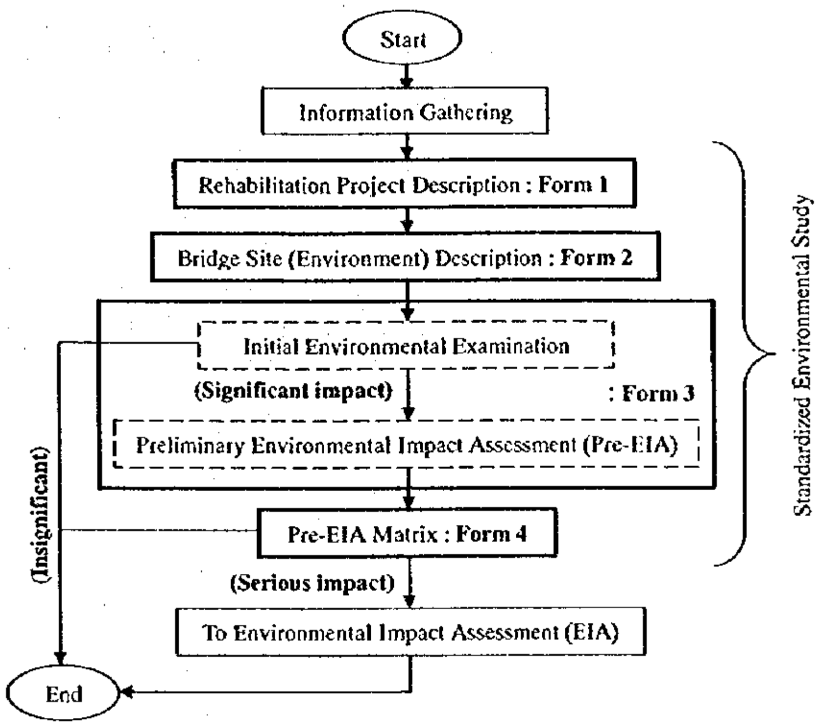


Figure 17 Standardized Process of Environmental Study

Table 19 Standard Environmental Survey Form

Form 1 (Project Description)

David Garcia

Item	Description
Background	The bridge was built in 1930's and deteriorated condition. Bridge length is not enough width of river flow. Many damages on railing portions and expansion joints are recognized. Increase of traffic volume will be highly required on the load capacity of the bridge. Narrow width for pedestrian sidewalks of the bridge. Problems of traffic accidents on pedestrian crossing on the bridge.
Objectives	Replacement of the bridge due to strengthen of deteriorated existing structure condition and increasing of traffic volume. Widen of carriage way and sidewalk. Safeguard and security for pedestrian path on the bridge
Executing Agency	Ministry of Public Works (MOP)
Beneficiaries	Maintain of smooth and safety in increased traffic volume. Safety pedestrian crossing on the bridge sidewalks if enough width of side walks.
Project Components	
Existing bridge structure bridge length, width Other specific features	Slab(Conc.), Beam(conc.), Abutment(Conc.), Pier(Conc.), Foundation(Conc.) Length(93.5m), Width(8.3m) Carriage way width (6.0m), Side walk width (1.15m)
Project Type	(X) Replacement, ( ) Repair
Road Type	(X)Urban / ( )Rural area, (X)Plain area /( )Mountain area (X)Paved / ( )Unpaved
Existing traffic volume	Year 79/6/12(Thr.), 6/30 (255)Cars/hour, ( )Cars/day
Road width/lanes	Exist Width =(3x2 m) Nos. lanes = (2)
Road structure	(X)Embankment / ( )Elevated / ( )Others: Embankment at left bank with 100m
Supplemental facilities	Concrete revetment with 2m in high, 200m in length at right bank of upper watershed.
Others	River name: Aconcagua, Flow direction: NW Road: Town road (Los Andes - San Esteban) of Los Andes. Bridge locates at 1.2km from town center of Los Andes. The bridge was the first reinforced concrete bridge built in 1930's.

Form 2 (Site Description)

David Garcia

Item	Description	
Social environment		
Inhabitants: Residents, Indigenous people	**Upperstream: Left bank area:** None **Downstream: Left bank area:** None	**Right bank area:** Farm house locate at approx. 70m distance from the bridge **Right bank area:** Cattle market facility site locates adjacent the bridge.
Their views on the project Others		
Landuse and facilities: Urban area, Farm land, Others Historic & cultural site, Scenic spot Hospitals and other facilities	**Upperstream: Left bank area:** Barren land, Residential at hinterland **Downstream: Left bank area:** Barren land, residential at hinterland	**Right bank area:** Agriculture (Vine yard) **Right bank area:** Barren land, Cattle market facility Residential at hinterland
Economy: Commerce,Agriculture, Forestry Others	**Upperstream: Left bank area:** Barren land, Small sand borrow pits **Downstream: Left bank area:** Agriculture	**Right bank area:** Agriculture **Right bank area:** Barren land
Transport: Bus terminal, etc.	None	
Natural environment		
Topography, (Feature of river bank area) Steep slopes, Soft ground, Wetland	**Upperstream: Left bank area:** Slope and terrace mixed bank **Downstream: Left bank area:** Slope and terrace mixed bank	**Right bank area:** Slope and terrace mixed bank **Right bank area:** Slope and terrace mixed bank
Geology, (feature of river bank/bed): Outcrop, stone, gravel, sand / Fault Soil type, etc.,	**Left bank area:** Gravel and silt soil mixed bank **River bed:** Flat river bed with round grovels and stone river bed	**Right bank area:** Gravel and silt soil mixed bank
Hydrology, (Feature of river flow, Water level, flood level)	Flow regime divides 2 flows and gravel dunes exist in the water flow. Water depth of 1.3m at flow center of the river. Flow velocity of Aprox... 1.5m/sec. Flood level comes up to 3.5m from the river bottom. Flow direction: NW	
Fauna & Flora / habitats Rare species /community, etc.,	Pre-cordilleran deciduous forest area, dry land vegetation, Eucalipurus plantings at left bank. Commoo fish fauna and birds No specific area of importance. Rare species are not recognized	
Pollution		
Complaints: Population of the upmost concern	No specific complaint	
Measures taken: Institutional measures Compensation	No necessity	
Others	River bank areas are under the circumstance of damp yard of construction waste. One of the worse environmental degradation area of the bridge surroundings. Daily pedestrian flow activities cross over the bridge is facing traffic threaten.	

Form 4 (Preliminary Impact Assessment)

David Garcia

Environmental component		Identification of activities	Project activities: Pre-construction stage										Construction stage																Operation and maintenance stage						Consequent projects		
			Access roads	River crossings	Site surveying	Boring test	Site cleaning /Burning	Earthworks	Equipment	Waste disposal & recover	Land acquisition	Resettlement/compensatio	Access roads	River crossing/deture root	Earth works	Demolition	Building relocation	Reclamation	Erosion control	Drainage alteration	Piling	Structures	Equipment	Revegetation	Landscaping	Labour force	Utilities	Waste disposal & recover	Equipment	Transportation / traffic	Pedestrian traffic	Waste disposal & recover	Accidents	Labour force	Amenities	Utilities	Transportation
Socio economic environment	Land & property	Land aquisition																																			
		Resettlement																																			
	Economic	Economic activities																																			
		Employment																							E												
	Traffic & facility	Transportation / Traffic												P																E	E		E				
		Public facilities																																			
	Community	Disintegration of communities																																			
	Amenity	Amenities																												E	E						
	Historical & cultural	Historic assets																																			
		Cultural properties																																			
	Vested rights	Fishery rights, right of common																																			
	Waste	Generated waste & waste disposal														P												P									
	Hazard	Accidental damages												P																E	E						
Natural environment	Land	Topographic feature/river bank,bed													P																						
		Geological condition																																			
		Land use																																			
		Soil erosion													P																						
		Hydrological feature																																			
	Surface water	Water use																																			
		Water quality													P																						
		Floating debris																																			
		Flood affection																																			
	Species & population	Terrestrial vegetation / Flora																																			
		Terrestrial wildlife / fauna																																			
		Aquatic flora																																			
		Aquatic fish fauna													P																						
	Aesthetic	Landscape																							P									E			
Pollution	Atmosphere	Air pollution													P																						
	Water	Water pollution													P																						
	Noise, vibratio	Noise and vibration																					P														

Form 3 (Initial Environmental Evaluation)

David Garcia

No	Environmental component	Identification of activities	Description of activities	IEE evaluation	Preliminary EIA evaluation	Remarks (Reason)
Socio economic Environment						
1	Land and Property	Land aquisition	Transfer of right of land ownership compensation	No		
		Resettlement	Transfer of rights of residence / compensation	No		
2	Economic	Economic activities	Loss of basis of economic activities, such as land, and change of economic structure	No		
		Employment	Increase or decrease of employment opportunity	Increase		Const. Period
3	Traffic and Public facilities	Traffic	Impact on present traffic conditions, increase of traffic congestion	Temporal	Temporal	Use of detour route Safety control
		Public facilities	Impacts on schools, hospitals caused by increase of traffic volume	No		
4	Communities	Disintegration of communities	Community split due to interruption of area traffic	No		
5	Amenity	Amenities	Increase or loss of existing amenities	Increase	Enhance	Aesthetic condition
6	Historical and Cultural	Historical assets	Damage or loss of the value of historic or archaeological remains	No		
		Cultural properties	Damage or loss of the value of cultural assets	No		
7	Vested rights	Water rights and rights of common	Obstruction of fishing rights, water rights, or other rights of common	No		
8	Waste	Waste	Generation of construction and demolition debris	Yes	Temporal	Obligation to the construction side
9	Hazards	Risk and damage	Risk of accidents, traffic damage	Slightly	Temporal	Safety control
Natural Environment						
10	Land	Topographic feature /river bank and bed	Changes of valuable topographic land form condition	No		
		Geological condition	Changes of geological condition	No		
		Land use	Change of original land use	No		Negligible
		Soil erosion	Topsoil erosion by rainfall after earth work and vegetation removal	Slightly	Temporal	Negligible
11	Surface water	Hydrological feature	Changes of flow variation	No		
		Water use	Change of existing water use	No		
		Water quality	Change of water quality	slightly	Temporal	Negligible
		Floating debris	Floating obstacles	No		
		Flood affection	Flood affected area	No		
12	Species and their population, habitat	Terrestrial vegetation /flora	Obstruction of valuable species and their community, habitat	No		
		Terrestrial wildlife /fauna	Obstruction of breeding and extinction of species, communities, habitat	No		
		Aquatic flora	Obstruction of valuable species	No		
		Aquatic fish fauna	Obstruction of breeding and extinction of species, communities , habitat	Slightly	Temporal	Negligible
13	Aesthetics	Landscape	Changes of topography and vegetation due to reclamation. Deterioration of aesthetic harmony by structure	No		
Pollution						
15	Atmosphere	Air pollution	Pollution caused by exhaust gas or toxic gas from vehicles	Slightly	Temporal	Control of soil dust
16	Water	Water pollution	Pollution by inflow of silt, sand and effluent into rivers	Slightly	Temporal	Negligible
17	Noise and vibration	Noise and vibration	Generation by construction machinery and traffic vehicles	Slightly	Temporal	Control operation hour.
Overall evaluation			Is Preliminary EIA necessary for the project implementation?	Need of Pre-EIA		

5. STANDARD BRIDGE CADD PROGRAM

1. Computer System

(1) Operating system and language

The operating system Windows 95 and language 'Visual Basic version 5' were utilized.

(2) Hardware and software

IBM/PC compatible computer for Windows 95 was available in Chile, and application software available on the market was utilized for the effective output of results.

Hard- and software utilized, and their specifications, are shown below.

Hardware		Software
- CPU Pentium	200 MHz	- Visual Basic Version 5
- RAM Memory	64 MB	- MS-Office PRO for Windows 95
- Hard Disk	2.0 GB	- Auto CAD R13 for Windows 95
- Monitor	17 inches	
- Printer	A3 size	
- Plotter	A1 size	

2. CADD Programming

(1) Design specifications

According to the bridge design standard of the MOP, the design specifications of the American Association of Highway and Transportation Officials (AASHTO) was adopted.

Major design conditions are as follows:

- Design method: Allowable stress method
- Live loads: 100 % of HS 20-44 loading
- Earthquake load: Category B by single mode spectral method

(2) Types of bridge

PC (Pre-stressed Concrete) beam and steel girder are the most common for the short to middle span length bridges in Chile. Therefore, pre-tensioned PC I-beam, post-tensioned PC I-beam, rolled steel H-beam, and steel plate girder were adopted for the superstructure of this CADD system according to span length. For economical reasons, a composite girder (PC beam or steel girder with reinforced concrete slab) was adopted.

For the substructure, the most basic types of inverted "T" style abutment and wall type pier with spread foundation were used in the program (see **Figure 18**). Pile foundation was not used.

(3) Outline of CADD program system See **Figure 19.**

(4) Input and output of data

A dialogic inputting method was adopted. With this method, the designer can proceed with his/her new design work by correcting the former design data of similar-type bridges already stored in the computer, like dialoguing with computer. The designer will be easy to verify calculation results of his own data input; and produce as output the final products: design calculation sheet, volumes calculation sheet, and design drafts.

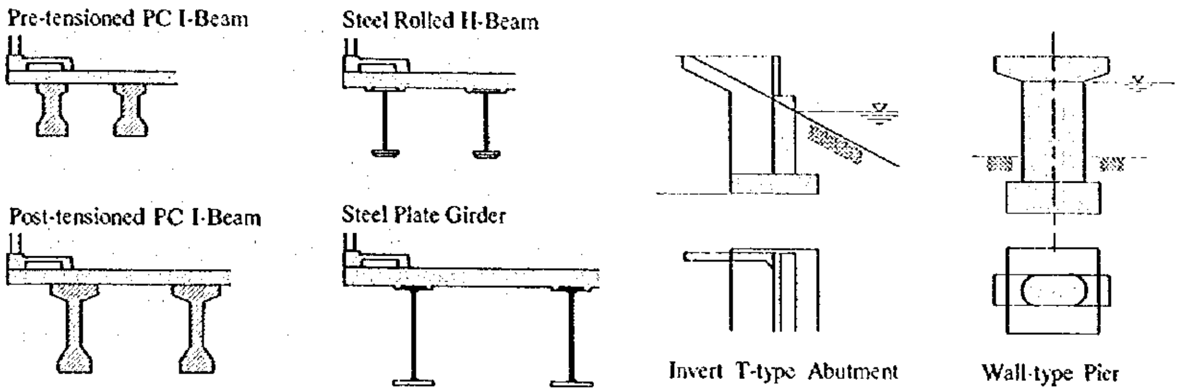


Figure 18 Bridge Types for CADD Program

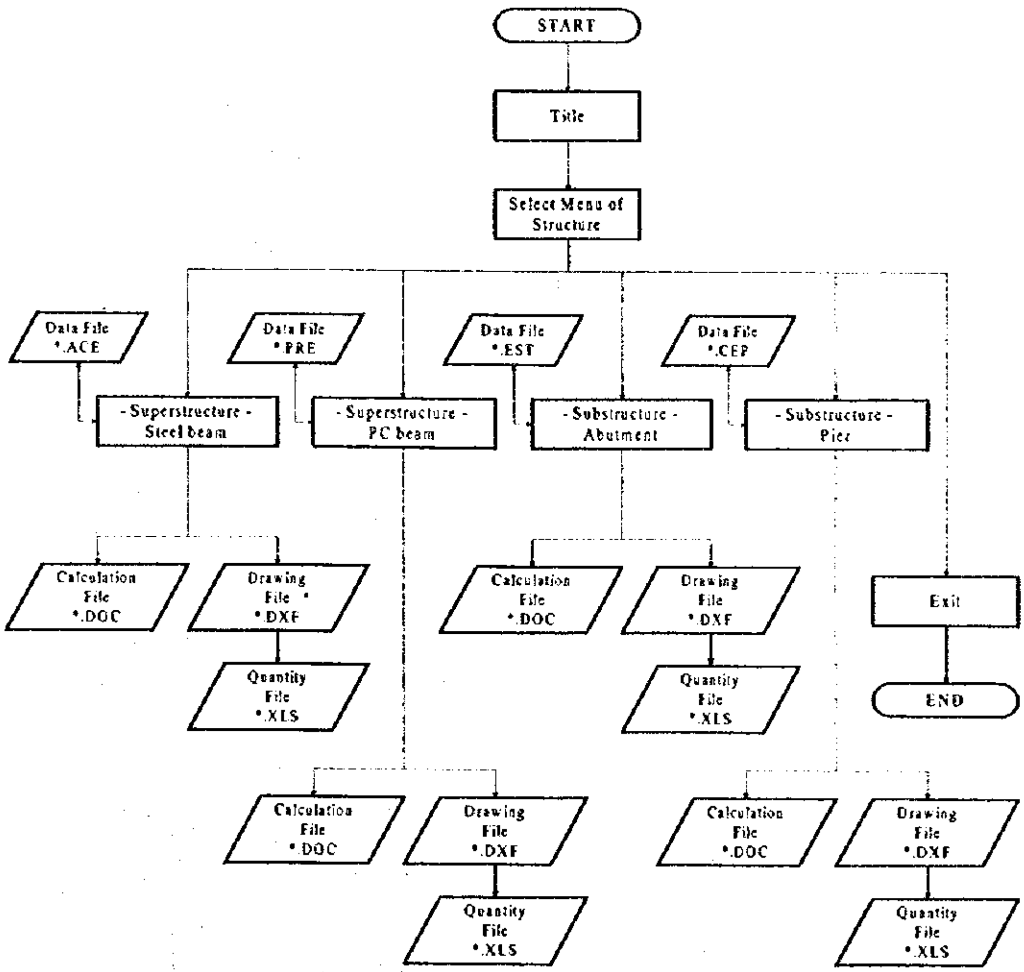


Figure 19 Outline of Whole CADD Program System

1. Standard Design Drawings

Standard drawings were prepared using the above mentioned CADD program. Prepared were the standard drawings for steel and PC bridges with one or two lanes (see **Figure 20**), with span length from 14 to 36 m with 2 m pitches.

The standard drawings and CADD program are used in different ways. The standard drawings are used to find the target bridge, and if one applicable is found, that is used in bridge planning. Furthermore, in case there is found no bridge which matches the criteria of the bridge in question, that data is initialized, and by correcting computer data by use of the CADD program, the bridge can be designed effectively. The standard bridge design drawings are compiled separately in **Volume 8/8**, but one example is shown on the following pages.

(2) Applied span length

The span lengths in the standard drawings were determined according to the best economic choice by structure type, as shown in **Table 20** below.

Table 20 Applied Span Length

Type of Bridge	Applied Span Length or Height
Superstructure	
Pre-tensioned PC I-Beam	14 m ~ 24 m (2 m pitches)
Post-tensioned PC I-Beam	24 m ~ 36 m (2 m pitches)
Steel Rolled H-Beam	14 m ~ 24 m (2 m pitches)
Steel Plate Girder	26 m ~ 36 m (2 m pitches)
Substructure	
Abutment (spread foundation)	5 m and 12 m
Pier (spread foundation)	5 m and 15 m

Furthermore, both the drawings and CADD programming assume right angle straight bridges, but with the inventiveness of the designer, designs for skewed or curved bridges are also possible.

(3) Comprehensive table of standard drawings

All major specifications of the bridges (beam spacing, beam height, beam cross section, super-imposed load reaction force, volumes of main materials, etc.) are listed in the standard drawings in order to assure effectiveness in use for preliminary design.

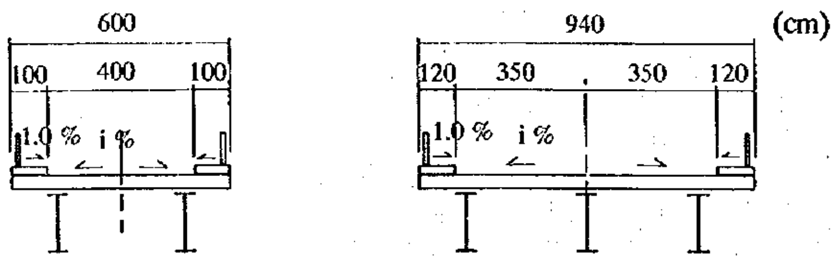
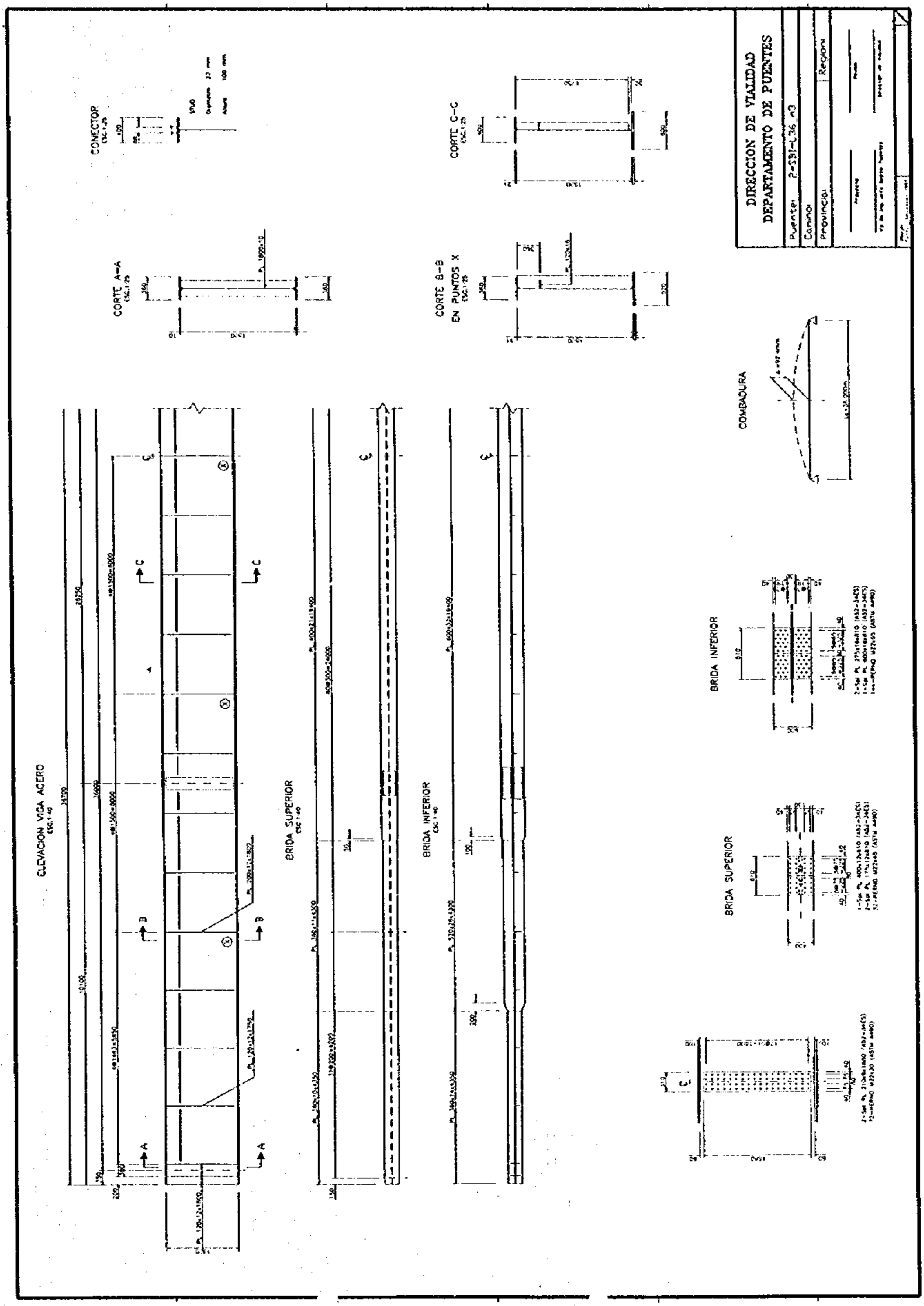
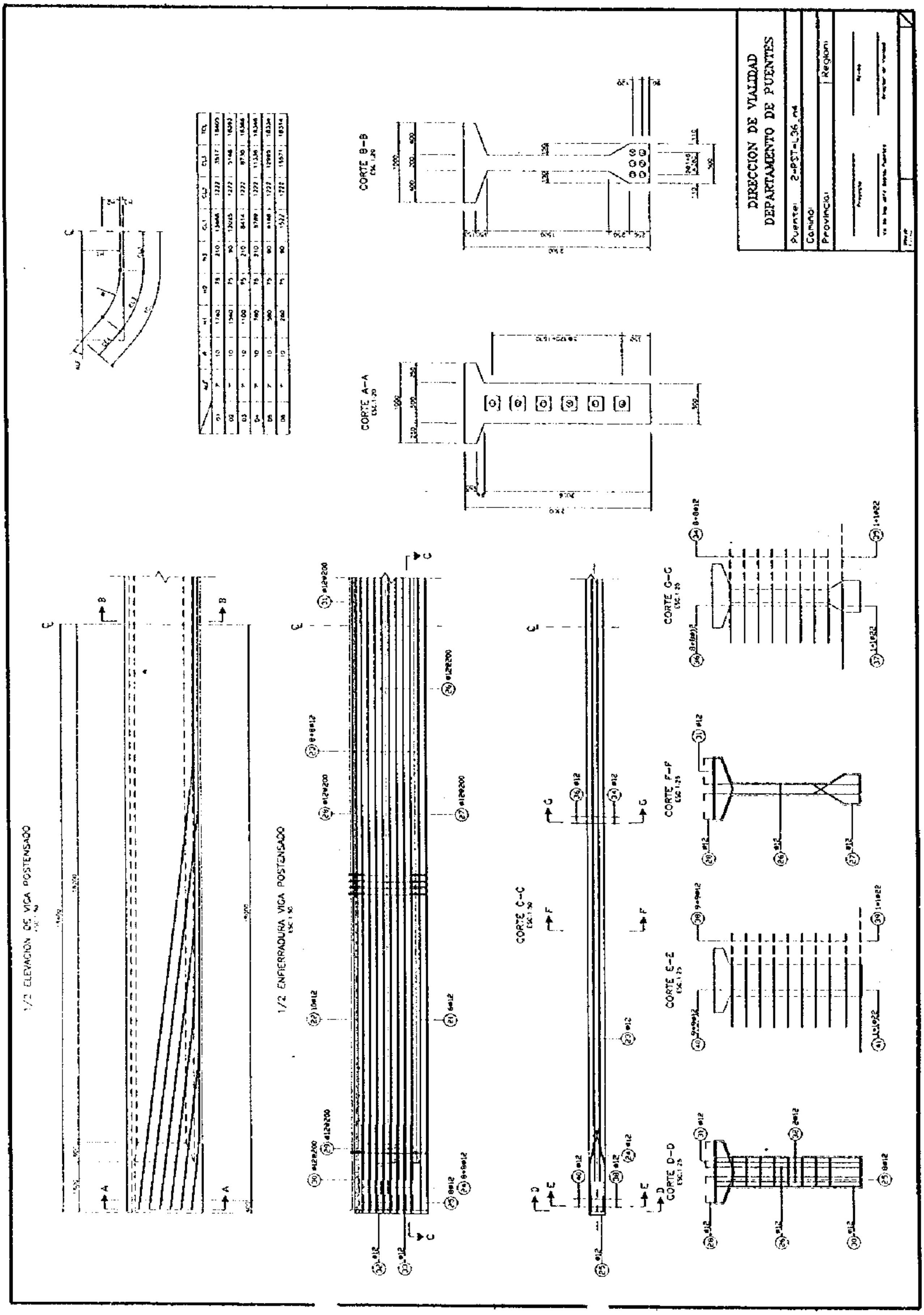


Figure 20 Standard Design Width


DIRECCION DE VIALIDAD
DEPARTAMENTO DE PUENTES
CONECTOR
CORTE A-A
CORTE B-B
EN PUNTOS X
CORTE C-C
COMBADURA
ELEVACION VIGA ACERO
BRIDA SUPERIOR
BRIDA INFERIOR


DIRECCION DE VIALIDAD
DEPARTAMENTO DE PUENTES
CORTE B-B
CORTE A-A
1/2 ELEVACION DE VIGA POSTENSADO
1/2 ENFIERRADURA VIGA POSTENSADO
CORTE C-C
CORTE G-G
CORTE F-F
CORTE E-E
CORTE D-D

6. CONCLUSION AND RECOMMENDATION

6. CONCLUSION AND RECOMMENDATION

The objective of the Study is to assist Chile technologically in rehabilitating rural bridges distributed throughout the country. The bridge inventory program, bridge inspection method and standard bridge CADD program developed in the Study may be utilized not only for rural bridges but for all bridges in general.

Conclusions and recommendations for the three main subjects of the Study are described below.

- Establishment of bridge rehabilitation plan method
- Preparation of sample bridge rehabilitation designs
- Development of standard bridge CADD programs and design drawings

1. Bridge Rehabilitation Plan

The bridge rehabilitation plan is composed of three systems, namely the bridge inventory system, rehabilitation cost estimation system, and rehabilitation priority system. The rehabilitation project investment plan was prepared through the information collected from the three systems.

(1) Bridge inventory system

Conclusion

A computerized bridge inventory system was proposed as it was necessary to grasp the present situation of existing bridges, especially the inventory data held by the MOP. The inventory data includes location, structural type, dimensions, etc., of bridges, and is essential as fundamental data for rehabilitation. Besides the bridge inventory data, such data as population, income and traffic volume were collected as indices by which necessity of a bridge can be measured, and may be defined as parts of bridge inventory in a wider sense.

Recommendation

The bridge inventory system was developed as a universal system that can be applied to all types of bridges and not merely a data tool to apply to the bridge rehabilitation plan in this Study. One advantage of utilizing the system is that once a network system linking regional organizations is constructed and the central MOP office centralizes the bridge inventory data, maintenance work of bridges may then be carried out effectively and the rehabilitation plan may be prepared or changed promptly.

(2) Cost estimation of rehabilitation

Conclusion

Rehabilitation method (to be repaired or reconstructed) was judged from the data combined of structural bridge type, scale (width and load carrying capacity), and rank of damage which came from the inventory data. The cost of bridge rehabilitation was calculated according to the selected rehabilitation method.

Recommendation

The elements which are considered in the Study for the cost estimation of each bridge are the width and the length of a bridge, although the average construction cost was set in order to process many bridge data. Therefore, data such as the location for reconstruction, type of bridge, span length and information of piles, etc., which effect cost but cannot be known until the bridge is planned, are not included. As primary data for bridge rehabilitation (horizontal topography of river crossing, geological quality of riverbed, etc.) are included in the inventory data, though not in such detail, more precise estimation may be possible, if other data such as the location for reconstruction, type of bridge, span length and information of piles are added to the width and bridge length. Other types of data that maybe needed will be recommended by the MOP.

(3) Judgement of priority for rehabilitation

Conclusion

In order to establish the system for judging the priority of rehabilitation, three indices were defined; those being economy index (traffic volume/rehabilitation cost), safety index (degree of bridge damage), and social index (income differential). First of all, these three indices were calculated, and then total index value was worked out by adding the three weighted indices. Next, bridges were allocated into each 'road link', and the maximum total index value of all bridges belonging to a link represents the link. A list of rehabilitation cost was prepared by arranging the link in the order of the higher index value for each region.

Recommendation

The three evaluation indices mentioned above were recommended based on the fundamental concept that safety and socioeconomic considerations must be made in public investments not placing priority only on economic feasibility, especially when considering the many bridges in rural areas where there may be low returns of investment. This recommendation is in conjunction with the MOP policy. In cases where there is a change in the situation of regional bridges, or where applied to a typical bridge, the MOP must make corrections.

(4) Rehabilitation project investment plan

Conclusion

Road links (bridges) are allocated into the scheduled rehabilitation program of each fiscal year in order of priority on the rehabilitation cost table. The allocation was made in such a manner that the total rehabilitation cost is approximately the same every year.

Recommendation

The project rehabilitation period is supposed as 10 years (first phase 5 years and second phase 5 years). The rehabilitation period was so established that the MOP could complete the rehabilitation project for each year within their budget and organization. It was judged from the conjectured volume of the rehabilitation for all regions based on the data collected at the model survey (IX) region that 10 years would be sufficient for the rehabilitation period. It is recommended that after the first 5-year period, that the plan review the whole rehabilitation plan including the rehabilitation principle on the analysis of the achieved rehabilitation thus far, as 10 years is a long period, and during that time the economical situation and traffic demand in rural roads would change.

2. Bridge Rehabilitation Design

Conclusion

The bridge rehabilitation design was prepared in order to show an actual technological example which would be useful for the MOP to decide rehabilitation method based on actual inspection results. The Study Team selected twenty bridges with the MOP counterparts and conducted inspection and analysis of amount of damage as well as designs for rehabilitation method.

Besides the inspection of bridge itself, an environmental study was conducted to estimate the effect which rehabilitation of bridges may have on its surroundings. A standardized and simplified method of the environmental study was recommended consequently after exchange of opinions with the staff of the Department of Environment in the MOP over the necessity and procedure of the environmental study for small-scale rural bridges.

Recommendation

To date there do not seem to be many bridges having been inspected and strengthened on a large scale in Chile. Furthermore, more money and effort has been spent on reconstruction rather than repair. Thus, many bridges have not been recognized in the inventory nor maintained over a long period. In order to maintain bridges systematically, it is most important to discover damage as early as possible and to make appropriate repairs without delay. It is therefore recommended to intentionally and actively maintain and repair damaged bridges by efficient use of the inspection method proposed by the Study.

Although the MOP intends to replace timber bridges with more permanent structures such as concrete or steel, the element of time must be considered. To construct a new timber bridge is difficult nowadays from economical and environmental aspects, but on the other hand there is still the advantage of easy repair; therefore the MOP must maintain their technology of timber bridges and not discard it.

Regarding the quality of concrete, it is proposed that the MOP makes effort to improve the quality of concrete implementation. The problem of the quality of concrete is not merely a construction-site issue. If the problem is not properly addressed, Chile will end up with many concrete bridges of poor quality, consequently bringing about the risk of deterioration of rural bridges in general. At the beginning of the rehabilitation plan, there is thus a chance to present bridges of high quality for future users.

In order to extract environmental problems accompanying bridge rehabilitation, it is recommended to start with the Project Description and the Site Description. Following scoping and screening, the initial environmental examination (IEE) is carried out using inspection forms for environmental considerations. In case that an obvious environmental impact is recognized, preliminary environmental impact assessment (Pre-EIA) is carried out. In the Pre-EIA, mitigation methods of remarkable negative impacts caused by the rehabilitation are considered. By proceeding with the study in the order described above, it is easier to grasp the existence of the little-understood environmental problems of the small bridges and measures for overcoming them.

3. Standard Bridge CADD Program

Conclusion

The bridge CADD program developed in the Study is based on the specifications of AASHTO which are usually adopted by the MOP. The representative bridge types to be developed as well as computer hardware and software were selected according to the investigation results of bridge design, bridge construction, and computer use in Chile.

The programs developed are as follows:

Superstructure

- Pre-tensioned PC beam
- Post-tensioned PC beam
- Steel rolled H beam
- Steel plate girder

All the beams and girders above are composite types with concrete deck.

Substructure

- Inverted T abutment with spread foundation
- Wall-type pier with spread foundation

The standard drawings were prepared by using the CADD program for the bridges both of one and two lanes with span length between 14 and 36 m.

The CADD program and the standard drawings can be applied to typical bridges with a straight alignment and a symmetric transverse cross section, but not to a skewed or curved bridge.

Due to the fact that AASHTO standards are not specific regarding high-strength bolt connections for steel girders or positioning of post-tensioned cables, design technology normally applied in Japan was interposed following discussion on technological matters with the MOP.

Recommendation

Verification and examination of the CADD program output as well as decision-making is the user's responsibility. Therefore, the program was developed so that the user can compile the output according to his/her purpose. It is possible to use the program out of the scope of its original specifications to some extent depending upon the user's creative capacity.

On developing such a program it is not necessarily advantageous to develop every detail by oneself in such an age when computer technology progresses quickly, therefore existing application software were implemented. In order to maintain the best status for the computer at all times, regular renewal of software and hardware versions must be kept in mind. At the same time, the program itself must be maintained and improved to keep up with the latest version of design standards.

It is recommended that the program be widely used in the country. For the technical staff of the MOP in charge of bridge planning, the basic use of the program is recommended for the estimation of approximate size of planned bridge. While, for the bridge designers both in the MOP and in private firms, the program would be used more in professional application to the identification of suitable design parameters and to the preparation of structural design drawings within the capacity of the program.

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