2.6 REHABILITATION PRIORITY AND PROJECT INVESTMENT PLAN

2.6.1 Number of Bridges and Period of Plan

(1) Number of Bridges to be Rehabilitated

Total number of bridges needed to be rehabilitated and to be appraised for their priorities, amounts to as many as about 1000 bridges. Average length of a bridge is about 26 m. They were selected from about 8,000 bridges from various regions throughout the country by the MOP as explained in the preceding **Chapter 2.2.1**. **Table 2.13** shows the number of bridges to be rehabilitated and their conditions in Region IX (model study). Out of 110 bridges, a bridge No. 45 "Aillinco" did not exist.

Table 2.13 Number and Condition of Bridges in Region IX

Bridge Condition	Number of Bridges
1: Dangerous	6
2: Potentially hazardous	58
3: Not functioning as originally designed	27
4: Functioning as originally designed	7
5: Good, new or like-new	11
Total	109

(2) Period of Plan

The period for the rehabilitation plan is set for 10 years based on the basic plan of the MOP and that was divided into the following two phases to facilitate implementation:

First 5 years rehabilitation plan	1998	1999	2000	2001	2002
Second 5 years rehabilitation plan	2003	2004	2005	2006	2007

The 10 years rehabilitation investment plan should comply with the financial policy of the Chile government, the national and local budget scale for roads and bridges of the MOP. Also, the plan should be examined from the implementation ability of works.

2.6.2 Concept for Rehabilitation Priority

(1) Characteristics of Rural Road Bridges

Priority and investment justification for most rehabilitation plans for trunk road bridges are decided by calculating internal economic rate of return. Accordingly, probable time for rehabilitation is calculated based on the time when existing bridge is closed. Selection of detour route and calculation of running cost by road and by vehicle types must be carried out. However, this appraisal system for trunk road bridges can not be applied to rural road bridges. Because, the role of rural road bridges is different from that of trunk road bridges: in general, rural roads bridges are small, traffic is few but their social need is not low.

The characteristics of rural road bridges are summarized as follows:

- length of a bridge is short, and thus running cost saving by bridges is little.
- There are many rural bridges.
- They are spread in vast area.
- Construction cost is inexpensive.
- Traffic volume is little and most traffic is local.
- 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.

(2) Rehabilitation Effects of Rural Road Bridges

The characteristics of rural road bridges mentioned above and the nine rehabilitation effects shown in **Table 2.14** are the two fundamentals to propose the rehabilitation priority appraisal system, which is quite different from the internal economic rate of return index for the rehabilitation of trunk road bridges.

Table 2.14 Nine Rehabilitation Effects of Rural Road Bridges

1)	To increase income of rural inhabitants;	Increase of income effect
2)	To increase rural productivity;	Increase of productivity effect
3)	To increase undeveloped rural resources;	Development of resources effect
4)	To disolve detour time;	Dissolution of detour time effect
5)	To shorten river crossing time;	Shortening of river crossing time effect
6)	To reduce traffic accidents;	Safeguarding of life and property effect
7)	To deter regional population outflow;	Deterring of population outflow effect
8)	To rectify regional income difference;	Rectification of income difference effect
9)	To mitigate regional isolation;	Mitigation of regional isolation effect

(3) Rehabilitation Appraisal for Rural Road Bridges

For rural road bridges, it is necessary to appraise rehabilitation priority systematically by using indicators. **Table 2.15** explains the basic concept for the priority appraisal of rural road bridges.

Table 2.15 Rehabilitation Appraisal for Rural Road Bridges

- Rehabilitation priority for rural road bridges should be decided in qualitative, not in quantitative way.
- Priority indicator for trunk road bridges is internal economic rate of return alone, while rehabilitation of rural road bridges has many effects so that need to consider several indicators.
- Indicators are to be calculated by bridge even if it is small.
- The nine effects shown in **Table 2.14** are the possible indices for the priority appraisal of rural road bridges.
- These indices in question shall be compared and integrated each other to simplify the appraisal procedure.
- Importance of indices are various, so that weighting each index is important.
- For the first step of appraisal, all indices of each bridge are to be calculated and by which priorities of all bridges are to be decided.
- For the second step, bridges are to be grouped for further rehabilitation priorities.

2.6.3 Priority Indicators for Rural Road Bridges

(1) Introduction

There is a great number of rural road bridges and they are scattered over regions. Accordingly, the priority appraisal system shall be a simple one applicable to all regions and manageable by any MOP engineers in charge. For this purpose, the nine rehabilitation effects introduced in the above section were analyzed to think out the priority indicators suitable for the system by taking the following procedure:

- Visiting the IX region, opinions were collected by hearing from the residents and the MOP officials.
- the nine effects were studied by the Study Team members and opinions were collected from the experts of different fields.
- Further, meetings were held to adjust opinions with the MOP counterparts.

As the result, the following three indices were figured out considering a large number of bridges, limitation of work force and availability of data. **Figure 2.11** summarizes the process how the nine rehabilitation effects are integrated into the three indices.

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 life and property	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

Figure 2.11 Process from Nine Effects to Three Indices

To compare with the idea of three indices shown in **Figure 2.11** alternative idea which is to be integrated into two indices as shown in **Figure 2.12** also suggested on the half way of the Study.

- Increase of income - Increase of productivity - Development of resources - Dissolution of detour time - Shortening of river crossing time - Safeguarding of life and property	→ Safety Improvement Index
- Deterring of regional population outflow - Rectification of regional income differences - Mitigation of regional isolation	→ Social Index

Figure 2.12 Alternative Method Nine Effects to Two Indices

The detail of the suggested idea and its comparison study is explained in **Appendix 1-7 (Volume 3/8)**. In the result, the alternative method is defined as a simple type of feasibility evaluation to integrate all project effects into a benefit-cost relation. The alternative method is different from the original method in approach, but there is no significant difference in priority order between the two methods. It is considered that the original method is easier for the MOP to realize its rehabilitation policy by adjusting weight on the three indices independently. Therefore, the study proceeds further with the original three indices.

There three selected indices (economic, safety, and social) are all important, but their importance is not the same. "Policy weight" may be considered for instance at 40:40:20. In actual analysis, another figures will be tried to see how they influence the priority order.

(2) Economic Index (Traffic-cost ratio)

1) Increase of income effect 2) Increase of productivity effect 3) Development of resources effect	① Economic index (= Traffic volume/Rehabilitation cost)

These are economically interrelated and they can be handled under one item. However, it would be difficult to properly decide these effects without any adjustment for the following reasons (See **Appendix I-8 (Volume 3/8)** - Indextization of Each Effect by Bridge Rehabilitation).

- Increase of income effect: It is difficult to estimate production increase and total income increase owing to rehabilitation.
- Increase of production effect: It is difficult to estimate production increase after bridge rehabilitation.
- Development of resources effect: Above production increase and increase of production by resources development are overlapped.

Theoretically, the economic benefit of bridge rehabilitation project means the difference of the benefits between with project by which bridge is rehabilitated and without project by which bridge is not rehabilitated. However, the benefit of small bridge rehabilitation is hardly estimated as explained above, so that overall benefit effects of the small bridge rehabilitation will be measured indirectly by the increase of traffic volume.

The increase of traffic volume can be properly estimated by the traffic analyses for the cases of with and without project on road network, but this approach is too laborious and complicated to be practiced for many small bridges scattered wide in the country. The second best method to take traffic volume itself for benefit was therefore recommended, based on the assumption that the increase of traffic volume be in proportion to the traffic volume before rehabilitation.

(3) Safety Index (Damage rank)

4) Dissolution of detour time effect 5) Shortening of river crossing time effect 6) Safeguarding of life and property effect	② Safety index (= Rank of bridge damage)

Both the time savings of crossing a bridge and by dissolving detouring are considered depending upon the degree of bridge damage. Also, traffic accidents on bridges are related to the damages of bridge structures. Accordingly, bridge damage index will represent those three effects. It is difficult to decide these three effects separately for the following reasons (See **Appendix I-8**).

- Dissolution of detour time effect: It is difficult to decide distance, road surface condition, and origin and destination of detour route.
- Safeguarding of life and property effect: It is difficult to estimate the traffic accident risk due to the damage of bridge facility, but it is definite that the severer the bridge damage is, the higher the accident risk is.

(4) Social Index (Income difference correction)

7) Deterring of population outflow effect 8) Rectification of income difference effect 9) Mitigation of regional isolation effect	③ Social index (= National average income/ Regional average income)

Above three effects can be put together for the following facts obtained in the survey of Region IX.

- In last five years, population has decreased in seven out of the 31 communes in the region.
- Such population decreasing communes are located in eastern mountainous or western coastal area isolated far from Temuco, the regional capital.
- Geographically isolated communes are isolated socially, too.
- Income per capita in these isolated communes are far less than the average income of Region IX.
- Thus, it is said that population outflow communes, low income communes and isolated communes correspond each other.

The reasons for the income difference correction index represents those three effects, are as follows (See **Appendix I-8**):

- Deterring of population outflow effect: Difference of the effect between population decreasing and increasing regions turns up significantly.
- Rectification of income difference effect: Difference of per capita income shows more between regions than between communes.
- Mitigation of regional isolation effect: Subjective factor is involved easily.

2.6.4 Process of Priority Appraisal and Project Investment Planning

Figure 2.13 shows the outline of the overall process from appraising the priority of individual bridges through formulating the project investment plan. To complete the process, the following four kinds of data are collected such as a) traffic volume, b) rehabilitation cost, c) bridge condition and d) income per capita, and three steps are taken.

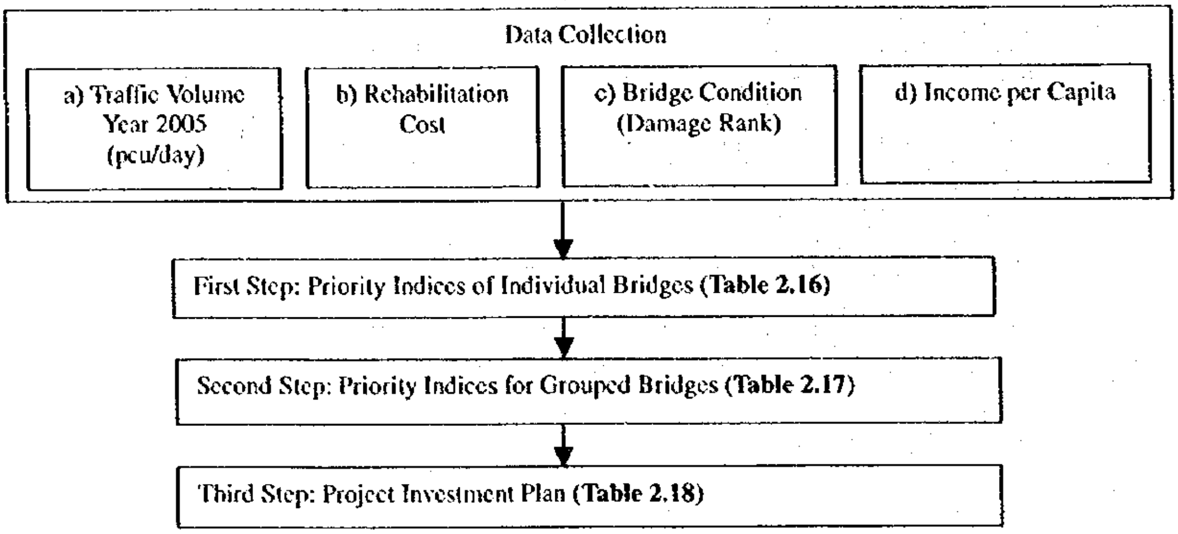


Figure 2.13 Process of Priority Appraisal and Project Investment Planning

The four data were collected through the following surveys and studies reported in the preceding chapters.

- Bridge condition (damage degree) from **Chapter 2.2**
- Income per capita from **Chapter 2.3**
- Traffic volume from **Chapter 2.4**
- Rehabilitation cost from **Chapter 2.5**

The first through third steps are explained in the succeeding **Chapter 2.6.5 through 2.6.7** using the actual data collected by the model survey in Region IX.

2.6.5 Priority Indices of Individual Bridges (First Step)

Table 2.16 is the result of the priority calculation for the 110 individual bridges in Region IX by using the above mentioned three indices. The main items of the table consist of Bridge Location, Existing Bridge Data, Bridge Rehabilitation Data, and the Three and Total Indices. The input data needed to calculate the indices are; A) Damage Rank (bridge condition), B) Rehabilitation Cost, C) Traffic Volume (of year 2005) and D) Income per capita Commune.

The methods of calculating the three indices are explained as follows.

Table 2.16 Priority Indices of Individual Bridges (First Step: Order of Bridge No.)

(IX Region)

Bridge Location: Link No.	Bridge Location: Comuna Name	Bridge Location: Bridge No.	Bridge Location: Bridge Name	Existing Bridge Data: Bridge Type	Existing Bridge Data: Length (m)	Existing Bridge Data: Width (m)	Existing Bridge Data: Load Limit (t)	Existing Bridge Data: Damage Rank A	Bridge Rehabilitation Data: Rehabili. Mehod	Bridge Rehabilitation Data: Number of Lanes	Bridge Rehabilitation Data: Cost (mil.peso) B	Bridge Rehabilitation Data: Traffic (pcu) C	Bridge Rehabilitation Data: Income (thou.peso) D	Economic Index: Traffic /Cost E=C/B	Economic Index: Std.Index F=(E-ave.E) /stdv.E	Economic Index: Weight 0.30 G=0.30F	Safety Index: Damage Rank H=6-A	Safety Index: Std.Index I=(H-ave.H) /stdv.H	Safety Index: Weight 0.50 J=0.50I	Social Index: Nat.Ave.Inc. /Com.Inc. K=450/D	Social Index: Std.Index L=(K-ave.K) /stdv.K	Social Index: Weight 0.20 M=0.20L	Total Index N=G+J+M	Bridge No.
35	LAUTARO	IX-001	NIBLINTO	Timber	24.80	3.60	8	2	Reconst.	2	167.5	1098	165.8	6.555	0.255	0.076	4	0.597	0.299	2.714	0.011	0.002	0.377	IX-001
35	LAUTARO	IX-002	MUCOBAJO	Timber	34.50	3.70	6	2	Reconst.	2	214.1	1098	165.8	5.128	0.062	0.018	4	0.597	0.299	2.714	0.011	0.002	0.319	IX-002
36	VILCUN	IX-003	QUINTRILPE	Timber	10.00	2.90	8	2	Reconst.	1	72.0	309	213.9	4.291	-0.052	-0.016	4	0.597	0.299	2.104	-0.505	-0.101	0.182	IX-003
40	VILLARRICA	IX-004	LLAMUCO	Steel	22.00	4.00	12	4	Reconst.	1	108.9	293	161.9	2.694	-0.268	-0.080	2	-1.203	-0.601	2.779	0.066	0.013	-0.668	IX-004
40	VILLARRICA	IX-005	PEDREGOSO	Timber	16.50	3.20	-	2	Reconst.	1	92.0	293	161.9	3.189	-0.201	-0.060	4	0.597	0.299	2.779	0.066	0.013	0.252	IX-005
40	VILLARRICA	IX-006	CALBUCO	Timber	13.00	3.55	8	4	Reconst.	1	81.2	293	161.9	3.613	-0.144	-0.043	2	-1.203	-0.601	2.779	0.066	0.013	-0.631	IX-006
41	VILLARRICA	IX-007	EL TIGRE	Timber	19.50	3.75	8	2	Reconst.	1	101.2	29	161.9	0.283	-0.595	-0.178	4	0.597	0.299	2.779	0.066	0.013	0.134	IX-007
42	VILLARRICA	IX-008	CHOME2	Timber	10.00	3.20	12	4	Reconst.	1	72.0	29	161.9	0.398	-0.579	-0.174	2	-1.203	-0.601	2.779	0.066	0.013	-0.762	IX-008
42	VILLARRICA	IX-009	EL SALTO	Timber	11.70	3.50	6	3	Reconst.	1	77.2	29	161.9	0.371	-0.583	-0.175	3	-0.303	-0.151	2.779	0.066	0.013	-0.313	IX-009
39	VILLARRICA	IX-010	LAN1	Timber	21.80	3.60	10	4	Reconst.	2	153.0	525	161.9	3.433	-0.168	-0.050	2	-1.203	-0.601	2.779	0.066	0.013	-0.638	IX-010
39	VILLARRICA	IX-011	LAN2	Timber	8.80	3.95	8	4	Reconst.	2	90.5	525	161.9	5.803	0.153	0.046	2	-1.203	-0.601	2.779	0.066	0.013	-0.542	IX-011
34	NUEVA IMPERIAL	IX-012	HUECHUCON	Timber	30.60	4.10	-	2	Reconst.	2	195.4	628	110.1	3.212	-0.198	-0.059	4	0.597	0.299	4.087	1.173	0.235	0.475	IX-012
33	NUEVA IMPERIAL	IX-013	HUAMAQUI	Timber	19.10	4.00	8	2	Reconst.	2	140.0	628	110.1	4.483	-0.026	-0.008	4	0.597	0.299	4.087	1.173	0.235	0.526	IX-013
78	VILCUN	IX-014	PUMALAL	Timber	32.20	4.20	2	2	Reconst.	1	140.2	180	213.9	1.287	-0.459	-0.138	4	0.597	0.299	2.104	-0.505	-0.101	0.060	IX-014
56	GORBEA	IX-015	CHARLEO	Timber	20.40	3.90	8	2	Reconst.	2	146.3	527	193.4	3.601	-0.145	-0.044	4	0.597	0.299	2.326	-0.317	-0.063	0.192	IX-015
56	GORBEA	IX-016	LAS LUMAS	Timber	13.20	3.90	6	5	Reconst.	2	111.6	527	193.4	4.721	0.007	0.002	1	-2.103	-1.051	2.326	-0.317	-0.063	-1.112	IX-016
57	GORBEA	IX-017	POLUL 1	Timber	22.70	3.90	10	2	Reconst.	1	111.0	198	193.4	1.783	-0.391	-0.117	4	0.597	0.299	2.326	-0.317	-0.063	0.119	IX-017
58	GORBEA	IX-018	PUYEHUE	Timber	32.10	4.00	10	2	Reconst.	2	202.6	621	193.4	3.064	-0.218	-0.065	4	0.597	0.299	2.326	-0.317	-0.063	0.171	IX-018
59	GORBEA	IX-019	DONGIL	Timber	44.10	4.00	12	2	Reconst.	1	176.8	370	193.4	2.090	-0.350	-0.105	4	0.597	0.299	2.326	-0.317	-0.063	0.131	IX-019
59	GORBEA	IX-020	RINCO	Steel	12.20	3.85	12	2	Reconst.	1	78.8	370	193.4	4.689	0.002	0.001	4	0.597	0.299	2.326	-0.317	-0.063	0.237	IX-020
63	VILLARRICA	IX-021	PEDREGOSO	Steel	38.00	3.85	12	2	Reconst.	2	231.0	1909	161.9	8.266	0.487	0.146	4	0.597	0.299	2.779	0.066	0.013	0.458	IX-021
61	VILLARRICA	IX-022	LONG LONG	Timber	14.60	3.95	10	3	Reconst.	1	86.2	407	161.9	4.722	0.007	0.002	3	-0.303	-0.151	2.779	0.066	0.013	-0.136	IX-022
72	VILLARRICA	IX-023	QUEBRADA HONDA	Steel	18.00	3.52	12	5	NoAction	-	0.0	613	161.9	0.000	-10.000	-3.000	0	-10.000	-5.000	0.000	-10.000	-2.000	-10.000	IX-023
62	VILLARRICA	IX-024	SALVA TU ALMA	Steel	40.70	3.77	15	2	Reconst.	2	244.0	1427	161.9	5.847	0.159	0.048	4	0.597	0.299	2.779	0.066	0.013	0.360	IX-024
75	VILLARRICA	IX-025	COLLICO	Timber	9.60	4.04	4	3	Reconst.	2	94.3	718	161.9	7.610	0.398	0.119	3	-0.303	-0.151	2.779	0.066	0.013	-0.019	IX-025
75	VILLARRICA	IX-026	CRUCES	Timber	20.00	5.70	8	3	Reconst.	2	144.4	718	161.9	4.970	0.040	0.012	3	-0.303	-0.151	2.779	0.066	0.013	-0.126	IX-026
74	PUCON	IX-027	EL CRISTO	Timber	26.00	3.50	6	1	Reconst.	2	173.2	1504	254.0	8.686	0.544	0.163	5	1.497	0.749	1.771	-0.786	-0.157	0.755	IX-027
73	PUCON	IX-028	CARHUELLO	Timber	21.90	3.91	8	3	Reconst.	2	153.5	1504	254.0	9.800	0.695	0.208	3	-0.303	-0.151	1.771	-0.786	-0.157	-0.100	IX-028
60	CUNCO	IX-029	LA BASTILLA	Timber	74.10	3.97	6	2	Reconst.	1	268.9	427	341.2	1.587	-0.418	-0.125	4	0.597	0.299	1.319	-1.169	-0.234	-0.060	IX-029
46	CUNCO	IX-030	CODULTO	Timber	10.80	4.00	8	5	Reconst.	1	74.5	65	341.2	0.868	-0.515	-0.155	1	-2.103	-1.051	1.319	-1.169	-0.234	-1.440	IX-030
45	VILLARRICA	IX-031	HUICAHUE	Timber	33.00	3.70	10	5	Reconst.	1	142.7	36	161.9	0.255	-0.598	-0.180	1	-2.103	-1.051	2.779	0.066	0.013	-1.218	IX-031
64	CUNCO	IX-032	MEDINA	Steel	170.00	3.97	8	3	Reconst.	1	563.5	384	341.2	0.682	-0.541	-0.162	3	-0.303	-0.151	1.319	-1.169	-0.234	-0.547	IX-032
66	LONQUIMAY	IX-033	ICALMA	Timber	17.90	3.70	10	2	Reconst.	1	96.3	190	91.0	1.975	-0.365	-0.110	4	0.597	0.299	4.947	1.900	0.380	0.569	IX-033
65	MELPEUCO	IX-034	ALLIPEN	Timber	58.00	3.82	4	2	Reconst.	1	219.5	286	91.0	1.301	-0.457	-0.137	4	0.597	0.299	4.947	1.900	0.380	0.542	IX-034
47	FREIRE	IX-035	NEGRO	Steel	20.70	3.85	8	2	Reconst.	2	147.7	755	178.9	5.115	0.060	0.018	4	0.597	0.299	2.515	-0.157	-0.031	0.286	IX-035
48	FREIRE	IX-036	PELALES	Timber	15.80	3.92	8	3	Reconst.	2	124.1	576	178.9	4.642	-0.004	-0.001	3	-0.303	-0.151	2.515	-0.157	-0.031	-0.183	IX-036
49	FREIRE	IX-037	CHUCAUCO	Timber	17.50	3.97	8	2	Reconst.	1	95.1	257	178.9	2.700	-0.267	-0.080	4	0.597	0.299	2.515	-0.157	-0.031	0.188	IX-037
49	FREIRE	IX-038	FIN FIN	Timber	10.00	4.00	8	4	Reconst.	1	72.0	257	178.9	3.567	-0.150	-0.045	2	-1.203	-0.601	2.515	-0.157	-0.031	-0.677	IX-038
50	NUEVA IMPERIAL	IX-039	BOROA	Timber	15.90	3.75	12	3	Reconst.	2	124.6	588	110.1	4.718	0.006	0.002	3	-0.303	-0.151	4.087	1.173	0.235	0.086	IX-039
77	CARAHUE	IX-040	SAN JUAN	Timber	31.60	4.00	10	2	Reconst.	2	200.2	1830	110.3	9.142	0.605	0.182	4	0.597	0.299	4.080	1.167	0.233	0.714	IX-040
77	CARAHUE	IX-041	LONCOMAYO	Timber	18.00	3.84	12	3	Reconst.	2	134.7	1830	110.3	13.588	1.208	0.362	3	-0.303	-0.151	4.080	1.167	0.233	0.444	IX-041
53	TEODO. SCHMIDT	IX-042	PUYEHUE	Timber	8.40	4.00	10	3	Reconst.	1	67.1	492	118.3	7.332	0.360	0.108	3	-0.303	-0.151	3.803	0.932	0.186	0.143	IX-042
52	TEODO. SCHMIDT	IX-043	ALLLIPEN	Timber	9.10	4.05	10	2	Reconst.	1	69.3	404	118.3	5.825	0.156	0.047	4	0.597	0.299	3.803	0.932	0.186	0.532	IX-043
54	PITRUFQUEN	IX-044	QUINQUE	Timber	24.80	4.12	8	2	Reconst.	2	167.5	997	304.3	5.953	0.173	0.052	4	0.597	0.299	1.479	-1.033	-0.207	0.144	IX-044
32	GALVARINO	IX-045	AILLINCO	NoBridge				0	NoAction	-	0.0	562	0.0	0.000	-10.000	-3.000	0	-10.000	-5.000	0.000	-10.000	-2.000	-10.000	IX-045
55	PITRUFQUEN	IX-046	MAHUIDANCHE	Timber	36.40	4.00	10	3	Reconst.	2	223.3	851	304.3	3.810	-0.117	-0.035	3	-0.303	-0.151	1.479	-1.033	-0.207	-0.393	IX-046
18	COLLIPULLI	IX-047	LAS TOSCAS	Timber	10.80	3.85	6	2	Reconst.	2	100.1	543	150.1	5.421	0.101	0.030	4	0.597	0.299	2.997	0.251	0.050	0.379	IX-047
71	LONQUIMAY	IX-048	ÑANCUREO	Timber	10.00	3.00	6	2	Reconst.	2	96.2	4660	91.0	48.446	5.929	1.779	4	0.597	0.299	4.947	1.900	0.380	2.458	IX-048
71	LONQUIMAY	IX-049	ÑIRECO	Timber	8.20	3.70	10	2	Reconst.	2	87.6	4660	91.0	53.202	6.574	1.972	4	0.597	0.299	4.947	1.900	0.380	2.651	IX-049
7	LOS SAUCES	IX-050	HUADABA	Timber	19.90	3.60	10	2	Reconst.	1	102.4	181	130.7	1.765	-0.394	-0.118	4	0.597	0.299	3.444	0.629	0.126	0.307	IX-050
6	LOS SAUCES	IX-051	AGUA SANTA	Timber	15.50	3.80	12	3	Reconst.	1	88.9	181	130.7	2.033	-0.358	-0.107	3	-0.303	-0.151	3.444	0.629	0.126	-0.132	IX-051
13	PUREN	IX-052	PINGUIDAHUE	Timber	11.00	3.40	12	5	Reconst.	2	101.0	594	145.0	5.879	0.163	0.049	1	-2.103	-1.051	3.104	0.341	0.068	-0.934	IX-052
13	PUREN	IX-053	ÑATO	Timber	28.40	3.80	12	3	Reconst.	2	184.8	594	145.0	3.213	-0.198	-0.059	3	-0.303	-0.151	3.104	0.341	0.068	-0.142	IX-053
13	PUREN	IX-054	CHACRE	Timber	20.10	3.70	10	2	Reconst.	2	144.8	594	145.0	4.101	-0.077	-0.023	4	0.597	0.299	3.104	0.341	0.068	0.344	IX-054
13	PUREN	IX-055	VILUCO	Timber	8.30	3.90	10	2	Reconst.	2	88.0	594	145.0	6.748	0.281	0.084	4	0.597	0.299	3.104	0.341	0.068	0.451	IX-055

15	LOS SAUCES	IX-056	RANQUILEO	Timber	15.30	3.60	10	3	Reconst.	2	121.7	669	130.7	5.495	0.111	0.033	3	-0.303	-0.151	3.444	0.629	0.126	0.008	IX-056
25	VICTORIA	IX-057	HULLINLEBU	Timber	10.40	4.20	12	5	Reconst.	2	98.2	953	239.7	9.705	0.682	0.204	1	-2.103	-1.051	1.877	-0.697	-0.139	-0.986	IX-057
11	LOS SAUCES	IX-058	REHUE	Timber	30.50	3.80	8	2	Reconst.	1	135.0	103	130.7	0.763	-0.530	-0.159	4	0.597	0.299	3.444	0.629	0.126	0.266	IX-058
10	LOS SAUCES	IX-059	NAPAÑIR	Timber	11.10	3.10	8	2	Reconst.	1	75.4	103	130.7	1.367	-0.448	-0.134	4	0.597	0.299	3.444	0.629	0.126	0.291	IX-059
11	LOS SAUCES	IX-060	CATALINA N°2	Timber	28.90	3.75	8	2	Reconst.	1	130.1	103	130.7	0.792	-0.526	-0.158	4	0.597	0.299	3.444	0.629	0.126	0.267	IX-060
10	LOS SAUCES	IX-061	CATALINA N°1	Timber	20.40	4.00	8	2	Reconst.	1	104.0	103	130.7	0.991	-0.499	-0.150	4	0.597	0.299	3.444	0.629	0.126	0.275	IX-061
10	LOS SAUCES	IX-062	PELEHUITO	Timber	17.80	2.80	8	2	Reconst.	1	96.0	103	130.7	1.074	-0.487	-0.146	4	0.597	0.299	3.444	0.629	0.126	0.279	IX-062
22	VICTORIA	IX-063	MALLECO	Timber	32.20	3.70	4	1	Reconst.	1	140.2	131	239.7	0.937	-0.506	-0.152	5	1.497	0.749	1.877	-0.697	-0.139	0.458	IX-063
22	VICTORIA	IX-064	LOS SOLDADOS	Timber	33.50	3.80	8	2	Reconst.	1	144.2	130	239.7	0.902	-0.511	-0.153	4	0.597	0.299	1.877	-0.697	-0.139	0.007	IX-064
24	VICTORIA	IX-065		Timber	12.00	3.50	8	5	Reconst.	1	78.2	283	239.7	3.620	-0.143	-0.043	1	-2.103	-1.051	1.877	-0.697	-0.139	-1.233	IX-065
17	LOS SAUCES	IX-066	QUINQUEN	Timber	36.10	3.80	6	2	Reconst.	2	221.8	736	130.7	3.319	-0.183	-0.055	4	0.597	0.299	3.444	0.629	0.126	0.370	IX-066
5	ANGOL	IX-067	VEGAS BLANCAS	Timber	8.00	3.40	10	3	Reconst.	1	65.9	160	365.2	2.434	-0.303	-0.091	3	-0.303	-0.151	1.232	-1.242	-0.248	-0.490	IX-067
5	ANGOL	IX-068	EL MANZANO	Timber	15.40	4.00	10	3	Reconst.	1	88.6	160	365.2	1.810	-0.388	-0.116	3	-0.303	-0.151	1.232	-1.242	-0.248	-0.515	IX-068
9	LOS SAUCES	IX-069	MIRAFLORES	Timber	44.40	3.60	10	2	Reconst.	2	261.8	624	130.7	2.382	-0.310	-0.093	4	0.597	0.299	3.444	0.629	0.126	0.332	IX-069
8	LOS SAUCES	IX-070	LA OBRA	Timber	10.40	3.40	5	2	Reconst.	2	98.2	641	130.7	6.529	0.251	0.075	4	0.597	0.299	3.444	0.629	0.126	0.500	IX-070
19	COLLIPULLI	IX-071	CALLIN	Timber	13.60	4.00	12	2	Reconst.	2	113.6	1126	150.1	9.913	0.710	0.213	4	0.597	0.299	2.997	0.251	0.050	0.562	IX-071
20	COLLIPULLI	IX-072	MININCO	Timber	16.30	4.30	10	2	Reconst.	1	91.4	229	150.1	2.505	-0.294	-0.088	4	0.597	0.299	2.997	0.251	0.050	0.261	IX-072
21	COLLIPULLI	IX-073	ÑANCO	Timber	14.40	4.20	10	5	Reconst.	1	85.5	229	150.1	2.678	-0.270	-0.081	1	-2.103	-1.051	2.997	0.251	0.050	-1.082	IX-073
1	RENAICO	IX-074	TOLPAN	Steel	93.40	3.20	10	2	Reconst.	1	328.2	229	334.9	0.699	-0.538	-0.161	4	0.597	0.299	1.344	-1.148	-0.230	-0.092	IX-074
68	LONQUIMAY	IX-075	LOS SOLDADOS	Timber	10.00	3.35	8	3	Reconst.	2	96.2	639	91.0	6.642	0.267	0.080	3	-0.303	-0.151	4.947	1.900	0.380	0.309	IX-075
68	LONQUIMAY	IX-076	MIRAFLORES	Timber	19.70	3.90	6	4	Reconst.	2	142.9	639	91.0	4.471	-0.027	-0.008	2	-1.203	-0.601	4.947	1.900	0.380	-0.229	IX-076
67	LONQUIMAY	IX-077	RUCAÑUCO	Timber	22.80	3.60	4	3	Reconst.	2	157.8	639	91.0	4.049	-0.085	-0.025	3	-0.303	-0.151	4.947	1.900	0.380	0.204	IX-077
31	TRAIGUEN	IX-078	HUIÑILHUE	Timber	33.30	4.20	-	2	Reconst.	2	208.4	3356	181.5	16.101	1.548	0.464	4	0.597	0.299	2.479	-0.187	-0.037	0.726	IX-078
12	PUREN	IX-079	LA ISLA	Timber	36.70	3.50	1	1	Reconst.	1	154.0	303	145.0	1.970	-0.366	-0.110	5	1.497	0.749	3.104	0.341	0.068	0.707	IX-079
23	VICTORIA	IX-080	DUMO	Timber	32.90	3.97	12	2	Reconst.	1	142.4	149	239.7	1.049	-0.491	-0.147	4	0.597	0.299	1.877	-0.697	-0.139	0.013	IX-080
26	CURACAUTIN	IX-081	AMANTIBLE	Timber	18.20	3.50	12	2	Reconst.	2	135.7	563	688.4	4.148	-0.071	-0.021	4	0.597	0.299	0.654	-1.731	-0.346	-0.068	IX-081
27	CURACAUTIN	IX-082	CORCOLUDO	Timber	13.80	3.70	8	2	Reconst.	1	83.7	23	688.4	0.270	-0.596	-0.179	4	0.597	0.299	0.654	-1.731	-0.346	-0.226	IX-082
27	CURACAUTIN	IX-083	SANTA RITA	Timber	11.70	3.80	8	3	Reconst.	1	77.2	23	688.4	0.293	-0.593	-0.178	3	-0.303	-0.151	0.654	-1.731	-0.346	-0.675	IX-083
28	CURACAUTIN	IX-084	DILLO	Timber	10.00	4.60	8	3	Reconst.	1	72.0	23	688.4	0.314	-0.590	-0.177	3	-0.303	-0.151	0.654	-1.731	-0.346	-0.674	IX-084
66	LONQUIMAY	IX-085	HUILLINCO	Timber	16.80	4.10	10	2	Reconst.	1	92.9	190	91.0	2.047	-0.356	-0.107	4	0.597	0.299	4.947	1.900	0.380	0.572	IX-085
3	ANGOL	IX-086	MALLECO	Timber	92.00	3.60	8	2	Reconst.	1	323.9	246	356.2	0.760	-0.530	-0.159	4	0.597	0.299	1.263	-1.216	-0.243	-0.103	IX-086
29	CURACAUTIN	IX-087	TRAHUILCO	Timber	39.70	3.80	12	1	Reconst.	1	163.3	31	608.4	0.188	-0.608	-0.182	5	1.497	0.749	0.740	-1.658	-0.332	0.235	IX-087
29	CURACAUTIN	IX-088	CAUTIN	Steel	39.40	3.85	12	2	Reconst.	1	162.3	31	608.4	0.189	-0.607	-0.182	4	0.597	0.299	0.740	-1.658	-0.332	-0.215	IX-088
30	CURACAUTIN	IX-089	COLORADO	Timber	21.50	3.75	3	2	Reconst.	1	107.3	31	608.4	0.286	-0.594	-0.178	4	0.597	0.299	0.740	-1.658	-0.332	-0.211	IX-089
37	LAUTARO	IX-090	EL TRUENO	Timber	43.80	3.55	-	2	Reconst.	1	175.9	51	165.8	0.292	-0.593	-0.178	4	0.597	0.299	2.714	0.011	0.002	0.123	IX-090
38	LAUTARO	IX-091	COLLIN	Timber	21.80	3.76	-	1	Reconst.	1	108.3	43	165.8	0.398	-0.579	-0.174	5	1.497	0.749	2.714	0.011	0.002	0.577	IX-091
2	ANGOL	IX-092	LAS ANIMAS	Timber	24.70	4.20	15	2	Reconst.	1	117.2	246	365.2	2.101	-0.348	-0.105	4	0.597	0.299	1.232	-1.242	-0.248	-0.054	IX-092
2	ANGOL	IX-093	PELLOMENCO	Timber	14.10	4.20	10	2	Reconst.	1	84.6	246	365.2	2.910	-0.239	-0.072	4	0.597	0.299	1.232	-1.242	-0.248	-0.021	IX-093
70	LONQUIMAY	IX-094	LOLEN	Timber	67.00	2.60	4	2	Reconst.	2	370.6	4660	91.0	12.576	1.071	0.321	4	0.597	0.299	4.947	1.900	0.380	1.000	IX-094
16	LOS SAUCES	IX-095	REÑICO	Timber	20.70	3.40	8	2	Reconst.	1	104.9	251	130.7	2.392	-0.309	-0.093	4	0.597	0.299	3.444	0.629	0.126	0.332	IX-095
69	LONQUIMAY	IX-096	PUNTA NEGRA 1	Timber	28.60	3.50	18	5	Reconst.	2	185.7	1516	91.0	8.163	0.473	0.142	1	-2.103	-1.051	4.947	1.900	0.380	-0.529	IX-096
69	LONQUIMAY	IX-097	PUNTA NEGRA 2	Timber	28.80	3.55	18	3	Reconst.	2	186.7	1516	91.0	8.119	0.467	0.140	3	-0.303	-0.151	4.947	1.900	0.380	0.369	IX-097
4	ANGOL	IX-098	LEALTAD	Timber	63.70	3.50	10	2	Reconst.	2	354.7	9887	365.2	27.873	3.143	0.943	4	0.597	0.299	1.232	-1.242	-0.248	0.994	IX-098
51	TEODO.SCHMIDT	IX-099	POCULON	Timber	31.00	1.85	0	1	Reconst.	2	197.3	958	118.3	4.856	0.025	0.007	5	1.497	0.749	3.803	0.932	0.186	0.942	IX-099
14	PUREN	IX-100	LAS MINAS	Timber	12.50	3.70	10	2	Reconst.	1	79.7	251	115.0	3.146	-0.207	-0.062	4	0.597	0.299	3.914	1.026	0.205	0.442	IX-100
43	VILLARRICA	IX-101	MALLA	Timber	10.00	4.00	12	5	Reconst.	1	72.0	312	161.9	4.333	-0.046	-0.014	1	-2.103	-1.051	2.779	0.066	0.013	-1.052	IX-101
44	VILLARRICA	IX-102	PUELLO	Timber	14.50	3.50	6	5	Reconst.	1	85.8	119	161.9	1.388	-0.445	-0.133	1	-2.103	-1.051	2.779	0.066	0.013	-1.171	IX-102
76	GORBEA	IX-103	PLANCHADO 1	Timber	7.00	4.00	12	3	Reconst.	1	62.8	147	193.4	2.345	-0.315	-0.095	3	-0.303	-0.151	2.326	-0.317	-0.063	-0.309	IX-103
76	GORBEA	IX-104	PLANCHADO 2	Timber	9.60	4.00	12	3	Reconst.	1	70.8	147	193.4	2.080	-0.351	-0.105	3	-0.303	-0.151	2.326	-0.317	-0.063	-0.319	IX-104
76	GORBEA	IX-105	PLANCHADO 3	Timber	8.00	2.65	12	2	Reconst.	1	65.9	147	193.4	2.235	-0.330	-0.099	4	0.597	0.299	2.326	-0.317	-0.063	0.137	IX-105
76	GORBEA	IX-106	PLANCHADO 4	Timber	11.30	2.84	12	3	Reconst.	1	76.0	147	193.4	1.938	-0.370	-0.111	3	-0.303	-0.151	2.326	-0.317	-0.063	-0.325	IX-106
76	GORBEA	IX-107	PLANCHADO 5	Timber	10.00	2.70	12	3	Reconst.	1	72.0	147	193.4	2.045	-0.356	-0.107	3	-0.303	-0.151	2.326	-0.317	-0.063	-0.321	IX-107
76	GORBEA	IX-108	PLANCHADO 6	Timber	8.90	3.95	12	3	Reconst.	1	68.6	147	193.4	2.147	-0.342	-0.103	3	-0.303	-0.151	2.326	-0.317	-0.063	-0.317	IX-108
76	GORBEA	IX-109	PLANCHADO 7	Timber	14.80	3.50	12	3	Reconst.	1	86.8	147	193.4	1.697	-0.403	-0.121	3	-0.303	-0.151	2.326	-0.317	-0.063	-0.335	IX-109
76	GORBEA	IX-110	PLANCHADO 8	Timber	12.80	4.00	12	2	Reconst.	1	80.6	147	193.4	1.827	-0.385	-0.116	4	0.597	0.299	2.326	-0.317	-0.063	0.120	IX-110
			Average					2.700						4.673			3.336			2.701				
			Standard Deviation					1.031						7.382			1.111			1.182				

(1) Economic Index (Traffic-cost ratio)

Economic index is defined by the following formula:

Economic Index = Traffic Volume/Rehabilitation Cost

Column 'B' = Rehabilitation Cost

Rehabilitation cost is estimated for each bridge according to the rehabilitation method and scale criteria classified by traffic volume, bridge type, bridge condition rating (damage rank 1 through 5), bridge roadway width and bridge load carrying limit. All timber bridges even rated to 5 are to be reconstructed regardless of the above criteria (refer to **Chapter 2.5** - Rehabilitation Cost Estimate). In Region IX, the total rehabilitation cost for 110 bridges is estimated at some 14,750 million pesos.

Column 'C'= Traffic Volume

Traffic volume estimated for the year 2005 is used based on the traffic census and survey (refer to **Chapter 2.4** - Traffic Survey). The year 2005 is the middle point of the second 5 years rehabilitation plan. The traffic volume is converted into passenger car unit (PCU).

Example of No IX-001 Niblinto Bridge:

			Conversion Rate			
Passenger car	25 / day	x	1.00	=	25	pcu/day
Truck	418 / day	x	2.50	=	1,045	pcu/day
Bus	11 / day	x	2.49	=	28	pcu/day
Total	454 / day				1,098	pcu/day

The largest traffic volume estimated in Region IX is 9,887 pcu per day and the smallest volume 23 pcu per day.

Column 'E' = Traffic/Cost

From Column 'B' and 'C', the traffic/cost index is calculated for each bridge. The average and the standard deviation of the indices for 110 bridges are calculated on the bottom of the table. In relation to Column 'F', in order to objectively appraise the index across the regions under unified scale, the average index and the standard deviation should be calculated for the total of bridges in all regions in plan.

Column 'F' = Standardized Index

Standardized index is adopted to combine the three different indices under unified scale. The standardized index is defined by the following formula:

Standardized Index = (Individual Index – Average Index)/Standard Deviation

Column 'G' = Weight for Index

The importance of the three indices is not same. Therefore, weight is a measure for the MOP to reflect its rehabilitation policy upon the priority order of bridges by changing the weights between the three indices. The table shows a sample of weight at 30 % for economic index.

(2) Safety Index (Damage rank)

Safety index is directly given by the rating results of bridge condition in the bridge inspection. The condition of bridge is defined by the numerical designation of '1' to '5' according to the degree of bridge damage (refer to **Chapter 2.2** - Bridge Inspection).

Column 'H' = Damage Rank Index

The damage rank rated at site needs to be converted to index so as higher number shows higher priority as follows.

Bridge Condition	Engineering Rating	Damage Rank Index
Dangerous	1	6 – 1 = 5
Potentially hazardous	2	6 – 2 = 4
Not functioning as originally designed	3	6 – 3 = 3
Functioning as originally designed	4	6 – 4 = 2
Good, new or like-new	5	6 – 5 = 1

Column 'I' = Standardized Index

See the explanation of Column 'F'.

Column 'J' = Weight for Index

See the explanation of Column 'G'. The table shows a sample of weight at 50 % for safety index.

(3) Social Index (Income difference correction)

Social index is defined by the following formula:

Social Index = National Average Income/ Regional Average Income

Column 'D' = Commune Average Income

There was no direct income data available in commune level. Therefore, the incomes shown in

Column 'D' were calculated based on the following statistic data:

a) GDP per capita by region in 1995 (Central Bank of Chile)
b) Extreme poor population (Regional Planning Ministry)

From the data a), the GDP per capita of Region IX is 145,592 pesos and the average GDP per capita in the country is 447,230 pesos. From the data b), the percentage of poor population to the population of commune is obtained. Then, the income per capita of commune could be calculated by multiplying the GDP per capita of Region IX (145,592 pesos) with the percentage of poor population of commune. This commune average income calculation is detailed in **Appendix I-9 (Volume 3/8)** - Estimate of Commune Average Income.

<u>Column 'K' = National Average Income/ Commune Average Income</u>

From Column 'D' and the national average income, the income difference correction index is calculated. The national average income (447,230 pesos) is rounded to be 450,000 pesos for the standard value to be used in every region.

<u>Column 'L' = Standardized Index</u>

See the explanation of Column 'F'.

<u>Column 'M' = Weight for Index</u>

See the explanation of Column 'G'. The table shows a sample of weight at 20 % for social index.

2.6.6 Priority Indices for Grouped Bridges (Second Step)

(1) Grouping of Neighboring Bridges

Some bridges are located in close proximity. Such neighboring bridges should be rehabilitated at the same time to maximize the economic effect of bridge rehabilitation investment on a certain road section where the bridges lie. Therefore, a group of individual bridges neighbored in a same road section (road link) is treated as a bridge group.

"Road link" is defined in **Chapter 2.4** as "a elementary unit of road network between adjacent intersections without any branch in it, where uniform traffic volume is assumed." In Region IX, 110 bridges are grouped into 78 links.

(2) Priority Indices for Grouped Bridges

In the second step, as shown in **Table 2.17**, the bridges located in a same road link are grouped. The priority index of a bridge group takes the highest value among those of the bridges in a group, but does not take average.

In the table:

Column 'A' shows the total indices of individual bridges posted from Column 'N' of **Table 2.16**, and

Column 'B' shows the indices for grouped bridges.

2.6.7 Project Investment Plan (Third Step)

(1) Project Investment Plan for Region IX

Table 2.18 shows the 10 years project investment plan for the rehabilitation of 110 bridges in Region IX. In the table, Column 'A' shows the total indices of individual bridges, Column 'B' the indices for grouped bridges and Column 'C' the rehabilitation costs.

The table was prepared by taking the following steps;

1) The total rehabilitation cost of Region IX amounts to about 14,750 million pesos. The average yearly cost is: 14,750 million pesos / 10 years = 1,475 million pesos.
2) 78 bridge groups are divided up into the 10 years investment plan following the order of indices, so as the yearly cost becomes as even as possible.
3) The rehabilitation costs are summed up for each year.

In Region IX, the indices adopted to the 10 years allotment are as follows:

	Total Index
Bridges to be rehabilitated in the 1st year	over 0.720
Bridges to be rehabilitated in the 2nd year	over 0.500
Bridges to be rehabilitated in the 3rd year	over 0.380
Bridges to be rehabilitated in the 4th year	over 0.330
Bridges to be rehabilitated in the 5th year	over 0.250
Bridges to be rehabilitated in the 6th year	over 0.170
Bridges to be rehabilitated in the 7th year	over 0.060
Bridges to be rehabilitated in the 8th year	over 0.090
Bridges to be rehabilitated in the 9th year	over 0.490
Bridges to be rehabilitated in the 10th year	under 0.490

Table 2.17 Priority Indices for Grouped Bridges (Second Step: Priority Order of Bridge Group)

(IX Region)

Bridge Location				Priority Index		Existing Bridge Data					Bridge Rehabilitation Data					
Link No.	Comuna Name	Bridge No.	Bridge Name	Individual Bridge A	Grouped Bridges B	Bridge Type	Length (m)	Width (m)	Load Limit (t)	Damage Rank	Traffic (pcu)	Rehabili. Method	Number of Lanes	Cost (mil peso)	Bridge No.	Link No.
71	LONQUIMAY	IX-049	ÑIRECO	2.651	2.651	Timber	8.20	3.70	10	2	4660	Reconst.	2	87.6	IX-049	71
71	LONQUIMAY	IX-048	ÑANCUREO	2.458	2.651	Timber	10.00	3.00	6	2	4660	Reconst.	2	96.2	IX-048	71
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	ANGOL	IX-098	LEALTAD	0.994	0.994	Timber	63.70	3.50	10	2	9887	Reconst.	2	354.7	IX-098	4
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
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
31	TRAIGUEN	IX-078	HUIÑILHUE	0.726	0.726	Timber	33.30	4.20	-	2	3356	Reconst.	2	208.4	IX-078	31
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
77	CARAHUE	IX-041	LONCOMAYO	0.444	0.714	Timber	18.00	3.84	12	3	1830	Reconst.	2	134.7	IX-041	77
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
38	LAUTARO	IX-091	COLLIN	0.577	0.577	Timber	21.80	3.75	-	1	43	Reconst.	1	108.3	IX-091	38
66	LONQUIMAY	IX-085	HUILLINCO	0.572	0.572	Timber	16.80	4.10	10	2	190	Reconst.	1	92.9	IX-085	66
66	LONQUIMAY	IX-033	ICALMA	0.569	0.572	Timber	17.90	3.70	10	2	190	Reconst.	1	96.3	IX-033	66
19	COLLIPULLI	IX-071	CALLIN	0.562	0.562	Timber	13.60	4.00	12	2	1126	Reconst.	2	113.6	IX-071	19
65	MELPEUCO	IX-034	ALLIPEN	0.542	0.542	Timber	58.00	3.82	4	2	286	Reconst.	1	219.5	IX-034	65
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
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
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
34	NUEVA IMPERIAL	IX-012	HUECHUCON	0.475	0.475	Timber	30.60	4.10	-	2	628	Reconst.	2	195.4	IX-012	34
63	VILLARRICA	IX-021	PEDREGOSO	0.458	0.458	Steel	38.00	3.85	12	2	1909	Reconst.	2	231.0	IX-021	63
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	VICTORIA	IX-064	LOS SOLDADOS	0.007	0.458	Timber	33.50	3.80	8	2	130	Reconst.	1	144.2	IX-064	22
13	PUREN	IX-055	VILUCO	0.451	0.451	Timber	8.30	3.90	10	2	594	Reconst.	2	88.0	IX-055	13
13	PUREN	IX-054	CHACRE	0.344	0.451	Timber	20.10	3.70	10	2	594	Reconst.	2	144.8	IX-054	13
13	PUREN	IX-053	ÑATO	-0.142	0.451	Timber	28.40	3.80	12	3	594	Reconst.	2	184.8	IX-053	13
13	PUREN	IX-052	PINGUIDAHUE	-0.934	0.451	Timber	11.00	3.40	12	5	594	Reconst.	2	101.0	IX-052	13
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
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
35	LAUTARO	IX-001	NIBLINTO	0.377	0.377	Timber	24.80	3.60	8	2	1098	Reconst.	2	167.5	IX-001	35
35	LAUTARO	IX-002	MUCOBAJO	0.319	0.377	Timber	34.50	3.70	6	2	1098	Reconst.	2	214.1	IX-002	35
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
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
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
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
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
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
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
68	LONQUIMAY	IX-076	MIRAFLORES	-0.229	0.309	Timber	19.70	3.90	6	4	639	Reconst.	2	142.9	IX-076	68
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
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
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
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
47	FREIRE	IX-035	NEGRO	0.286	0.286	Steel	20.70	3.85	8	2	755	Reconst.	2	147.7	IX-035	47
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
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
20	COLLIPULLI	IX-072	MININCO	0.261	0.261	Timber	16.30	4.30	10	2	229	Reconst.	1	91.4	IX-072	20
40	VILLARRICA	IX-005	PEDREGOSO	0.252	0.252	Timber	16.50	3.20	-	2	293	Reconst.	1	92.0	IX-005	40
40	VILLARRICA	IX-006	CALBUCO	-0.631	0.252	Timber	13.00	3.55	8	4	293	Reconst.	1	81.2	IX-006	40
40	VILLARRICA	IX-004	LLAMUCO	-0.668	0.252	Steel	22.00	4.00	12	4	293	Reconst.	1	108.9	IX-004	40
59	GORBEA	IX-020	RINCO	0.237	0.237	Steel	12.20	3.65	12	2	370	Reconst.	1	78.8	IX-020	59
59	GORBEA	IX-019	DONGIL	0.131	0.237	Timber	44.10	4.00	12	2	370	Reconst.	1	176.8	IX-019	59
29	CURACAUTIN	IX-087	TRAHUILCO	0.235	0.235	Timber	39.70	3.80	12	1	31	Reconst.	1	163.3	IX-087	29
29	CURACAUTIN	IX-088	CAUTIN	-0.215	0.235	Steel	39.40	3.65	12	2	31	Reconst.	1	162.3	IX-088	29
67	LONQUIMAY	IX-077	RUCANUCO	0.204	0.204	Timber	22.80	3.60	4	3	639	Reconst.	2	157.8	IX-077	67
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	GORBEA	IX-016	LAS LUMAS	-1.112	0.192	Timber	13.20	3.90	6	5	527	Reconst.	2	111.6	IX-016	56
49	FREIRE	IX-037	CHUCAUCO	0.188	0.188	Timber	17.50	3.97	8	2	257	Reconst.	1	95.1	IX-037	49
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
36	VILCUN	IX-003	QUINTRILFE	0.182	0.182	Timber	10.00	2.90	8	2	309	Reconst.	1	72.0	IX-003	36
58	GORBEA	IX-018	PUYEHUE	0.171	0.171	Timber	32.10	4.00	10	2	621	Reconst.	2	202.6	IX-018	58
54	PITRUFQUEN	IX-044	QUINQUE	0.144	0.144	Timber	24.80	4.12	8	2	997	Reconst.	2	167.5	IX-044	54
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
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
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
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
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
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
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
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
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
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
37	LAUTARO	IX-090	EL TRUENO	0.123	0.123	Timber	43.80	3.55	-	2	51	Reconst.	1	175.9	IX-090	37
57	GORBEA	IX-017	POLUL 1	0.119	0.119	Timber	22.70	3.90	10	2	198	Reconst.	1	111.0	IX-017	57

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
78	VILCUN	IX-014	PUMALAL	0.060	0.060	Timber	32.20	4.20	2	2	180	Reconst.	1	140.2	IX-014	78
23	VICTORIA	IX-080	DUMO	0.013	0.013	Timber	32.90	3.97	12	2	149	Reconst.	1	142.4	IX-080	23
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
75	VILLARRICA	IX-025	COLLICO	-0.019	-0.019	Timber	9.60	4.04	4	3	718	Reconst.	2	94.3	IX-025	75
75	VILLARRICA	IX-026	CRUCES	-0.126	-0.019	Timber	20.00	5.70	8	3	718	Reconst.	2	144.4	IX-026	75
2	ANGOL	IX-093	PELLOMENCO	-0.021	-0.021	Timber	14.10	4.20	10	2	246	Reconst.	1	84.6	IX-093	2
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
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
26	CURACAUTIN	IX-081	AMANTIBLE	-0.068	-0.068	Timber	18.20	3.50	12	2	563	Reconst.	2	135.7	IX-081	26
1	RENAICO	IX-074	TOLPAN	-0.092	-0.092	Steel	93.40	3.20	10	2	229	Reconst.	1	328.2	IX-074	1
73	PUCON	IX-028	CARHUELLO	-0.100	-0.100	Timber	21.90	3.91	8	3	1504	Reconst.	2	153.5	IX-028	73
3	ANGOL	IX-086	MALLECO	-0.103	-0.103	Timber	92.00	3.60	8	2	246	Reconst.	1	323.9	IX-086	3
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
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
48	FREIRE	IX-036	PELALES	-0.183	-0.183	Timber	15.60	3.92	8	3	576	Reconst.	2	124.1	IX-036	48
30	CURACAUTIN	IX-089	COLORADO	-0.211	-0.211	Timber	21.50	3.75	3	2	31	Reconst.	1	107.3	IX-089	30
27	CURACAUTIN	IX-082	CORCOLUDO	-0.226	-0.226	Timber	13.80	3.70	8	2	23	Reconst.	1	83.7	IX-082	27
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
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
42	VILLARRICA	IX-008	CHOME2	-0.762	-0.313	Timber	10.00	3.20	12	4	29	Reconst.	1	72.0	IX-008	42
55	PITRUFQUEN	IX-046	MAHUIDANCHE	-0.393	-0.393	Timber	36.40	4.00	10	3	851	Reconst.	2	223.3	IX-046	55
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
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
39	VILLARRICA	IX-011	LAN2	-0.542	-0.542	Timber	8.80	3.95	8	4	525	Reconst.	2	90.5	IX-011	39
39	VILLARRICA	IX-010	LAN1	-0.638	-0.542	Timber	21.80	3.60	10	4	525	Reconst.	2	153.0	IX-010	39
64	CUNCO	IX-032	MEDINA	-0.547	-0.547	Steel	170.00	3.97	8	3	384	Reconst.	1	563.5	IX-032	64
28	CURACAUTIN	IX-084	DILLO	-0.674	-0.674	Timber	10.00	4.60	8	3	23	Reconst.	1	72.0	IX-084	28
25	VICTORIA	IX-057	HULLINLEBU	-0.986	-0.986	Timber	10.40	4.20	12	5	953	Reconst.	2	98.2	IX-057	25
43	VILLARRICA	IX-101	MALLA	-1.052	-1.052	Timber	10.00	4.00	12	5	312	Reconst.	1	72.0	IX-101	43
21	COLLIPULLI	IX-073	ÑANCO	-1.082	-1.082	Timber	14.40	4.20	10	5	229	Reconst.	1	85.5	IX-073	21
44	VILLARRICA	IX-102	PUELLO	-1.171	-1.171	Timber	14.50	3.50	6	5	119	Reconst.	1	85.8	IX-102	44
45	VILLARRICA	IX-031	HUICAHUE	-1.218	-1.218	Timber	33.00	3.70	10	5	36	Reconst.	1	142.7	IX-031	45
24	VICTORIA	IX-065		-1.233	-1.233	Timber	12.00	3.50	8	5	283	Reconst.	1	78.2	IX-065	24
46	CUNCO	IX-030	CODULTO	-1.440	-1.440	Timber	10.80	4.00	8	5	65	Reconst.	1	74.5	IX-030	46
32	GALVARINO	IX-045	AILLINCO	-10.000	-10.000	NoBridge				0	562	NoAction	-	0.0	IX-045	32
72	VILLARRICA	IX-023	QUEBRADA HONDA	-10.000	-10.000	Steel	18.00	3.52	12	5	613	NoAction	-	0.0	IX-023	72
													Total Cost	14748.6		

Table 2.18 Project Investment Plan (Third Step)

(IX Region)

Priority Order	Bridge Location: Link No.	Comuna Name	Bridge No.	Bridge Name	Priority Indicator: Individual Bridge A	Grouped Bridges B	Existing Bridge Data: Bridge Type	Length (m)	Width (m)	Load Limit (t)	Damage Degree	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	3.84	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	MELPEUCO	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	68.0	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	PINGUIDAHUE	-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	0.380								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	0.286	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	1508.1	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 1	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	0.066	0.066	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	0.006	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	CARIRRELLO	-0.100	-0.100	Timber	21.90	3.91	8	3	1504	Reconst.	2	153.5	IX-028	73
86	3	ANGOL	IX-086	MALLECO	-0.103	-0.103	Timber	92.00	3.60	8	2	246	Reconst.	1	323.9	IX-086	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	LONO LONO	-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	CHOMEZ	-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	3.95	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	384	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	HUELLINLEBU	-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	-1.052	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	COQUILTO	-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

(2) Project Investment Plan for the Country

Based on the total cost of Region IX, the scale of the total investment of the country can be estimated as follows:

1) Average cost of a bridge in Region IX is: 14,750 million pesos/110 bridges = 134 million pesos /bridge
2) The total investment amount for 1,000 bridges rehabilitation will be: 1,000 bridges x 134 million peso/bridge = 134,000 million pesos.
3) Therefore, the investment amount per year is: 134,000 million pesos/10 years = 13,400 million pesos.

Based on the above estimation, **Table 2.19** shows a sample form of the project investment plan for all regions.

Although the total investment of the country can be assured after the MOP will have completed data compilation for all the regions, it is tentatively said that the yearly investment amount of the country for the rehabilitation of 1000 bridges will be a manageable figure for the MOP. Because, the scale of the MOP's budget for roads and highways in 1994 to 1995 ranged in around 180,000 to 200,000 million pesos, and the above estimated amount of 13,400 million pesos is only about 7 % of the budget.

Table 2.19 10 Years Project Investment Plan of the Country

First 5 Years Plan									
Region		I –VIII		IX (Model)		X – XIII		Total	
Year	Indicator	No.Bridge	Mill.Peso	No.Bridge	Mill.Peso	No.Bridge	Mill.Peso	No.Bridge	Mill.Peso
1st Year	over 0.000			7	1,488				13,400
2nd Year	over 0.000			11	1,427				13,400
3rd Year	over 0.000			10	1,409				13,400
	over 0.000			7	1,482				13,400
5th Year	over 0.000			14	1,508				13,400
Total				49	7,314				67,000
Second 5 Years Plan									
6th Year	over 0.000			11	1,439				13,400
7th Year	over 0.000			15	1,471				13,400
8th Year	over 0.000			9	1,437				13,400
9th Year	over 0.000			13	1,572				13,400
10th Year	under 0.000			11	1,516				13,400
Total				59	7,435				67,000
Grand Total				108	14,750			1000	134,000
No Action				2					

2.6.8 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.

2.7 STUDY OF BRIDGE MAINTENANCE AND MANAGEMENT

2.7.1 General

The study of bridge maintenance and management system is broadly divided into the following two parts:

a. Present Situation of Bridge Maintenance and Management
   - Organization and Administrative Settings
   - Current Road Transport , and Status of Existing Bridges and Maintenance

b. Findings and Recommendations

2.7.2 Present Situation of Bridge Maintenance and Management

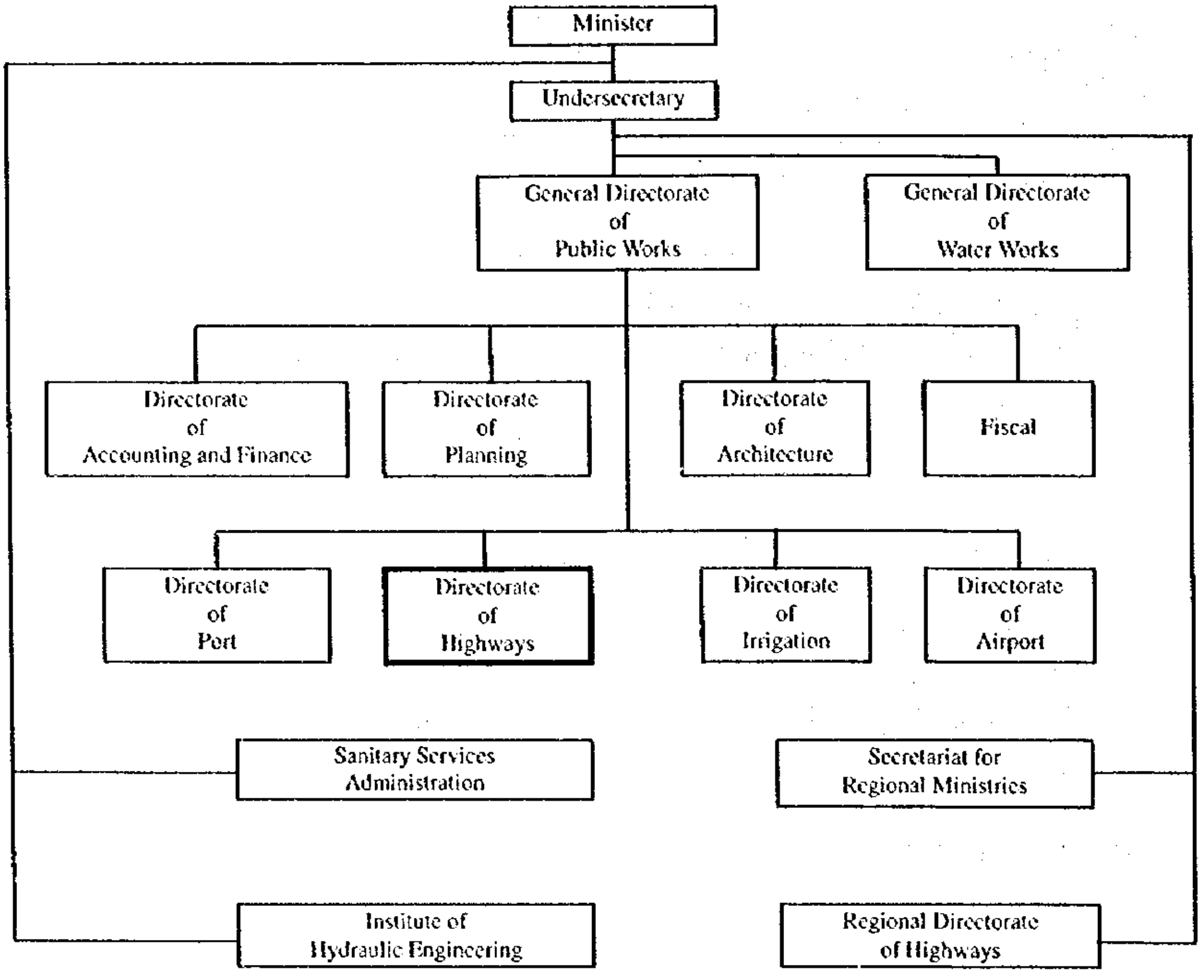
(1) Organization of the MOP (Ministry of Public Works)

Organization chart of the MOP (Ministry of Public Works) is shown in **Figure 2.14**. As seen in the figure, the MOP has two general directorates of public works and water resources. Directorate of highways is under the control of General Directorate of Public Works together with other seven (7) directorates.

(2) Directorate of Highways

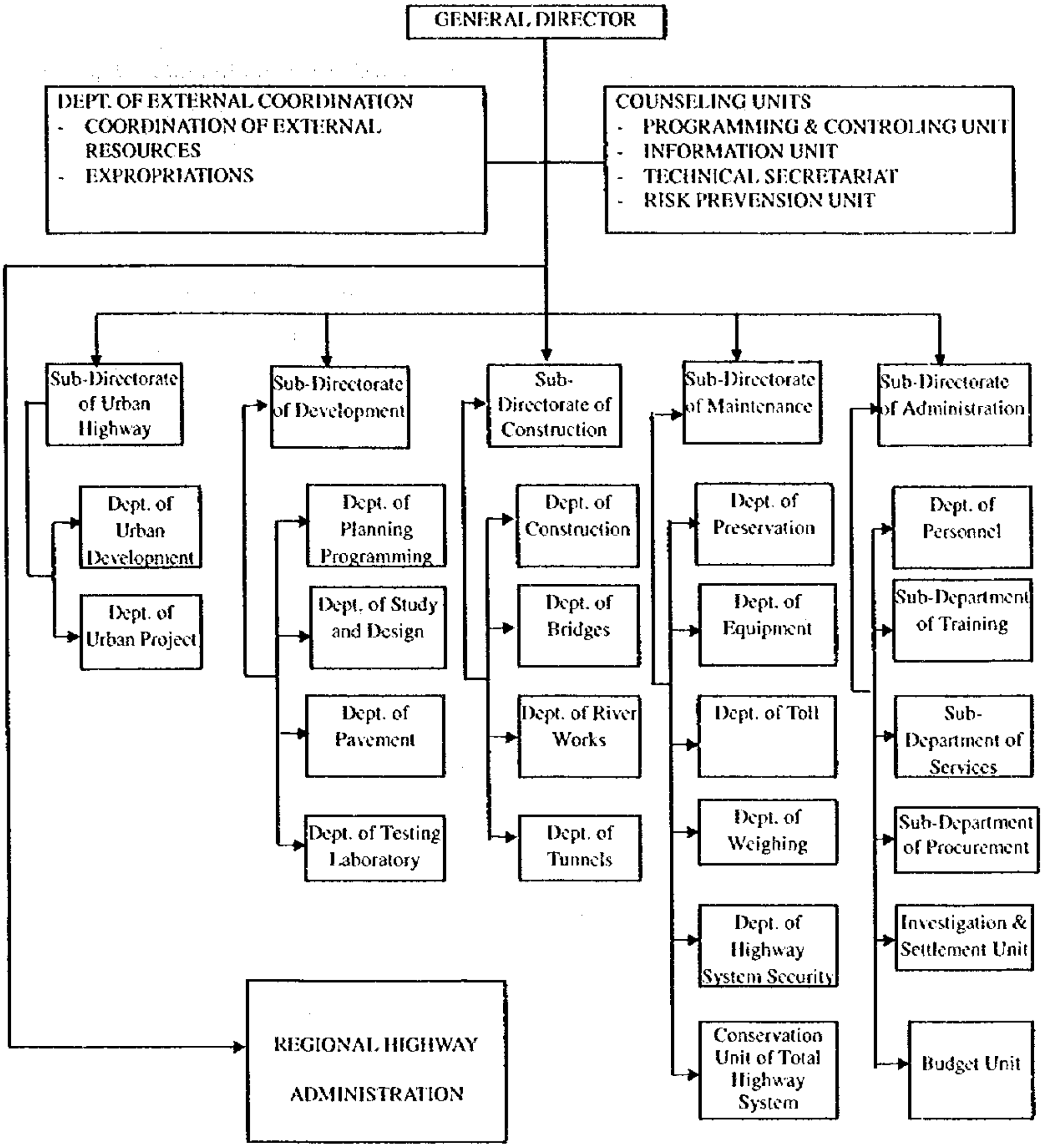
1) Organization and management

Organization chart of the Directorate of Highways (hereinafter referred to as "DOH") is shown in the **Figure 2.15**. The DOH is a Government agency responsible for the planning, construction, maintenance and operation of the nation's state highways and provincial roads (the total length of 79,330 km in 1995).



Source: Ministry of Public Works, 1997

Figure 2.14 Organization of the MOP (Ministry of Public Works)



Source: Ministry of Public Works, 1996

Figure 2.15 Organization of the DOH (Directorate of Highways)

As seen in **Figure 2.15**, there are five (5) Sub-Directorates which are in charge of urban highway, highway development, construction, maintenance and administration under the General Director (Director Nacional de Vialidad). The Department of Bridges under the Sub-Directorate of Construction, and the Department of Preservation under the Sub-Directorate of Maintenance are the agencies directly responsible for the construction and maintenance of highway bridges.

As seen in **Figure 2.14**, Secretariat for Minister of Regional Ministries has been set-up in all of thirteen (13) regions. The major role of the Secretariat for Minister of Regional Ministries is:

- Coordination, management and inspection of public works in regional level;
- Approval of regional maintenance program; and
- Planning of development program in regional level.

Further, the DOH is organized in the province, city, town and village administration levels and all these local DOHs are directly connected with the central DOH of the MOP.

2) Personnel

The DOH has in total 4,273 staffs which is the largest number among eight (8) directorates and general directorate of public works. **Table 2.20** shows the number of staffs in the General Directorate of Public Works, and **Table 2.21** shows the number of engineers.

Table 2.20 Number of Staffs in the General Directorate of Public Works

Directorate	Number of Staffs
Highways (DOH)	4,273
Architecture	395
Port	208
Irrigation	424
Airport	173
Accounting and Finance	411
Planning	147
Inspection	54
General Directorate of Public Works	532
Total	6,617

Source: Ministry of Public Works, 1995

Table 2.21 Number of Engineers by Directorate / General Directorate

Directorate / General Directorate	Architects	Geographer	Engineer *	Engineer **	Execution	Others ***	Total
Highways	5	6	221	202	119	98	651
Architecture	89	0	60	2	2	24	177
Port	0	0	12	26	5	7	50
Irrigation	0	3	20	43	4	24	94
Airport	7	0	11	15	6	6	45
Accounting and Finance	0	0	0	1	6	9	16
Planning	7	1	7	24	5	6	50
Inspection	0	0	0	0	0	0	0
General Directorate of Public Works	4	0	3	10	0	5	22
Total	112	10	334	323	147	179	1,105

Source: Ministry of Public Works, 1995

Notes: * Graduate of technical college (Constructor Civil, CC)

** Graduate of university (Ingeniero, Ing.)

*** Graduate of technical college or university

(3) Current Road Transport

1) Road Network

The ratio of road density within the country is 0.11 km/km2, which is a fair rate compared to the neighboring countries. Surface conditions of the nation-wide road network are shown in **Table 2.22.** Due to these circumstances the current main focus is on the improvement of roads facilities, that is, road widening, paving and bridge improvement.

Table 2.22 Road Conditions in Chile

Class		Concrete		Asphalt		Gravel		Dirt		Total Km.	
Unit		Km.	%	Km.	%	Km.	%	Km.	%	Km	%
Basic Network		2,990	92.0	8,568	92.4	9,267	25.7	1,897	6.2	22,932	28.9
National Roads	A	1,868	57,5	3,057	33.0	1,033	2.9	0	0.0	6,051	7.6
Regional Primary	B	763	23.5	3,544	38.2	2,570	7.1	288	0.9	7,234	9.1
Regional Secondary Roads	C	359	11.0	1,967	21.2	5,664	15.7	1,609	5.3	9,647	12.2
Communal Network		260	8.0	707	7.6	26,789	74.3	28,552	93.8	56,398	71.1
Communal Primary Roads	D	205	6.3	487	5.3	13,594	37.7	9,970	32.7	24,305	30.6
Communal Secondary Roads	E	55	1.7	220	2.4	13,195	36.6	18,582	61.0	32,093	40.5
Total by Pavement Type		3,250	100.0	9,275	100.0	36,056	100.0	30,449	100.0	79,330	100.0
% by Pavement Type			4.1		11.7		45.5		38.4		100.0

Source: Ministry of Public Works, 1995

2) Traffic

The shares of traffic volume by road category is shown in **Table 2.23.** The table shows that the regional and local roads share about 36%.

Table 2.23 Share of Traffic Volume by Road Category

Designation	Road Category		Share (%)
Trunk Road (Red Principal)	National Road	A	63.4
	Regional Road		
	Primary	B	15.9
	Secondary	C	10.4
Ordinary Road (Red Ordinaria)	Local Road		
	Primary	D	6.9
	Secondary	E	3.4
Total			100.0

Source: Ministry of Public Works, 1995

The share of road transport for the nationwide total of freight movement is 66 % and the next is 22 % by rail. These shares have been changing year by year, however the share of road transport seems to decrease in future.

3) Registered Number of Vehicles

Past trend of registered number of vehicles is shown in **Table 2.24**. The table shows the average increase during 1991-1996 is about 8 %.

Table 2.24 Registered Number of Vehicles

(Vehicles in Operation)

Year	Passenger Car	Truck	Bus	Total
1991	858,420	323,233	24,008	1,205,661
1992	922,225	361,704	26,146	1,310,075
1993	995,017	401,273	29,547	1,425,837
1994	1,008,110	418,392	32,620	1,459,122
1995	1,125,954	458,687	37,592	1,622,233
1996	1,219,978	499,362	47,215	1,766,555

Source: Institute of National Statistics, 1996

4) Highway Development and Maintenance

The Chile Government has been attached importance to the highway development and maintenance. As seen in **Table 2.25** the budget of the DOH in 1995 accounted for 76 % in the entire budget of the MOP. The second 5-year development plan which had started in 1990 laid emphasis on highway maintenance as shown in **Figure 2.16**.

Table 2.25 Budget of the MOP (1990-1995)

Agency	1990	1991	1992	1993	1994	1995
Directorate of Highways (DOH)	91,500,154	111,076,911	129,730,084	150,676,880	188,380,955	198,744,633
Directorate of Architecture	24,411,541	4,555,415	2,764,434	2,365,551	2,223,464	2,338,887
Directorate of Port	1,480,714	6,967,260	9,422,029	13,142,395	13,482,154	16,730,240
Directorate of Irrigation	872,372	4,098,953	11,211,534	15,577,009	17,792,093	15,703,785
Directorate of Airport	2,225,925	2,790,283	2,332,543	2,805,047	4,541,896	5,308,299
Concession	0	0	0	0	0	11,757,936
Undersecretary	129,342	168,584	1,034,128	882,512	475,227	398,021
General Directorate of Water Works	701,650	782,866	938,434	1,084,236	1,378,998	1,698,580
Institute of Hydraulic Engineering	1,506	0	41,423	44,825	28,529	49,962
Directorate of Accounting and Finance, Planning and Inspection	58,491	155,672	417,918	1,042,099	2,761,026	7,769,785
Superintendence	71,587	181,504	226,006	144,412	298,614	610,525
Total	121,453,282	130,777,448	158,121,533	187,764,966	231,362,956	261,110,653

Source: Ministry of Public Works, 1995

The policies of the Government concerning the highway development and maintenance are, among others:

- Maintenance and improvement of regional and local road network to stimulate economic activities in the strategic regional and local development areas;
- Participation of private sector to supplement shortage of the Government budget for road development, and
- Intensification of axle load control increasing permanent weigh-bridges to avoid excessive damage to the pavement.

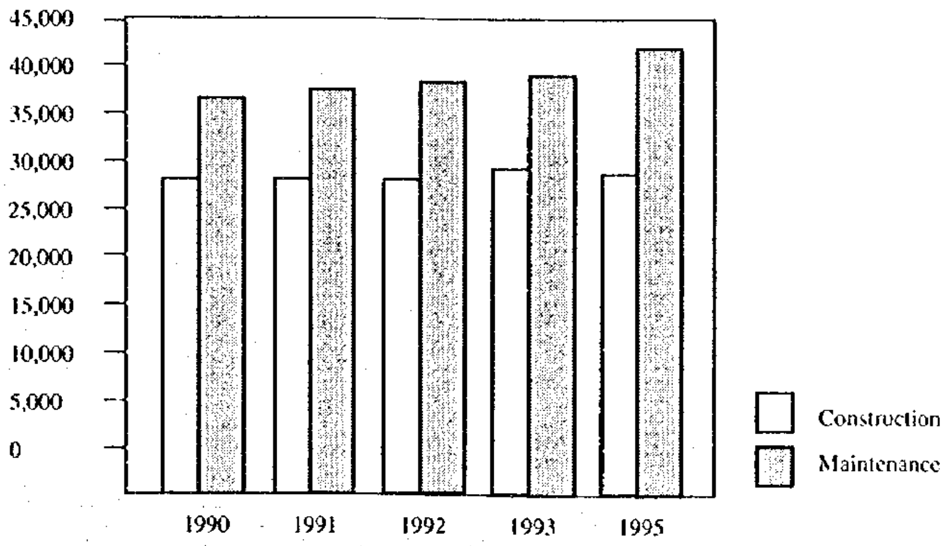


Figure 2.16 Highway Construction and Maintenance Budget in Second 5-Years Development Plan

(4) Status of Existing Bridges

1) Geographical and Weather Situations of Chile

The geography of Chile is complex and of the extraordinary variety. In the north the Atacama desert; to the west, lies the Pacific Ocean; to the east the boundary is in the Andes Mountain Range, with heights of up to 7,000 m above sea level; and to the south, the Drake Sea and Antarctica.

The terrain condition has three clearly defined features: to the east the Andes mountain range; to the west a long coast mountain range, and the depressions or flatlands enclosed these two mountain ranges.

The significant variety of climates in Chile is due mainly to four factors that are: the latitude, the action of the sea, the terrain condition and the east winds. In Chile temperatures descend gradually towards the south. The desertic type climate prevail from Arica to La Serena. On the coast of Arica the mean annual temperature is 18°C and 0 mm of rainfall.

From La Serena to the north of Santiago, the arid climate is similar to warm steppes, with a slight decrease of temperature and occasional winter rains that allow the existence of vegetation consisting mainly of low bushes.

From Santiago to Concepción, mediterranean climate prevails, with a dry summer season, rainfall ranging from 340 mm to 1,200 mm and mean average temperatures between 14°C and 15°C.

To the south of the city of Concepción, temperatures decrease gradually and the rainfall increases exceeding 2,500 mm on to Puerto Montt.

Further the south, to parallel 47°S, the climate is maritime temperate, with more abundant rains and moderate temperatures because of the marine influence; high volcanoes close to the coast are covered with eternal snow.

2) General Problems in Bridge Maintenance

Appropriate bridge development and maintenance have not been made due to the lack of the national budget for about 30 years in the past. Followings are main problems in the bridge maintenance in the country:

- About a half of existing bridges use timber for bridge deck and about 20 % are all timber construction.
- There are many old bridges which had adopted lower design loading standard.

- Scouring hazard of bridge foundations (i.e. abutments and piers) is other problem reflecting the severe geographical condition of Chile.
- The bridge distribution is quite different by region, careful bridge maintenance is necessary considering inherent characteristics of each region.

3) General Features of Existing Bridges

There exist about 8,000 bridges which totals approximately 180,000 m of bridge length. The distribution of bridges in regions is shown in **Table 2.26**. Viewing the existing bridges from the construction material, about half of the Chilean bridges use timber members as shown in **Table 2.27**.

Regions VII, VIII, IX and X hold about 70 % of the nation's total bridge length. On the other hand, bridge distribution is very low in the northern Regions I, II and III, where the total share of the three regions marks only 1.6 %, reflecting the geographical and weather condition of the area.

Table 2.26 Estimated Distribution of Existing Bridges by Region

Region	Total Bridge Length (m)	Percentage (%)
I	970	0.54
II	360	0.20
III	1,529	0.85
IV	8,429	4.68
V	11,716	6.51
RM (XIII)	11,420	6.34
VI	11,923	6.62
VII	23,810	13.23
VIII	31,832	17.68
IX	28,449	15.81
X	40,368	22.43
XI	5,687	3.16
XII	3,507	1.95
Total	180,000	100.00

Source: Directorate of Highways, MOP.

Table 2.27 Existing Bridges by Construction Type

Construction Type	N° of Bridges	Bridge Length (m)	Share by Bridge Length (%)
CCC	1,789	70,200	39.0
CSC	731	23,040	12.8
CST	1,481	26,460	14.7
CTT	1,150	14,760	8.2
STT	610	10,440	5.8
TTT	2,237	35,100	19.5
Total	7,998	180,000	100.0

Source: Directorate of Highways, MOP.

Note: Construction type is categorized as shown in the following table:

Construction Type	Materials		
	Substructure	Beams	Bridge Deck
CCC	Concrete	Concrete	Concrete
CSC	Concrete	Steel	Concrete
CST	Concrete	Steel	Timber
CTT	Concrete	Timber	Timber
STT	Steel	Timber	Timber
TTT	Timber	Timber	Timber

From **Table 2.27** it is found that:

- Permanent bridge types CCC and CSC hold only 52 % bridge length;
- Bridges adopting concrete substructure hold about 75 % in bridge length; and
- Timber is widely used for bridge deck and all timber bridges (TTT) still exist at about 20 %.

Condition of bridges have been changing year by year. **Table 2.28** shows the indicative summary of the conditions of existing bridges.

Table 2.28 Conditions of Existing Bridges

Structural Condition	Share to Total Bridge Length (%)	Remarks
Good	20	* Construction types of CCC and CSC. * Minor rehabilitation or repair may be needed.
Fair	35	* Construction types of CST, CTT, STT and TTT. * In fair condition but need some degree of repairs/replacement.
Poor/Bad	45	* Lack of enough loading capacity. * Serious deterioration of bridge structure (excessively aged). * Major repair or replacement with new bridge is necessary.

Source: Directorate of Highways, MOP.

2.7.3 Findings and Recommendations

(1) Major Findings

1) Necessity of Bridge Replacement

Reportedly by the MOP, there are about 3,600 bridges in critical conditions which are suffering from:

- Severe deterioration of structures due to excessive aging over their design lives;
- Lack of load carrying capacities which require severe loading limitations (low design loadings); and
- Existence of many timber bridges.

Above conditions were identified in Region IX and vicinity regions by the Study Team through the bridge inspections. It was found that reusing of existing bridges by repairs seemed not to be a practical solution from the technical and economical point of view, instead aged and deficient bridges needed to be replaced with new structures.

In such circumstances, it is urgent to start a national bridge replacement program, because the country's regional road network will face difficulties unless the bridge problem will be solved.

2) Project Cost for Bridge Replacement

The results of the bridge rehabilitation planning study (see **Chapter 2.6.7**) revealed that the bridge replacement cost for 110 bridges with 2,640 m in Region IX was about 14,750 million pesos (some 36.0 million US dollars) based on the price in 1997. The Department of Bridges is now considering the national bridge replacement program for selected 1,000 bridges. Therefore, a magnitude total cost for 1,000 bridges will be roughly 134,000 million pesos (US$ 327 million).

Project cost normally consists of costs for construction, physical contingencies (10%), design and construction supervision services (10%) and prices escalation. **Table 2.29** shows the summary of a magnitude project cost for the national bridge replacement program (provisional estimate) based on the 10 years program.

Table 2.29 Summary of Project Cost of Bridge Replacement Program

Category	Cost	
	in million Pesos	in million US$
Construction (in 1997 prices)	134,00	326.8
Physical Contingencies (10 %)	13,400	32.7
Design and Supervision (10 %)	14,700	35.8
Price Escalation Allowance based on 10 years Program (8 % per year) *	91,500	223.2
Total	253,600	618.5

Note * : Project starts in 1998 and ends in 2007.

The cost of the replacement program does not include repair cost which will be required for maintenance before the program has completed.

3) Bridge Repair Cost

As above mentioned, bridge repair will be required at least for those bridges which replacement is scheduled in the second 5-years bridge replacement program, refer to **Chapter 2.6.1**.

The total repair cost for 110 bridges in Region IX is totaled at about 130 million pesos (US$ 0.3 million). This repair cost is minor compared with the bridge replacement cost (about 1.0 % of replacement cost).

It is advantageous to execute repair works as soon as possible before damages will become serious. Repair works can be applied only for about 50 % of the 1,000 bridges, because the bridges selected for the first 5-years program will be omitted, if the replacement program will be started earlier.

Based on the study of Region IX, the national total repair cost can be estimated at roughly 600 million pesos (US$ 1.4 million) but certain allowances must be added due to:

- Inspection and design work;
- Supervision of repair work;
- River banks and scour protections works; and
- Physical contingencies and price escalation.

(2) Recommendations

1) The repair work for those bridges scheduled in the second 5-years program shall be proceeded at the earliest.
2) Preventive maintenance should be accomplished with sufficient financial resources.
3) Force account activities for bridge repair works should be reduced except for the minor and emergent repairs requiring quick response.

4) Bridge management unit should be established in the Department of Bridges in order to:

- Improve maintenance service level;
- Control bridge inventory and inspection; and
- Plan and execute maintenance program.

Bridge maintenance section should be set up in each region. Major duties and responsibilities of the section will be:

- Bridge inventory and inspection;
- Assist to preventive and minor bridge maintenance works; and
- Preparation of maintenance record.

Recommended personnel, inspection tools/instruments and vehicles per region are:

Personnel	Bridge Management Unit	Bridge Maintenance Section
Chief Engineer	1	-
Engineer	2	13
Technical Staff	3	26
Computer Operator	1	-
Typist	1	-
Clerk	1	-
Total	9	39

Inspection Tools, Testing Instruments and Vehicles	Bridge Management Unit	Bridge Maintenance Section
Ultrasonic Steel Thickness Meter	1	-
Plofometer	1	-
Concrete Neutralization Liquid Test Set	2	-
Schmidt Hammer	1	-
Camera, Binoculars, Steel Tape, Plum Bob, Crack Scale, etc.	1 for all	1 for all
Van	1	-
Sedan	1	-

CHAPTER 3

BRIDGE REHABILITATION DESIGN

CHAPTER 3 BRIDGE REHABILITATION DESIGN

3.1 CONCEPT OF BRIDGE REHABILITATION DESIGN

3.1.1 Purpose and Scope of the Rehabilitation Design

Sample designs of bridge rehabilitation were prepared for the purposes:

- to transfer technical skills of inspection and rehabilitation of bridges to the MOP personnel in charge for bridge maintenance, and
- to obtain technical information for the preparation of Bridge Inspection & Rehabilitation Manual and Bridge Rehabilitation Plan of the Study.

The study for bridge rehabilitation design consists of 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.

While, the MOP is required to provide the following data of the sample bridges:

- General bridge information including location, scale and type of bridge, geographical site condition, etc.
- As-built drawings.
- Rehabilitation policy of MOP.

3.1.2 Process of the 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.

The overall process of the study in this chapter is outlined by a flowchart in **Figure 3.1**.

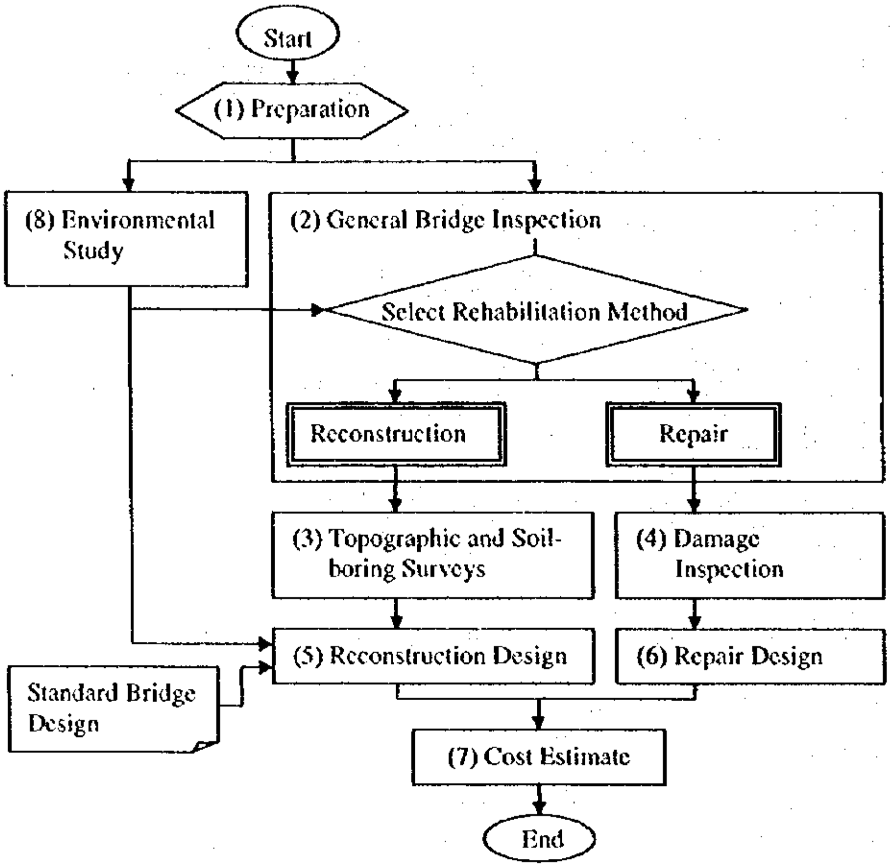


Figure 3.1 Process of Bridge Rehabilitation Design

In the above flowchart, each study item included the following activities:

(1) Preparation

- Confirm bridge location and arrange inspection schedule.
- Obtain existing bridge drawings (but no drawing available).

(2) General Bridge Inspection

- Collect general bridge data (length, span, width, bridge type, etc.).
- Inspect problems of bridge structures (damages, defects) and waterways (erosion, scoring).
- Select rehabilitation method; reconstruction or repair.
- Select reconstruction location for the bridges to be reconstructed.
- Select repairing method for the bridges to be repaired.

(3) Topographic and Soil-boring Surveys

- Topographic and soil-boring surveys for the bridges to be reconstructed.

(4) Reconstruction Design

- Prepare new bridge designs for the bridges to be reconstructed, by applying the standard bridge CADD program developed in this Study.

(5) Damage Inspection

- Inspect damages in detail following the repairing scheme decided in (2) General Bridge Inspection.
- Non-destructive instrument tests (Schmidt hammer, Profometer, concrete neutralization, etc.) to supplement visual inspection.

(6) Repair Design

- Prepare repair designs according to the repairing scheme and based on the results of damage inspection.

(7) Cost Estimate

- Estimate rehabilitation cost (direct construction cost only) both of the reconstruction and repair designs

(8) Environmental Study

- Inspect environmental condition (use project and site description forms).
- Identify project sites and presume environmental impacts.
- Assess environmental impacts by project activities (use IEE and preliminary EIA checklists).

3.1.3 Selection of the 20 Bridges

Twenty bridges for the rehabilitation design were selected in cooperation with the MOP considering the following points:

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

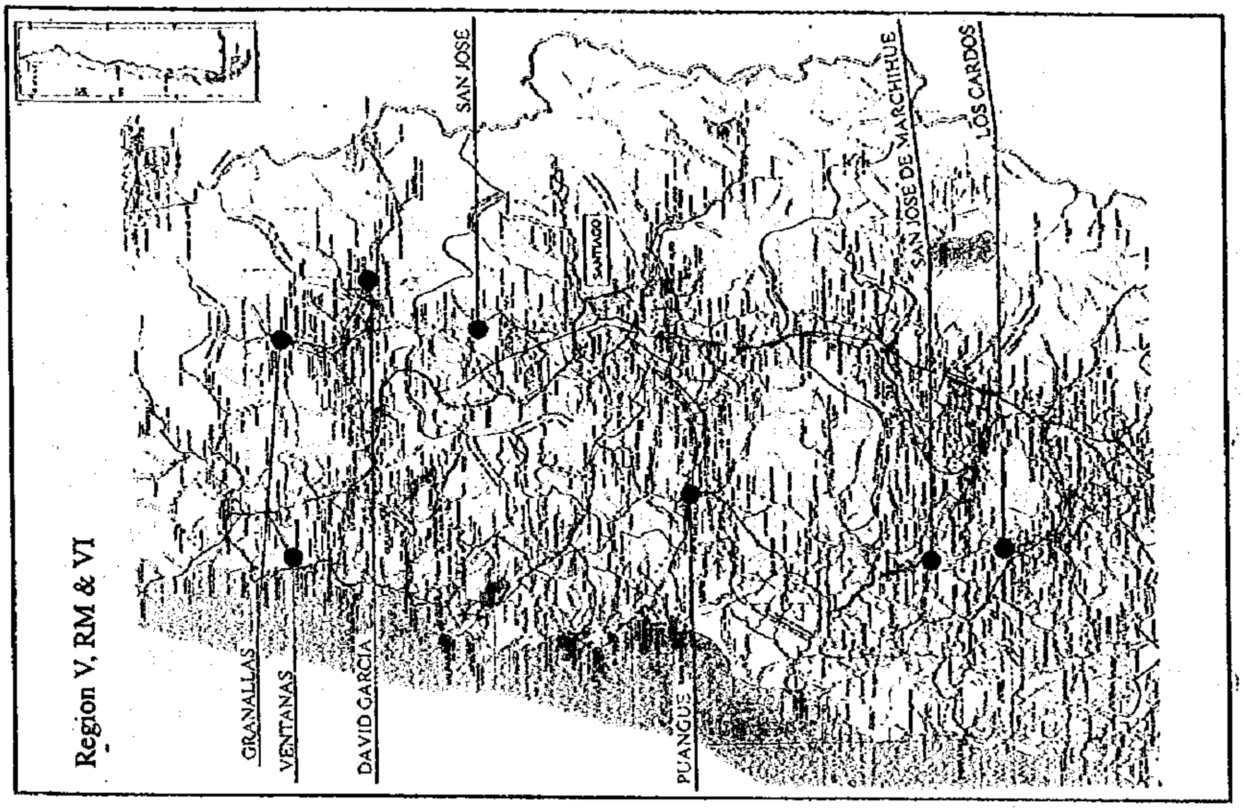
Actually, eleven bridges were selected from the bridges in Regions IX and X surveyed for the rehabilitation plan, and nine bridges from the bridges in Region IV, V, VI and RM which the MOP needed urgent rehabilitation. Common bridge types in Chile such as simply supported timber, concrete and steel beams were selected, but special types such as continuous beams, suspension bridges, arches, etc. were excluded.

The 20 bridges are listed in **Table 3.1** and their locations are shown in **Figure 3.2.**

Table 3.1 Twenty Bridges for Rehabilitation Design

	Bridge Name	Region	Structural Type	Length (m)	Reason of Selection
1	Confluencia	IV	ST	113.10	To show a repair of steel bridge.
2	David Garcia	V	RC	93.05	To show a rehabilitation of old RC bridge.
3	Granallas	V	ST	49.85	To show a rehabilitation of steel beam/timber deck bridge.
4	Ventanas	V	RC	30.00	To show a repair of RC bridge.
5	San Jose	RM	RC	16.10	To study a reconstruction of short and narrow bridge.
6	Puangue	RM	RC	105.10	To show a reconstruction of old RC bridge once extended for change of waterway.
7	San Jose de Marchiue	VI	ST	120.00	To study a reconstruction of low and narrow bridge blocking waterway, often closed.
8	Antivero No.2	VI	RC	102.90	To study reconstruction of flood-damaged bridge.
9	Los Cardos	VI	ST	73.55	To show a repair of steel beam/timber slab bridge.
10	Cautin	IX	RC	140.00	To show a repair of old RC bridge.
11	El Indio	IX	ST	21.10	To show a repair of steel bridge in mountain.
12	Quillen	IX	TM	25.90	To show a repair of timber bridge.
13	Poculon	IX	TM	31.00	To show a reconstruction of decayed timber bridge.
14	Malleco	IX	TM	92.00	To show a repair of long timber bridge.
15	Miraflores	IX	TM	44.40	To show a repair of timber bridge.
16	San Juan	IX	TM	31.60	To show a reconstruction of decayed timber bridge.
17	Medina	IX	ST	170.00	To show a repair of steel beam/timber slab bridge.
18	Cautin (88)	IX	ST	39.40	To show a repair of steel beam/timber slab bridge.
19	Salva Tu Alma	IX	ST	40.70	To show a repair of steel beam/timber slab bridge.
20	Quinchilca	X	RC	140.00	To show a repair of RC bridge.

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



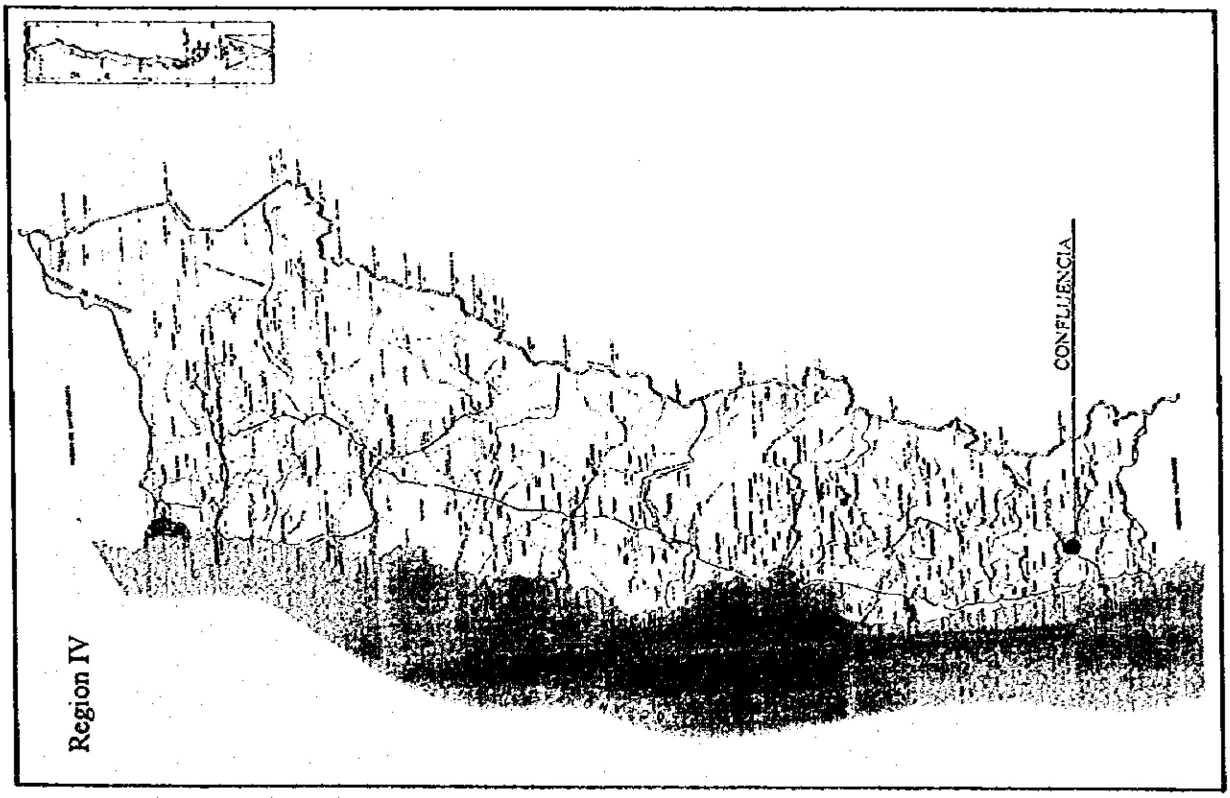
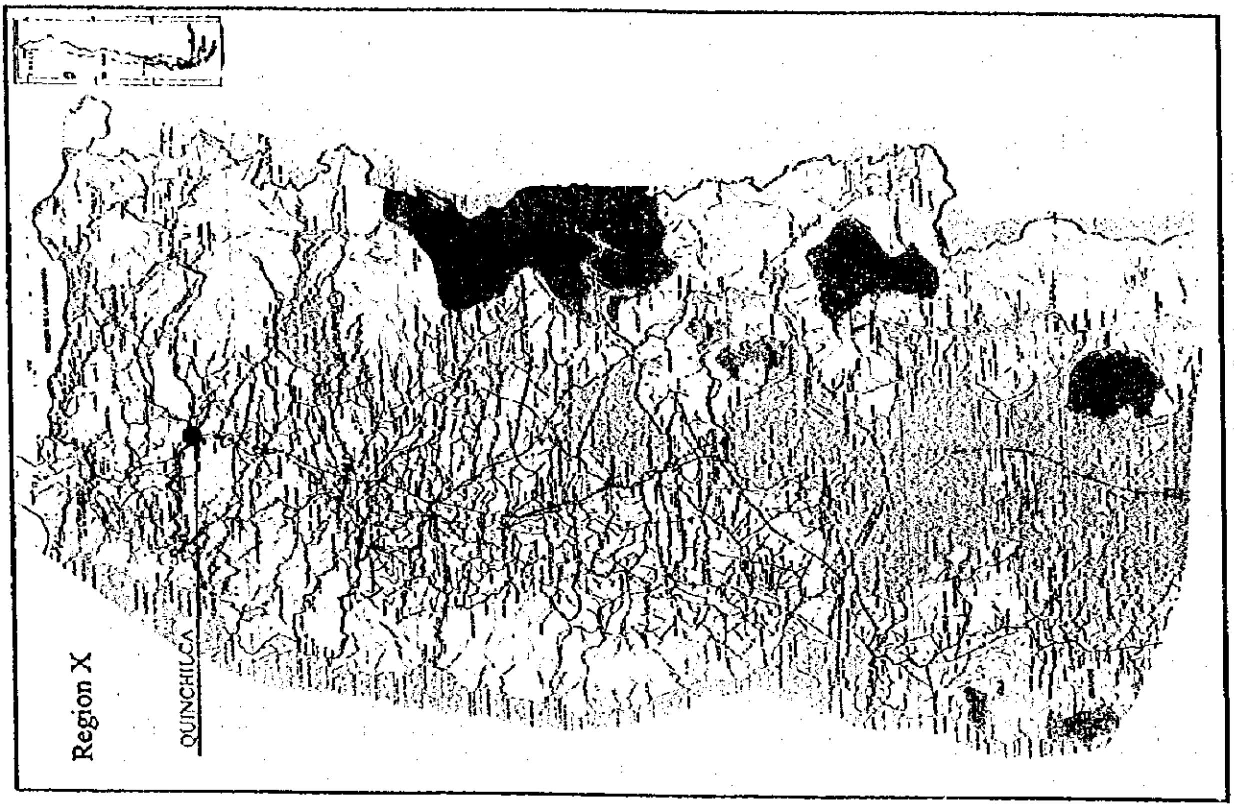


Figure 3.2 Location of Twenty Bridges for Rehabilitation Design (1/2)



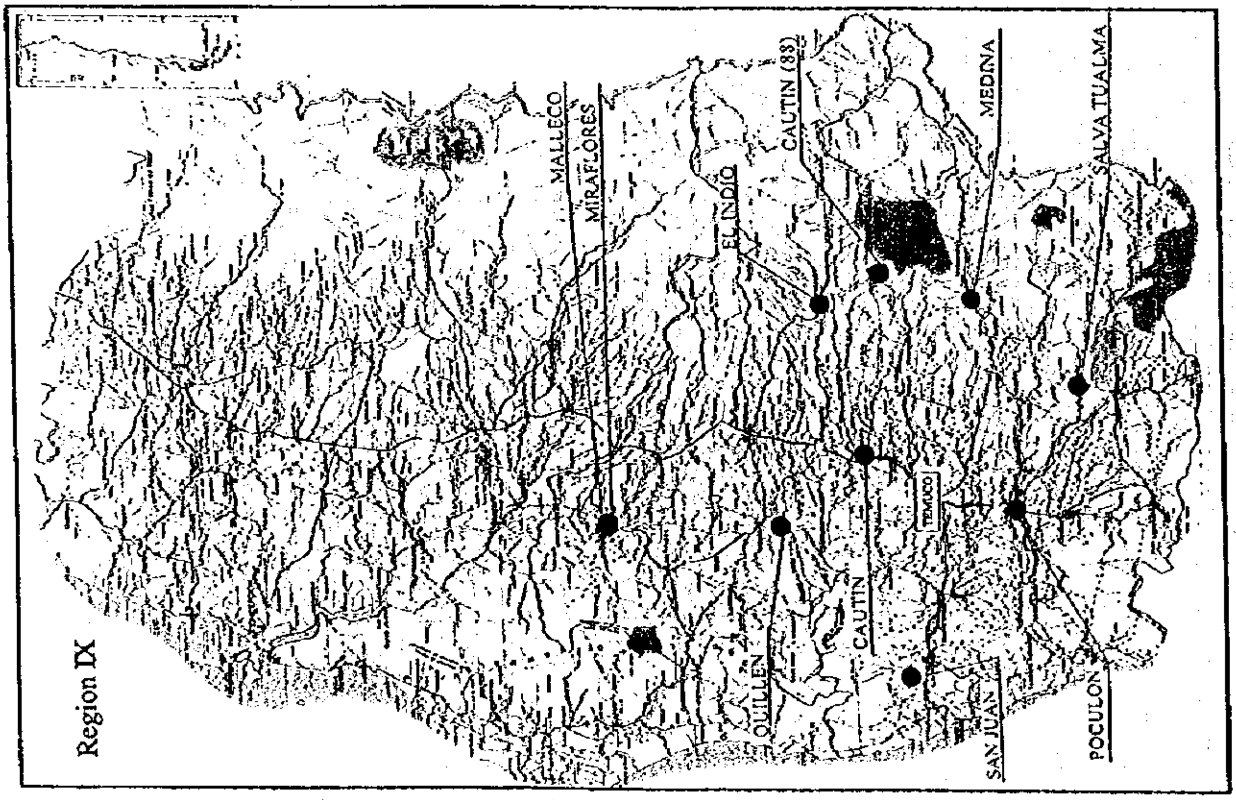


Figure 3.2 Location of Twenty Bridges for Rehabilitation Design (2/2)

3.2 GENERAL BRIDGE INSPECTION

3.2.1 Method of Inspection

(1) Joint Inspection

Bridges 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 matters such as construction year, past repair, design load, river flow at flood, traffic condition, etc., could be collected by hearing from the regional MOP staff and the local people taking advantage of the bridge.

The inspection work was carried out in June and July 1997.

(2) Collection of General Bridge Data

General site information and structural data of bridge were collected in accordance with the same inventory form as used in the bridge inspection in the Bridge Rehabilitation Plan.

General site information includes location, construction year, river and geographic condition and other administrative data of the bridge. Structural data covers bridge type, major dimensions, profile and cross-sectional sketches.

The bridge data inspected were compiled into a general view drawing. An example of that is shown in **Figure 3.3** and those for the 20 bridges are contained in **Appendix II-1 (Volume 4/8)**. The photographs of side and front views are also contained in the same Appendix.

(3) 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.

The damage pictures inspected and their evaluation are compiled into a damage table of the kind shown in **Table 3.2** and those for the 20 bridges are compiled into **Appendix II-1 (Volume 4/8)**.

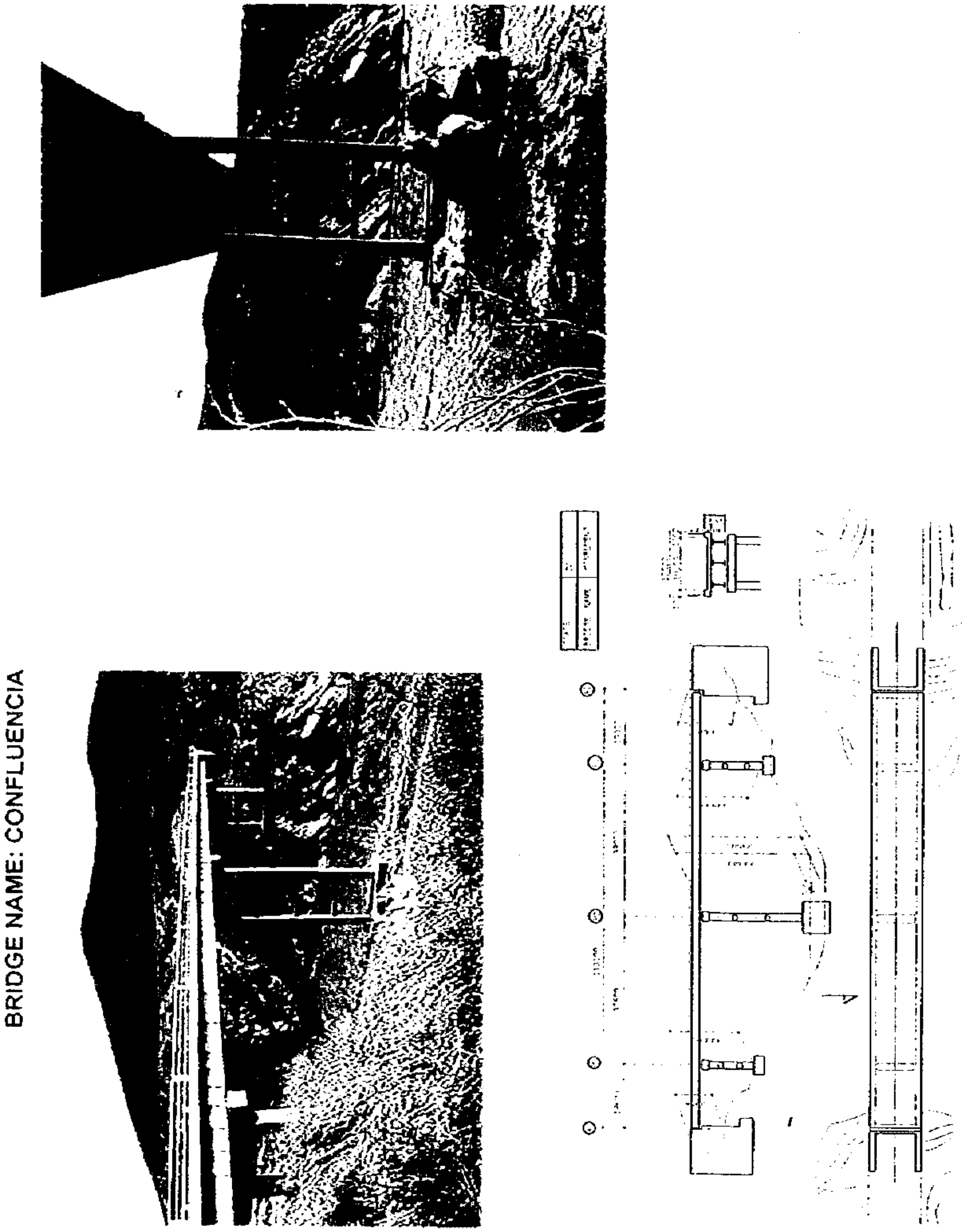
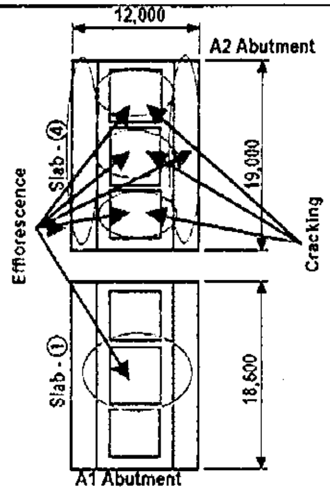
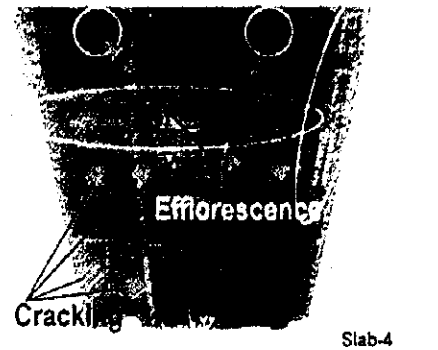
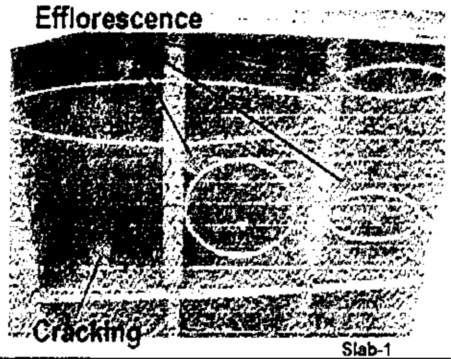
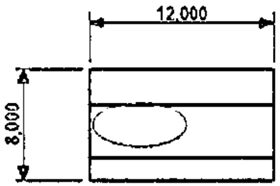


Figure 3.3 General View Drawing of Inspected Bridge

<table>
<tr><th>Bridge Component</th><th>Location of Damage</th><th>Damage</th><th>Evaluation of Damage</th><th>Damage Rank</th><th>Picture</th></tr>
<tr><td rowspan="2">Slab</td><td rowspan="2">

Cracking
X: one direction
0.3mm<Y<0.2mm
Z: less 50cm

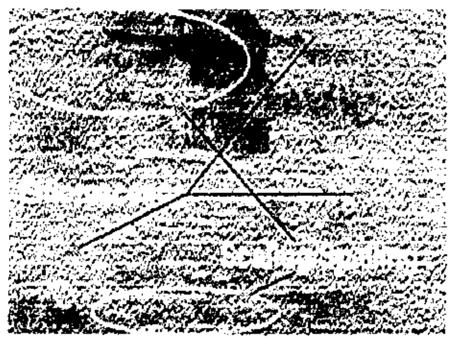
Efflorescence
Z: over 0.1m2</td><td>Cracking</td><td>
<table>
<tr><th>X</th><th>Y</th><th>Z</th><th>All member</th></tr>
<tr><td rowspan="6">Large</td><td rowspan="2">Large</td><td>Large</td><td>II</td></tr>
<tr><td>Small</td><td>II</td></tr>
<tr><td rowspan="2">Medium</td><td>Large</td><td>II</td></tr>
<tr><td>Small</td><td>III</td></tr>
<tr><td rowspan="2">Small</td><td>Large</td><td>III</td></tr>
<tr><td>Small</td><td>IV</td></tr>
<tr><td rowspan="6">Small</td><td rowspan="2">Large</td><td>Large</td><td>III</td></tr>
<tr><td>Small</td><td>III</td></tr>
<tr><td rowspan="2">Medium</td><td>Large</td><td></td></tr>
<tr><td>Small</td><td>IV</td></tr>
<tr><td rowspan="2">Small</td><td>Large</td><td>IV</td></tr>
<tr><td>Small</td><td>IV</td></tr>
</table>
Damage was observed,
but rehabilitation is not needed.
Follow-up inspection must be executed.</td><td>III</td><td rowspan="2">


</td></tr>
<tr><td>Efflorescense</td><td>
<table>
<tr><th>Z</th><th>Main Member</th><th>Secondary Member</th></tr>
<tr><td>Large</td><td></td><td>II</td></tr>
<tr><td>Small</td><td>III</td><td>IV</td></tr>
</table>
Degree of damage was large so that rehabilitation must be needed.</td><td>II</td></tr>
<tr><td>A1 Abutment</td><td>

Efflorescence is all over the surface.

Scaling/Spalling
Y: no exposed reinforcement bar
Z: less 1.0m2

Efflorescence
Z: over 1.0m2</td><td>Scaling/Spalling
Efflorescence</td><td>Scaling/Spalling
<table>
<tr><th>Y</th><th>Z</th><th>Main Member</th><th>Secondary Member</th></tr>
<tr><td rowspan="2">Large</td><td>Large</td><td>II</td><td>II</td></tr>
<tr><td>Small</td><td>II</td><td>IV</td></tr>
<tr><td rowspan="2">Small</td><td>Large</td><td>III</td><td>IV</td></tr>
<tr><td>Small</td><td></td><td>IV</td></tr>
</table>
Damage was observed, the degree must be recorded.
Efflorescence
<table>
<tr><th>Z</th><th>Main Member</th><th>Secondary Member</th></tr>
<tr><td>Large</td><td></td><td>II</td></tr>
<tr><td>Small</td><td>III</td><td>IV</td></tr>
</table>
Degree of damage is large, so that rehabilitation must be needed.</td><td>Scaling/ Spalling
IV

Efflorescence
II</td><td></td></tr>
</table>

(4) Damage Rating System

To rate damage rank (I through V), the Bridge Inspection Guidelines (1988 Proposal) of the Civil Engineering Institute of Japan's Ministry of Construction was used.

The system adopts the following three factors to rate the rank (I through V) of a damage.

① Location or pattern of damage (X)
② Depth of damaged part (Y)
③ Extent of damaged part (Z)

Each factor is evaluated by the magnitude of damage namely Large (or Deep), Medium, or Small (or Shallow). The rank of damage is decided based on a combination of the three factors by referring to the prescribed damage rank table. The rating factors and rank tables for major damages of concrete, steel and timber bridges are given in **Division III of Bridge Manuals (Volume 6/8).**

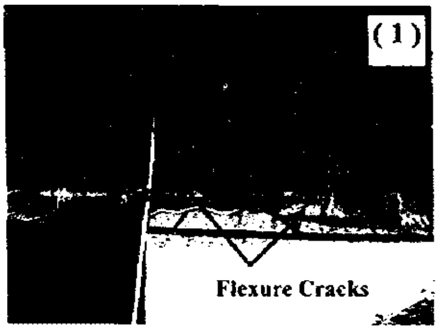
3.2.2 Evaluation of Typical Damages

Typical damages inspected are summarized and analyzed from engineering point as follows.

(1) Concrete Components

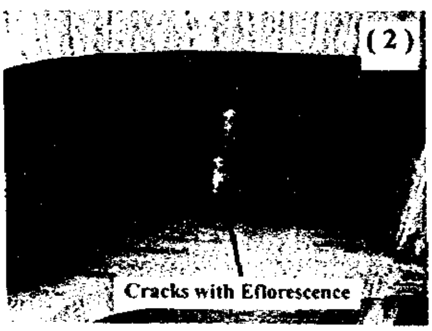
1) Cracks on main beams

There was little serious cracks on main beams except on those of Antivero No. 2 Bridge where vertical cracks were found (see Photo (1)) that was inferred as a kind of moment cracks from the direction of cracks. From the cracks, isolated lime effloresced.

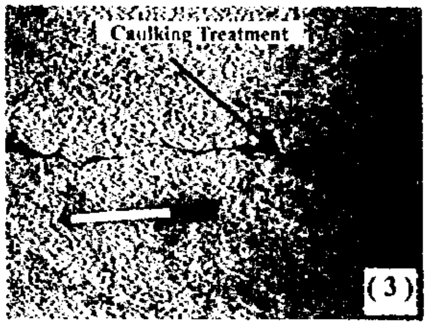


2) Cracks on deck slabs

All concrete slabs inspected were not covered with pavement, and so affected directly by vehicle running impact. Cracks were found underside of slabs at Confluencia, David Garcia, San Jose and Puangue Bridges. Direction of cracks was transverse (see Photo (2) of David Garcia Bridge), which implied that probable cause was the vibration of slabs by traffic. Cracks were also found on underside of the cantilever slabs of Confluencia Bridge accompanied with distinct lime efflorescence. This crack was considered to have occurred at the time of construction by shrinkage and



temperature difference of concrete. Scars of crack repairs being caulked with asphalt (see Photo (3)) were found on surface of the slabs of Confluencia Bridge.



Many of concrete slabs inspected were rather thin compared with those in Japan, and that seemed to be a cause of cracks.

3) Cracks on substructures

Many large cracks were observed on concrete walls of abutments and piers. Cracks were found more on substructure than on superstructure. From this fact, it was deemed that the quality of construction in superstructure was better than that of substructure. On abutment wall, pattern of cracks was various but vertical cracks prevailed.

Main cause of that was considered to be shrinkage of wall concrete and sunlight heating on surface, but not due to overload or settlement. However, a few but some horizontal or diagonal cracks were found on several concrete walls. That implied possibility of overload or settlement, but symptom was ambiguous. Photo (4) shows a large crack on the abutment wall of David Garcia Bridge.

4) Scaling/Spalling

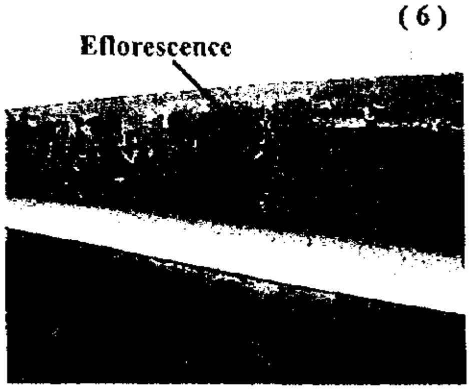
This damage was observed widely on concrete surface, but most were not serious and rated III or IV of damage rank. However, Photo (5) shows a serious damage of this type exposing reinforcement on the abutment wall of Antivero No. 2 Bridge, which was considered due to insufficient concrete cover and quality of concrete.

5) Efflorescence

As well as scaling/spalling, efflorescence was a common damage observed in the inspection. This damage shows efflorescing of lime isolated from concrete through cracks with water infiltration. Efflorescence was an important sign of deterioration of concrete, therefore this damage was rated rank II.

Photo (6) shows a sample of this damage on underside of the cantilever slab of Confluencia Bridge.

(6)

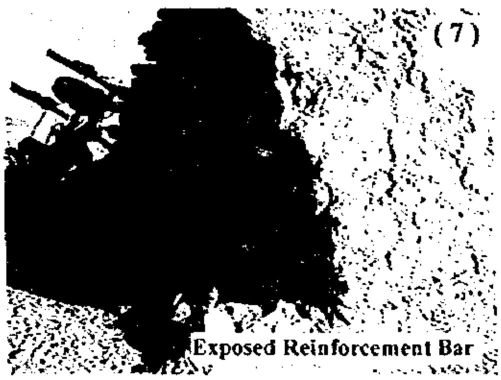


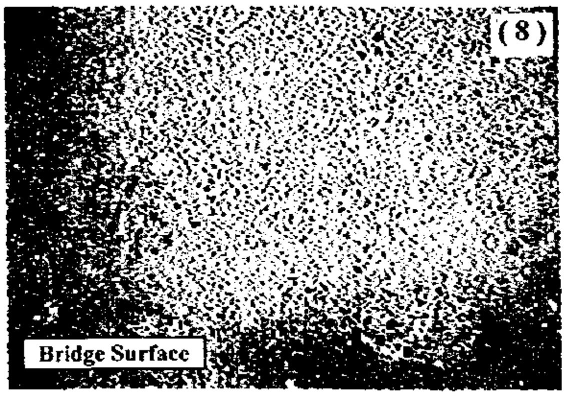
6) Breakage

There was a few breakage damage found in the inspection. A serious example (see Photo (7)) was found on the foot of pier at Granallas Bridge, which was considered hit by running stones during flood. The photograph suggests another cause, the quality of concrete.

7) Wear

Wear damage was seen on pier and abutment foundations caused by water flow, or on top of slab caused by vehicle running because of no pavement surfaced. Photo (8) shows a wear example on slab.





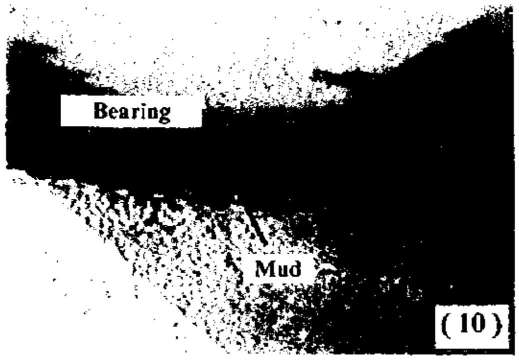
(2) Steel Components

1) Rusting on main beams

Main beams have rust on their web plate, top surface of the top flange and bottom surface of the bottom flange, especially in case that a bridge has timber deck and therefore rain water comes directly and runs along the surface of the beam and mud sticks to it, as seen in the Photo (9) of Granallas Bridge. No serious rust was found in the main beams as to reduce the cross-sectional area.

2) Rusting on bearings

Steel beams usually have steel bearings, and the result of the detailed bridge inspection showed they rusted seriously. Photo (10) indicates the heavily rusted bearing of Granallas Bridge. The cause can be easily guessed that mud falls through road surface opening and mud piles up on bridge seat. The mud keeps wet for a long time after rainfalls because it is usually shaded by deck, and the humid mud causes the steel bearing rusted.

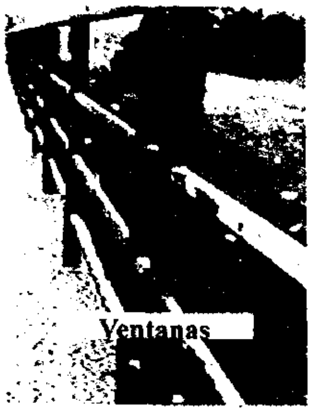


3) Rusting on handrails and expansion joints

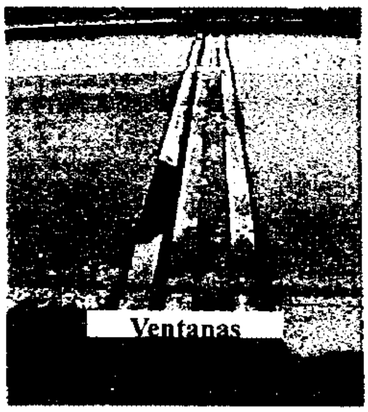
Steel handrails are exposed not only rainwater but also to exhausted gas and the composition of these promotes the steel rusted as seen in Photo (11).

As seen in Photo (12), the wet mud in gap encouraged rusting and reduced stiffness of expansion joint, and finally wheel impact hit the weakened part and broke it.

(11)

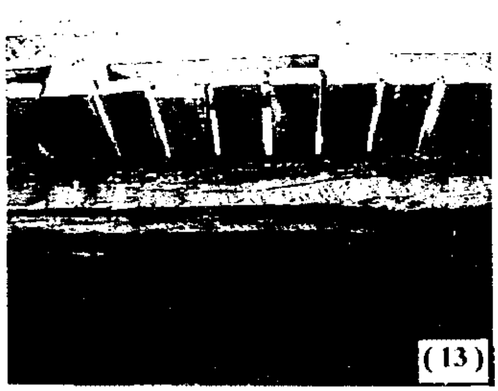


(12)

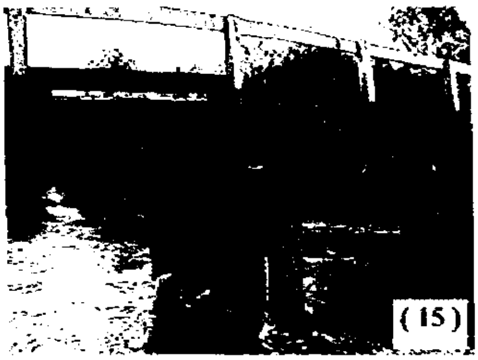


(3) Timber Components

There were few damages caused by fungi or parasites on timber components, therefore most damages were due to moisture and weathering by overage wood. As a few case, decay from fungi was observed on components of Miraflores Bridge (refer to Photo (13)). If proper protection on timber components were treated, propagation of these damages would be able to prevent. Unfortunately, timber components of objective bridges



didn't have such protection so that serious damage, especially for decay, was observed. All kind of damages of timber can be checked in Poculon Bridge of which the traffic was closed due to destruction as shown in Photo (14). It was difficult to find out the timber cracking because justification by whether the cracking was from external forces (live load or earthquake) or artificial device was impossible in this inspection. On the other hand, losses of timber components near the part touching with water were observed in many cases (Photo (15)). It was not kind of timber damage, but Malleco was destructed by fire as shown in Photo (16). Timber pavements were in good condition because of periodical replacement by the MOP.



3.2.3 Study of Rehabilitation Method

(1) Policy for Rehabilitation Method

In course of the general inspection, the MOP and the Study Team discussed on the method of rehabilitation for each bridge. Although the rehabilitation method was discussed in principle based on the observed damages in other words structural safety of bridges, importance was attached also to other geographical environment and socio-economic conditions around the bridge such as change of river flow, aging of bridge structures, insufficient bridge width and load carrying capacity for the today's traffic, and so improving or strengthening of existing bridge was considered difficult and costly.

On deciding the rehabilitation method of whether to be repaired or reconstructed, opinion and request from the MOP were taken as an important element 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 so deteriorated, and their width and load capacity become insufficient against the today's traffic burden. For such old bridges, the reconstruction scheme with new bridge is generally adopted rather than the repairing or strengthening of existing bridge. Because, strengthening work on old and deteriorated bridge is considered technically difficult and unreliable. Considering the life cost of a bridge, the life expectancy of such strengthened bridge is generally short, and so reconstruction scheme becomes economically logical. Therefore, existing timber bridges, for their short durable years and frequent maintenance required, should be replaced with permanent (concrete or steel) structures but never with timber again. Existing concrete or steel bridges should 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 should be given a preference to widening or strengthening.

(2) Selection of Rehabilitation Method

Rehabilitation method was studied for each of the 20 bridges in principle based on the results of the general inspection and considering the policy of the MOP for rehabilitation. However, in order to meet the purpose of this chapter of the Study, more repair examples were prepared to show various rehabilitation designs. It is considered that repair work is an important job for the MOP now and in future to maintain a large number of bridges. Repair work is required to maintain the existing bridge not to interrupt public service until the bridge has been finally rehabilitated.

As above mentioned, the MOP and the Study Team discussed the rehabilitation method of whether to be repaired or reconstructed for each bridge and concluded as indicated in **Table 3.3**.

(3) Process for Decision of Reconstruction Scheme

As mentioned above in the policy for rehabilitation method, the reconstruction scheme should be decided not only based on the structural safety of bridge but also taking account of the function, geographical and socio-economic conditions around the bridge.

An example of such decision process made for No. 2 David Garcia Bridge is shown in **Table 3.4** dividing into technical and social reasons, and those for all the eight bridges decided for reconstruction were attached to **Appendix II-2 (Volume 4/8)**.

Table 3.3 Rehabilitation Method

No.	Bridge Name	Region	Bridge Type	Bridge Length (m)	Road-way Width (m)	Bridge Condition (damage rank)		Proposed Rehabilitation Method
						Super-structure	Sub-structure	
1	Confluencia	IV	ST	113.10	10.00	III	III	Repair
2	David Garcia	V	RC	93.05	6.00	III	II	Reconstruction/Repair
3	Granallas	V	ST	49.85	3.50	II	II	Reconstruction/Repair
4	Ventanas	V	RC	30.00	8.96	III	II	Repair
5	San Jose	RM	RC	16.10	4.00	III	III	Reconstruction
6	Puangue	RM	RC	105.10	6.00	II	III	Reconstruction
7	San Jose de Marchiue	VI	ST	120.00	4.00	III	IV	Reconstruction
8	Antivero No.2	VI	RC	102.90	6.00	II	II	Reconstruction
9	Los Cardos	VI	ST	73.55	2.68	III	III	Repair
10	Cautin	IX	RC	140.00	5.00	III	III	Repair
11	El Indio	IX	ST	21.10	6.20	III	III	Repair
12	Quillen	IX	TM	25.90	2.85	II	III	Repair
13	Poculon	IX	TM	31.00	-	I	I	Reconstruction
14	Malleco	IX	TM	92.00	4.00	-	III	Repair
15	Miraflores	IX	TM	44.40	3.60	II	II	Repair
16	San Juan	IX	TM	31.60	4.00	II	III	Reconstruction
17	Medina	IX	ST	170.00	4.00	III	III	Repair
18	Cautin (88)	IX	ST	39.40	3.85	III	III	Repair
19	Salva Tu Alma	IX	ST	40.70	3,80	III	II	Repair
20	Quinchilca	X	RC	140.00	5.00	III	III	Repair

Notes: RM = Region metropolitan
RC = Reinforced concrete beam bridge
ST = Steel beam bridge
TM = Timber beam bridge
I ~ V = Damage rank of bad to good

In the table:

- As for No. 2 David Garcia and No. 3 Granallas Bridges, both methods of reconstruction and repair were propsoed.
- No. 13 Poculon Bridge had collapsed when it was inspected, therefore no width was measured.
- The superstructure of No. 14 Malleco Bridge was going to be reconstructed, when it was inspected, with timber by the regional MOP utilizing the existing concrete piers and abutments in consequence of destruction by fire. Therefore, only the abutment was inspected and its repair was designed.

Table 3.4 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.	1	Los Andes is the nearest city from the bridge having a population of 55,000.
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.	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 meters is not enough for that traffic volume.
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.		

Conclusion

In addition to the age and deterioration, the foundation is very likely to be unstable due to scouring. And furthermore the roadway is required to be widened. Thus the reconstruction was proposed.

(4) Study of Repairing Scheme

Type and scale of repairs are in general decided by the kind and magnitude of damage. However, level of repairs is intentionally decided upon the purpose and policy of rehabilitation, and that is broadly defined as conservative or constructive scheme. The repairs based on the conservative scheme consist of simple and small works limiting to surface treatment for damages in order to curb further worsening. Safety and service level of the bridge repaired by this scheme can not be justified. On the contrary, the constructive scheme involves comparatively large repairs aiming for restoring original level of safety and service of the bridge, and the appraisal of load carrying capacity is required. From the policy of rehabilitation as explained in Clause (1) of this chapter, repair work assumes merely the role of maintaining the existing bridge with minimum cost, but not of improving.

Through the above discussion, it was concluded between the MOP and the Study Team that the repair design adopt simple and small scale of repair methods based on the conservative scheme. The conclusion was made also from the fact that there was not enough information about the bridge structures to evaluate load carrying capacity, for neither drawings nor subsoil condition were available.

Therefore, sample repair designs would be prepared based on the conservative scheme to remedy only surface of bridge structures, but restoration of load carrying or stability capacity would not be dealt with in the design.

There were various damages observed on surface of the bridges by the general inspection. Typical damages often inspected were categorized in **Table 3.5** by the material types of bridge components namely concrete, steel and timber. Damage inspection and repair design were intended for such typical damages.

Table 3.5 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

3.3 DETAILED INVESTIGATION

3.3.1 Topographic and Soil-Boring Surveys

Based on the agreed rehabilitation method of each bridge, topographic and soil-boring surveys were carried out for eight bridge sites judged to be reconstructed, and then topographic maps for the new bridge designs were prepared. These data obtained through the soil and topographic survey may be taken advantage of by the MOP for their new designs or for change of the reconstruction designs prepared by the Study Team in the future.

The surveys were carried out from July to September of 1997 by a Chilean consultant employed. The scope and specifications for the surveys were outlined below. The area and location to be surveyed are defined in **Figure 3.4**. The results of surveys are summarized in **Table 3.6**.

Table 3.6 Results of Topographic and Soil-Boring Surveys

	Bridge Name	Region	Bridge Length (m)	Topographic Survey Area (ha)	Soil-boring Length (m)	
					Fine soil	Gravel
2	David Garcia	V	93.05	1.41	0.00	9.95
					0.00	10.10
3	Granallas	V	49.85	2.14	0.00	9.85
5	San Jose	RM	16.10	3.00	8.25	3.60
6	Puangue	RM	105.10	1.57	3.46	6.56
					6.20	6.52
7	San Jose de Marchiue	VI	120.00	1.80	3.71	6.59
					1.90	8.30
8	Antivero No.2	VI	102.90	1.96	0.00	10.10
					1.08	8.37
13	Poculon	IX	31.00	1.37	4.48	5.57
16	San Juan	IX	31.60	1.10	14.84	5.97
	Total			14.35	43.92	91.48

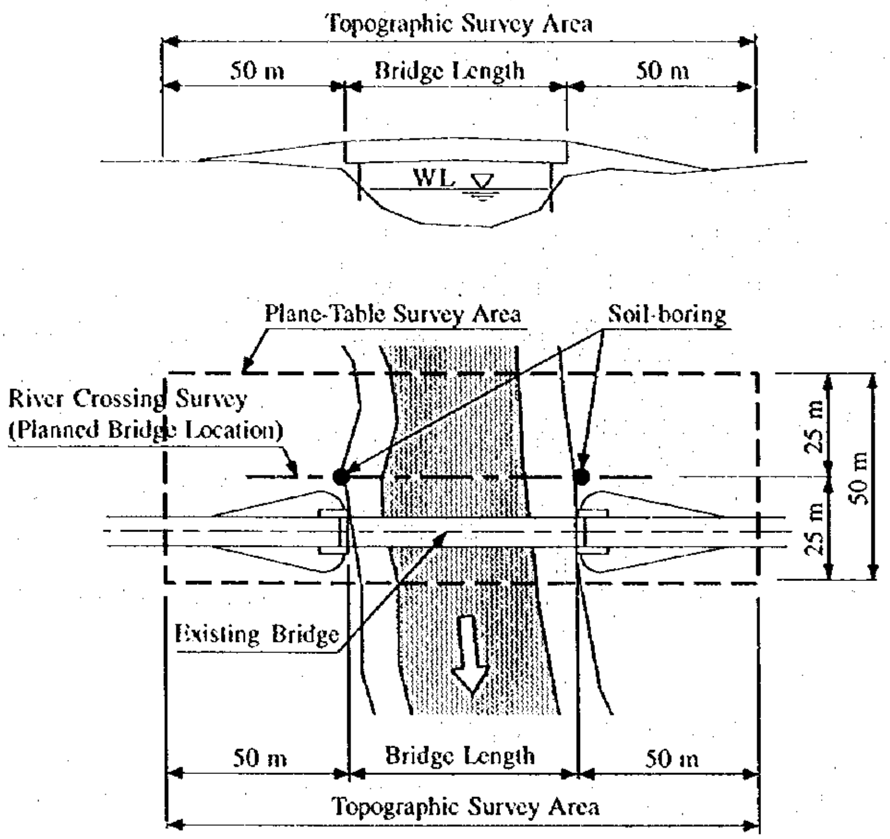


Figure 3.4 Area and Location for Surveys

(1) Scope and Specifications for Topographic Survey

1) Field Works

① Plane-Table Survey

- Survey area is 50 m wide and a length of a river width plus 50 m on each bank.
- Survey shall includes all natural and man-made topographies (including land-use, roadways, channels, ditches, etc.) and structural objects (buildings, houses bridges, fences, electric poles, etc.)

② River Crossing Survey

- River bed elevations, water level and flow velocity.

2) Survey Results

① Plane-Table Survey

- Topographic Maps (s = 1/200, contour lines at each 1 m height, and spot elevations).
- Data Floppy Disks (Auto-CAD).

② River Crossing Survey

- Profile Drawings (vertical s = 1/200, horizontal s = 1/200).
- Data Floppy Disks (Auto-CAD).

(2) Scope and Specifications of Soil-Boring Survey

1) Field Works

① Boring

- Boring shall be continued;

in case of granular (sandy) soil:	until 3 m after confirming SPT value over 40,
in case of cohesive (clayey) soil:	until 6 m after confirming SPT value over 20 or 3 m after SPT over 30, whichever reaching earlier, and then stopped.

- Check ground water level in bore hole.

② Sampling and Soil Classification (each layer).

③ Standard Penetration Test (SPT) (every 1 m).

2) Laboratory Tests

- Gravity, unit weight, and sieve (two specimens in each layer).

3.3.2 Damage Inspection

For the 12 bridges judged to be repaired, damage inspection using non-destructive test instrument, was performed in order to collect more in detail damage information for repair designs.

(1) Damages to be Inspected

Damage inspection was performed for the typical damages selected in **Table 3.5**. Characteristics and causes of these damages are explained in **Division III of Bridge Manuals (Volume 6/8).**

(2) Method of Inspection

The method of damage inspection is summarized in **Table 3.7** classifying into concrete, steel and timber members.

(3) Inspection Tools and Equipment

1) Standard tools

The following tools were used for damage inspection:

- Measuring : Convex, Tape (50 m), Calipers, Crack Gauge
- Visual Aid : Magnifying Glass, Binoculars
- Vertical Alignment : Plumb Bob
- Sounding : Hammer
- Cleaning Tools : Wire Brush, Scrapers

2) Nondestructive test equipment

Nondestructive test (NDT) is the in-place examination of a material for structural integrity without damaging the material. NDT equipment can detect inside of bridge element and assess deficiencies that may not be visible with naked eye. Generally, a trained technician is necessary to conduct NDT and interpret their results.

In the damage inspection, the following NDTs were performed for where the situation permitted.

Table 3.8 Nondestructive Tests

Material Type	Test Equipment	Objectives of Test
Concrete	Schmidt Hammer (NR-4 for normal concrete)	Strength of concrete
	Paco-Meter 3D Type Mini-Search 2 Model	Location and diameter of reinforcing bars
	Phenolphthalein Liquid	Neutralization of concrete
Steel	Ultrasonic Thickness Meter	Thickness of steel plate
	Dye Penetrant	Detecting cracks

Table 3.7 Method of Damage Inspection

Material Type	Damage	Objectives of Inspection	Inspection Items	Inspection Method	Inspection Tool
Concrete	Cracking	By observing cracks, stress or loading condition of the member can be inferred.	• Location • Direction • Width • Density	• Visual inspection and measuring	• Convex • Crack scale • Magnifying glass
	Scaling/ Spalling	Corrosion of reinforcing bars can be detected by the inspection of scaling/spalling.	• Location • Size • Depth	• Visual inspection, measuring and sounding	• Convex • Hammer • Wire brush
	Delamination	This damage also gives implication of corrosion of reinforcing bars as well as intrusion of cholorides.	• Location • Size • Depth • Exposed reinforcing bars	• Visual inspection, measuring and sounding	• Convex • Hammer • Wire brush
	Efflorescence	This damage gives implication of salt contamination in concrete.	• Location • Size • Length • Crystallization	• Visual inspection and measuring	• Convex • Wire brush
	Honeycombs	This damage implies improper compaction of concrete during construction.	• Location • Size	• Visual inspection and measuring	• Convex • Wire brush
	Wear	This damage gives an information of the environmental severity surrounding the bridge such as water flow and traffic volume.	• Location • Appearance • Aggregate condition	• Visual inspection	• Convex • Wire brush
	Breakage	This damage gives an information of collision of vehicles or other external force strike.	• Location • Kind of components	• Visual inspection	• Tape • Convex
Steel	Aging Coat	By observing coating film, state of aging and soundness, necessity of repainting can be judged.	• Location • Area • Degree of aging	• Visual observation of each inspection item	• Steel measure tape • Hammer
	Rusting	Depth and area give an information on the degree of cross-section reduction.	• Location • Area • Degree of rusting	• To clean, observing the surface and measure thickness	• Hammer • Wire brush • Ultrasonic thickness meter
	Loosening	By observation of whole structure visually, possibility for falling off of structural components can be found.	• Location • Kind of components • Number	• Visual inspection and sounding with hammering	• Wire brush • Hammer

Steel	Falling off	By visual inspection, missing components will be confirmed.	• Location • Kind of components • Number	• Visual inspection	
	Deformation	By visual inspection and measuring, unusual forces having worked can be detected.	• Location • Kind of components • Number	• Visual inspection and measuring	• Convex
	Cracking	Cracking gives an information of unusual forces having worked on the components, such as fatigue and overload.	• Location • Kind of components • Number	• Visual inspection and measuring	• Hammer • Wire brush • Dye penetrant
Timber	Decay	Stain of decay implies bidden deterioration of wood due to living fungi.	• Location • Area • Depth • Water level	• Visual inspection and measuring	• Convex • Hammer
	Split/Check	These damages give implication of collision or overloading.	• Location • Kind of components • Size	• Visual inspection and measuring	• Convex • Hammer
	Deflection/ Sagging	This damage implies overloading or weakness of structure	• Location • Kind of components • Sagging depth	• Visual inspection and measuring	• Convex
	Loosening	This phenomena shows deterioration of rigidness of connections of members.	• Location • Kind of components	• Visual inspection and sounding	• Hammer

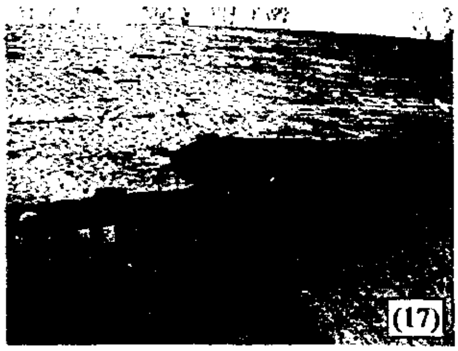
(4) Results of Damage Inspection

1) Phenolphthalein Liquid Test

By phenolphthalein liquid test, the deterioration of cover concrete was revealed at most of the bridges tested. The tests resulted in the alkalinity pH of about 9.0 in average, from which it was concluded that the concretes were carbonated. The test could be done mainly for abutments and piers, but could not for beams because they were located too high for access except of Cautin Bridge. Carbonation would accelerate rusting of reinforcing bars.

The carbonation of concrete, on the surface, results in loss of alkaline protection of the cover over the reinforcing bars against corrosion. Carbondioxide of atmosphere reacts with hydrated cement compounds causing reduction in pH and alkalinity (i.e. increase in acidity) in concrete. The depth of carbonation is measured by applying on the freshly broken surface of concrete a one per cent solution of phenolphthalein. The concrete undergoes a color change to purple red (red violet) when pH value is > 9.5. The color of the concrete surface after the spray may be compared with the classified standard test results to indicate the areas of serious carbonation. Where carbonation has taken place and acidity has been brought about, the pH reduces to below 9, concrete undergoes no color change.

An example of the test result at Cautin Bridge is shown on Photograph (17), and all of the test results are given in **Appendix II-3 (Volume 4/8)**.


(17)

2) Schmidt Hammer Test

Schmidt hammer was used to measure hardness at concrete surface, which could be related to its strength. This test could be carried out at piers and abutments but could not for beams except at Cautin and Ventanas Bridges for they were located at high position. Average strength of 270 kg/cm^2 (converted to compressive strength of cylindrical specimen) for piers/abutments and 300 kg/cm^2 for beams were measured. **Table 3.9** shows the test results.

The measured strength showed higher than the expectation despite the deterioration of concretes. It is noted that large error seems certain to occur in this kind of test for mechanics of equipment and depending on testing condition.

Table 3.9 Concrete Strength by Schmidt Hammer Test

(kg/cm^2)

No.	Bridge Name	Piers/Abutments	Beams
2	David Garcia	288	
3	Granallas	195	
4	Ventanas	388	317
10	Cautin	237	295
11	El Indio	264	
14	Malleco	237	
17	Medina	215	
18	Cautin (88)	298	
19	Salva Tu Alma	315	
20	Quinchilca	228	
	Average	267	306

3) Detection of Reinforcement by Pachometer

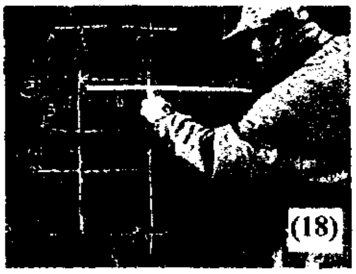
Position, volume and diameter of reinforcement (steel bars) inside of concrete were searched by Pachometer. However, accurate results except arrangement of bar could not be obtained because surface of concrete was rough and concrete cover was too deep to check by Pachometer. Pachometer has a limit for depth of concrete cover that is 60 mm, therefore it was estimated that almost all cover depth tested would be over 60 mm. On the other hand, although inspected cases were few to the main beam, appropriate results could be obtained from Cautin Bridge. Spacing of reinforcement was 25 cm to 30 cm to the vertical and horizontal direction for the abutment wall. Detection results are given in **Table 3.10**.

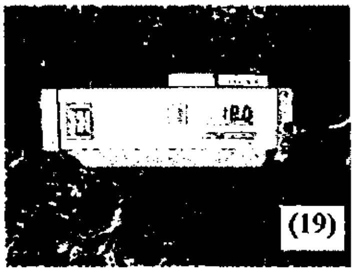
Table 3.10 Detection of Reinforcement by Pachometer

No.	Bridge Name	Location	Diameter (mm)	Spacing Horizontal x Vertical (mm)
2	David Garcia	Pier	23	200 x 200
3	Granallas	Pier	-	200 x 150
10	Cautin	Beam Abutment	41 -	100 x – 400 x 150
11	El Indio	Abutment	41	200 x 200
17	Medina	Abutment	32	250 x 200
18	Cautin (88)	Abutment	18	400 x 260

The scence of detection and the Pachometer used are shown on the following Photographs (18) and (19) respectively.

Cautin (88)


(18)


(19)

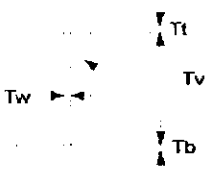
4) Ultrasonic Thickness Meter Test for Steel

The main purpose of investigating thickness of plates composing primary members is to know the current thickness, and then to estimate the load carrying capacity of the bridge by structural analysis using the current section obtained from the data measured at site. It would be preferable, if the current and design load capacities could be compared each other, but unfortunately the design data could not be found. Out of eight steel bridges, five bridges were examined, but for the other bridges the test was impossible because they are located too high to approach, or steel girders were submerged at the time of the test. The result on Medina Bridge is shown below as an example. Thickness of a top and bottom flange, web and vertical stiffener were measured, where five points of each component were examined and averaged.

Table 3.11 Result of Plate Thickness by Ultrasonic Meter

(Unit: mm)

No. of Test	Top Flange (Tt)	Bottom Flange (Tb)	Web (Tw)	Vertical Stiffener (Tv)
1	16.40	32.20	12.90	9.60
2	16.45	32.25	13.20	9.70
3	16.55	32.10	13.00	9.75
4	16.35	32.15	12.45	9.85
5	16.40	31.80	12.55	9.80
Average	16.43	32.10	13.91	9.74



5) Penetrating Dye Test for Steel

It is probably the most commonly used method of inspection for detecting defects and deterioration. It is generally limited to defects that are exposed on the surface of the component, yet it is inexpensive, easily applied, and easily interpreted. The part to be examined is first cleaned with a wire brush and then with chemicals, and a fluid is then placed on the surface and allowed to penetrate cracks and surface defects. After a short period of time, the penetrate is wiped off and a second solution (called a developer) is sprayed on. The developer usually dries to a chalky powder and remains unchanged in the regions where no defects exist. In the region of a crack, the penetrant seeps from the crack and stains the developer. By the test, defects on surface can be detected but depth of defects can not. This test was applied along filet weld between a bottom flange and a web plate of Granallas Bridge. No serious defect was detected there and Photograph (20) is shown below. Concerning the other steel bridges, penetrating test was not carried out for the reason why it was too dangerous to perform it.