CHAPTER III ABSTRACT OF THE STUDY

CHAPTER III

ABSTRACT OF THE STUDY

III-1 Selection of 100 Federal Bridges for Visual Inspection

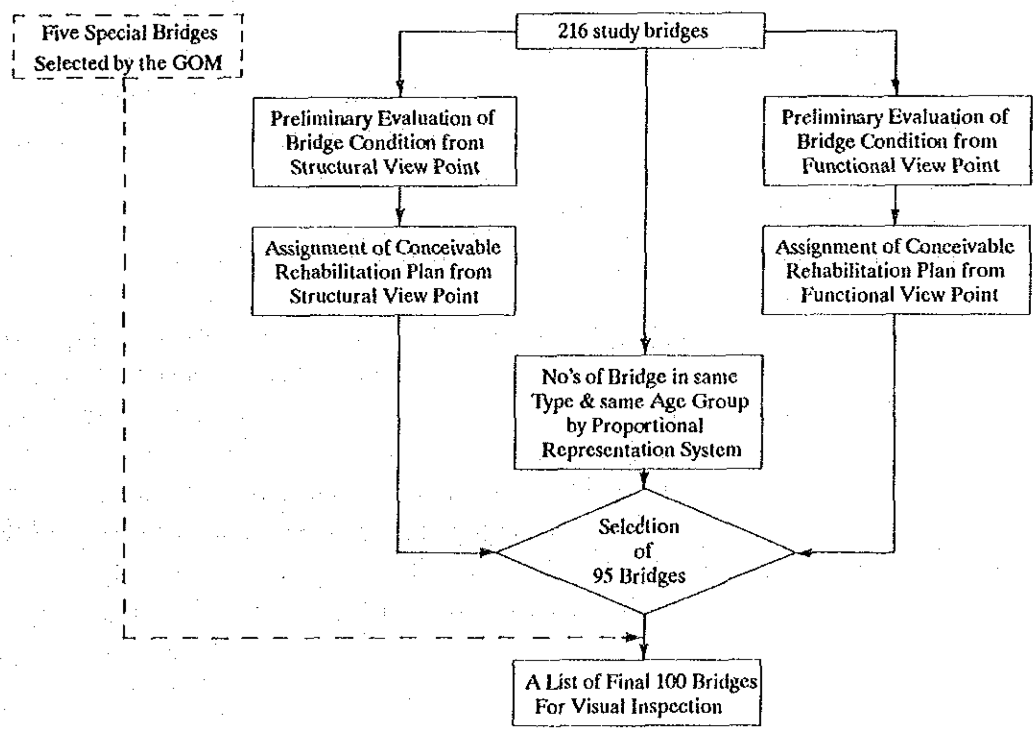
The study bridges, with the main aim of formulating a maintenance and rehabilitation program, are defined as all the bridges located along the federal roads on the Peninsular with condition rating 3, 4 or study category of SSAL in NALS. These study bridges were confirmed jointly with JKR counterparts and amounted to 216 bridges. With respect to the enormous number of study bridges, the specific number of bridges at various stages was set up in the Scope of Works (S/W) as a maximum of 100 numbers for visual inspection. The visual inspection results on these selected bridges were used to establish the selection criteria for 20 bridges, out of those 100, for further detailed inspection and to reflect in formulating the maintenance and rehabilitation program of the discarded bridges.

III-1-1 Selection Procedure of 100 Bridges

During the course of the Study, GOM requested to incorporate 5 special bridges into the 100 bridges hence leaving only 95 bridges to be selected for the visual inspection.

The selection procedure for 95 bridges from 216 bridges is charted in Figure III-1.

Figure III-1 Selection Procedure for 95 Bridges



III-1-2 Preliminary Evaluation of the Bridges

Preliminary evaluation of each of the 216 bridges was carried out from structural and functional viewpoints.

The preliminary evaluation from a structural viewpoint was conducted to identify the type and degree of damage, deficiency or distress in each structural member of every bridge based on data obtained from the computerized bridge inventory and the visual inspection sheets prepared in NALS.

All the bridges were also evaluated from three bridge functional viewpoints consisting of traffic capacity, pedestrian flow capacity and bridge opening capacity. Traffic capacity on bridge was evaluated by means of comparison between the calculated total service flow rate in both directions on the bridge and the present total traffic volume at traffic count stations near the bridge. The objective of this evaluation is to determine whether the traffic capacity on the bridge is adequate in catering for the present traffic demand. Pedestrian flow capacity on each bridge was also evaluated based on whether a bridge without sidewalks is located in an urban area or not or its proximity with public facilities such as schools, hospitals, mosques and other landmarks to the bridge. The bridge opening capacity, whether it can accommodate flood runoff discharge, was also evaluated based on the NALS data and flood information collected from each Drainage & Irrigation Department (DID) District office.

III-1-3 Assignment of A Conceivable Rehabilitation Plan

Based on the results of the preliminary evaluation from a structural viewpoint, conceivable rehabilitation plans for each defective member in every bridge were assigned based on certain criteria ruling each conceivable rehabilitation plan with its corresponding type of damage for each member.

Bridges which have inadequate traffic capacity, pedestrian flow capacity or bridge opening capacity were assigned conceivable rehabilitation plans, such as widening of the carriageway, adding sidewalks or raising bridge grade.

III-1-4 Selection Results of 100 Bridges

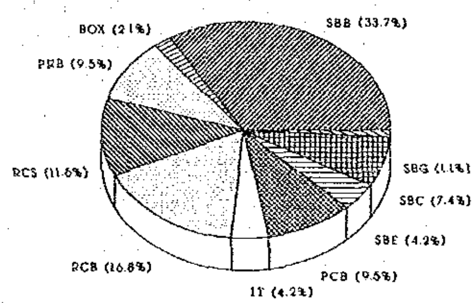
It is important to select representative 95 bridges which will cover all types of defects and conceivable rehabilitation plans taking into account the further feedback work. To assist in the selection of these bridges, the 216 bridges were then classified into the same bridge type and bridge age group, and the percentage of bridges in terms of each bridge type and age group was calculated against 216 bridges. A figure which indicates the number of bridges to be selected from the same bridge type and age group was worked out by multiplying the percentage of each type and age group by 95.

A representative bridge within the same bridge type and age group which has a large number of major conceivable rehabilitation plans is firstly selected. The next representative bridge which has also a large number of conceivable rehabilitation plans which are not covered in the earlier selected bridge is selected subsequently. The selection, with this criteria, is carried out until the number of the bridges selected has reached proportionate number of bridges for each bridge type and age group.

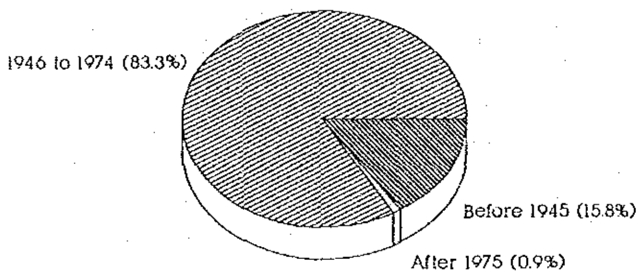
Through the above exercise, 95 bridges were selected and the bridge statistics in terms of bridge type and age group was charted in Figure III-2.

Figure III-2 Statistics of 95 Bridges Selected

Percentage of 95 Selected Bridges
by Type of Construction



Percentage of 95 Selected Bridge
by Age Group



Finally, 95 bridges selected through the above selection exercise together with 5 special bridges selected by GOM formed the final 100 bridges for visual inspection.

III-2 Visual Inspection and Findings

Visual inspection was carried out in the Study on 2 groups of bridges, the first group is 100 bridges on the federal roads in Peninsular Malaysia, and the second group is 70 bridges selected by GOM which is made up of 30 federal bridges in Sabah and Sarawak, and 40 state bridges in the three States of Perak, Selangor and Negeri Sembilan. The purposes of inspecting the second group of bridges were to demonstrate field inspection techniques, to introduce inspection recording methods, to recommend the required maintenance and rehabilitation works into the States and Districts JKR, and to reflect those inspection results into a Bridge Inspection, Maintenance and Rehabilitation Manual.

The procedure and findings of inspecting the first group are summarized herein. While inspection results of the second group are described in three (3) separate booklets titled as "Visual Inspection Report", one each for the States of Sabah and Sarawak and one report covering the three States in Peninsular (Perak, Selangor and Negeri Sembilan). These visual inspection reports were submitted to GOM in December 1990.

III-2-1 Visual Inspection Procedures

Visual inspection carried out at each bridge site involved field measurement, field interview, damage condition rating, photographing and assessment of possible rehabilitation plans.

Field measurement was carried out mainly to detect defects such as tilted substructure, local scouring, settlement, abnormal deflection, etc. While field interviews with local residents at the vicinity of bridge site were carried out for the purpose of confirming data related to flood and availability of detour roads. Damage condition rating was also carried out to quantify the damage or defect of various bridge members. The damage rating check list and rating criteria were adopted from the one originally developed by the Ministry of Construction, Japan after some modification to cater for the Malaysian local conditions.

Every defect or deficiency detected and general view of the bridge were photographed for the purpose of providing visual records. Assessment of maintenance and rehabilitation work at each bridge site was then carried out for the purpose of meeting the principal objective of the study based on the type and degree of damage observed and taking into account the possible cause of damage.

III-2-2 Bridge Rating

Damages in various members which were ticked on the bridge condition checklist at each bridges site were then rated referring to the damage rating criteria. From these rating results, member ratings were graded and finally the overall bridge rating was calculated based on the weighted average method similar to the one used in JKR-BMS, in order to express the existing bridge condition by a simple figurative indicator.

The indicator was graded into five ranks and the general criteria were defined below:

Rating	General Definition
1	No damage found and no maintenance required as a result of the inspection.
2	Damage detected and it is necessary to record the condition for observation purposes.
3	Damage detected is slightly critical and thus it is necessary to implement routine maintenance work.
4	Damage detected is critical and thus it is necessary to implement repair work or to carry out a detailed inspection to determine whether any rehabilitation works are required.
5	Being heavily and critically damaged and possibly affecting the safety of traffic, it is necessary to implement emergency temporary repair work immediately or rehabilitation work without delay after the provision of a load limitation traffic sign.

III-2-3 Findings of the Visual Inspection Results

Among the five special bridges requested by GOM, Yahya Petra bridge which has suffered inexplicable cracks requires to be diagnosed in the detailed survey, but the other four bridges are expected to function adequately for their life span provided some routine maintenance works. The findings of the visual inspection for 95 federal bridges are as follows:

(1) General Condition of the Bridges

The general condition by each main structure and by each bridge type is as depicted in Figure III-3 and Figure III-4 respectively.

Figure III-3 Average Rating by Each Main Structure

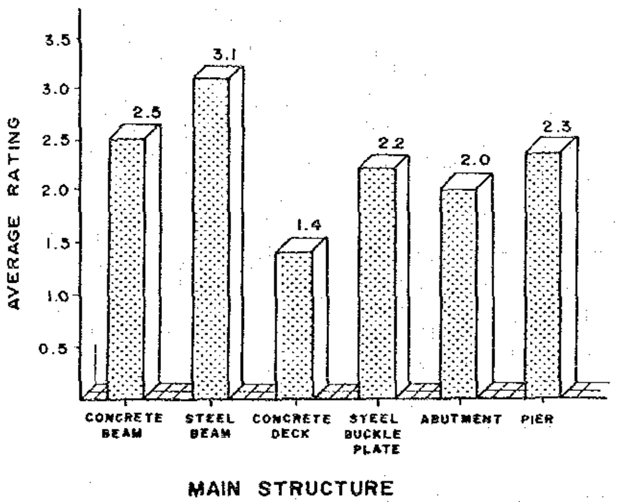
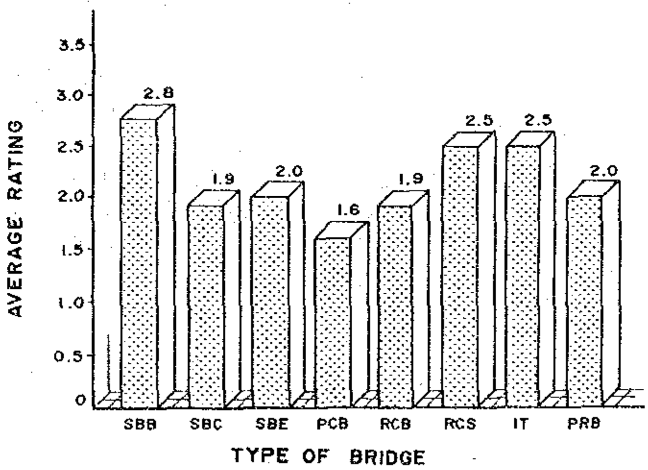


Figure III-4 Average Overall Rating by Each Bridge Type



The condition of steel and concrete beams have relatively deteriorated at an advanced stage compared to others, especially, for steel beams. Among the deck structures, the concrete deck slab is in better condition than steel buckle plate, in fact the concrete deck slab is the most sound member among the others. As for substructure, piers have deteriorated more than abutments. Visual inspection also revealed that Steel Beam Buckle Plate (SBB) is the most deteriorated bridge among the bridge types, while Prestressed Concrete Beam (PCB) bridges are generally in good condition.

(2) Assessment of Visual Inspection Results

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

The rating results of each bridge member were further analyzed using the specific damage ratio(1) and average rating of specific damage(2).

A summary of the assessment of visual inspection results from a structural viewpoint is tabulated in Table III-1.

Table III-1 Summary of the Assessment of Visual Inspection Results

Main Bridge Member	Dominant Damage Detected	Cause of Damage	Possible Rehabilitation Plan
Steel Beam or Steel Girder	. Corrosion...........(3.7)	. Poor maintenance . Water leak – no drip check – Inadequate length of drainage pipe	. Repainting . Reinforcement by adding steel plate . Partial replacement
Concrete Beam	. Crack..................(3.0) . Flaking/Rebar Exposure...........(2.8)	. Inadequate cover . Poor workmenship	. Injection . Patching . Reinforcement for severe cases
Steel Buckle Plate Slab	. Corrosion...........(3.2)	. Water leak . Poor maintenance	. Repainting . Provision of weep holes . Replacement of slab
RC Deck Slab	. Flaking/Rebar Exposure...........(2.7)	. Inadequate cover . Poor workmenship	. Injection . Patching . Bonding steel plate . Guniting with rebar
Abutment	. Crack..................(2.9) . Wear abrasion....(2.5)	. Chloride attack . Inadequate cover . Poor quality of concrete . Some chemical or acid attack	. Injection . Patching . Coating . Lining . Surface lining with additional rebar
Pier	. Crack..................(3.4) . Wear...................(2.8)	Same as abutment but more severe due to its being located at more severe environment	

Note : Figure in ( ) shows average rating

(3) Preparation of Standard Possible Rehabilitation Plans

Standard possible rehabilitation plans for each defective bridge member from structural viewpoints were prepared based on the assessment of the visual inspection results and reference was also made to rehabilitation works performed in Malaysia as well as in Japan. A summary of the standard rehabilitation plans which were divided into two categories: structural rehabilitation and functional rehabilitation plans are tabulated in Table III-2.

These rehabilitation plans were used in selecting the representative 20 bridges out of 100 bridges inspected and also used as a reference in the preliminary design.

---

(1) Specific damage ratio is defined as a percentage of the total number of bridges with a specific damage divided by the total number of the bridges with the specific structural member.

(2) Average rating of specific damage is defined as summation of the damage rating of a specific structural member of the bridges divided by the total number of bridges with the specific structural damage.

Table III-2 List of Standard Possible Rehabilitation Methods

Possible Rehabilitation Method from Structural View Point

Main Bridge Member	Conceivable Rehabilitation Plan	Possible Rehabilitation Method
Steel Beam	Protection/Restoration	. Repainting, Reshaping
	Reinforcement	. Welding additional steel plate, Adding additional beam
	Replacement	. Partial Replacement, Total Replacement
Steel Buckle Plate	Protection/Restoration	. Repainting, Minor repair (Providing Weephole)
	Reinforcement	. Adding stringer, Lining by concrete
	Replacement	. Total replacement
Concrete Beam	Protection/Restoration	. Injection, Patching, Coating, Shooting
	Reinforcement	. Bonding steel plate, Lining, Jacketing, Prestressing
	Replacement	. Partial replacement, Total replacement
Concrete Deck Slab	Protection/Restoration	. Injection, Patching, Coating, Shooting
	Reinforcement	. Bonding steel plate, Shooting w/rebar, Adding stringer
	Replacement	. Partial replacement, Total replacement
Bearing	Protection/Restoration	. Repainting, Resetting
	Replacement	. Total Replacement by Rubber bearing or Steel bearing
Concrete Abutment (body)	Protection	. Injection, Patching, Coating, Shooting
	Reinforcement	. Surface Lining . Steel sheet piling
(Foundation)	Protection	. Revertment, Foot Protection
	Reinforcement	. Underpinning
Pier	Protection	. Injection, Patching, Coating, Shooting
	Reinforcement	. Surface Lining, Total Lining, Prestressing
(Foundation)	Protection	. Scouring Protection, River bed Protection
	Reinforcement	. Underpinning
Steel Pier (body)	Protection	. Partial Lining, Repainting
	Reinforcement	. Surface Lining, Total Lining

Possible Rehabilitation Method from Functional View Point

Conceivable Rehabilitation Plan	Possible Rehabilitation Method
Widening of carriageway	. Cantilever support attached to substructure . Extension of both super and substructures
Adding sidewalks	. Cantilever support attached to substructure . Construction of an independent bridge
Raising of grade	. Raising of bridge grade . Extension of bridge length

III-3 Selection of Bridges for Detailed Survey

This Study involves two kinds of bridge selection; one is to select 20 representative bridges from the 95 federal bridges for detailed survey, and the other is to select 5 bridges or spans out of those 20 bridges for full scale loading test.

III-3-1 Selection of 20 Bridges for Detailed Survey

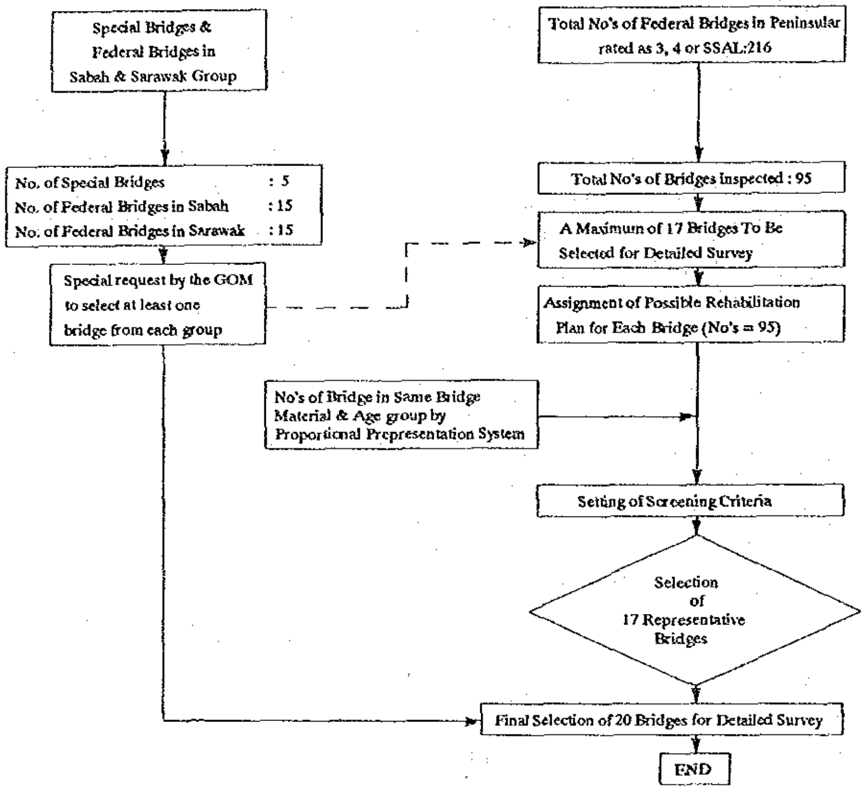
(1) Selection Procedure for 20 Bridges for Detailed Survey

Out of five special bridges requested by GOM, it was found that Yahya Petra bridge was in need to carry out the detailed survey. One bridge each in Sabah and Sarawak, from a total of 30 bridges inspected, was requested to conduct the detailed survey by GOM.

Consequently, 20 bridges, originally planned to be selected for the detailed survey from a total of 95 bridges, was reduced to 17 bridges after subtracting the above three bridges.

The selection procedure of totaling 20 bridges including the above three bridges for the detailed survey is charted in Figure III-5.

Figure III-5 Selection Procedures for 20 Bridges for Detailed Survey



(2) Assignment Criteria and Assignment of A Possible Rehabilitation Plan

In selecting 17 bridges which should cover all of representative bridge types and rehabilitation plans, it is necessary to assign possible rehabilitation plans to each of the 95 bridges based on a certain criteria derived from the visual inspection results. For this purpose, referring to the standard possible rehabilitation plans as well as the condition rating results carried out in the visual inspection, a criteria ruling relationship between a possible rehabilitation plan and the corresponding damage type, degree and extent of each bridge member was established for each concrete and steel member.

Referring to the above criteria, possible rehabilitation plans were assigned to each bridge based on the damages detected and the condition rating results.

(3) Selection Results of 20 Bridges for Detailed Survey

A maintenance and rehabilitation plan is closely related with bridge construction material, bridge type and year built. Thus, the 95 bridges were classified into the same bridge construction material and the same bridge age group.

Percentage of bridges in terms of each construction material and age group was calculated against the total number of 95 bridges and then a figure indicating the number of bridges to be selected from the same bridge construction material and age group was worked out by multiplying the percentage of each material and age group by 17.

Taking into account the above principle, a representative bridge within the same bridge material and age group which has a large number of major possible rehabilitation plans is firstly selected. The next representative bridge of which possible rehabilitation plans are not covered in the earlier selected bridge is subsequently selected. The selection with this criteria is carried out until the number of the bridges selected has been reached proportionate number of bridges for each construction material and age group.

Through the above exercise, 17 representative bridges selected and 3 special bridges formed the 20 bridges for the detailed survey as listed in Table III-3 and which locations are shown in Figure III-6.

III-3-2 Selection Results of Bridges for Loading Test

In order to select a maximum of 5 bridges from the 20 bridges selected for detailed survey, each of those was evaluated from the following viewpoints.

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

Based on the evaluation results, the following bridges were finally selected for the loading test and their locations are shown in Figure III-6.

KEY	STATE	DISTRICT	BRIDGE TYPE
00237200	PAHANG	KUANTAN	SBC & RCB
00319110	PAHANG	ROMPIN	PCB & PCB
00834850	KELANTAN	KUALA KRAI	RCS

Table III-3 List of the 20 Bridges Selected for Detailed Survey

NO.	KEY	STATE	DISTRICT	YEAR BUILT	STUDY CATE-GORY	CAPA-CITY	MAX. SPAN (M)	NO. OF SPAN	BRIDGE LENGTH (M)	TYPE OF BRIDGE
1	00114920	JOHOR	SEGAMAT	1955	3	STAL	6.43	2	12.86	Reinforced Concrete Beam
2	00161140	PERAK	KINTA	1950	3	STAL	9.77	2	19.11	Steel Beam Buckle Plate
3	00166510	PERAK	LRT MATANG	1935	3	STAL	10.72	1	10.72	Steel Box Girder +Reinforced Concrete Beam
4	00237200	PAHANG	KUANTAN	1960	3	STAL	8.90	3	26.70	Steel Beam R.C.Slab +Reinforced Concrete Beam
5	00317000	PAHANG	ROMPIN	1974	3	MTAL	45.78	9	397.32	Prestressed Concrete Beam
6	00319110	PAHANG	ROMPIN	1962	3	SSAL	30.46	7	121.96	Prestressed Concrete Beam
7	00341800	TRENGGANU	KEMAMAN	1955	3	STAL	12.10	3	36.14	Reinforced Concrete Beam
8	00346740	TRENGGANU	DUNGUN	1973	3	STAL	30.50	9	152.26	Prestressed Concrete Beam
9	00520850	MELAKA	JASIN	1950	3	STAL	4.27	1	4.27	Encased Steel Beam
10	00546560	SELANGOR	K.SELANGOR	1939	3	P/A	6.30	1	6.30	Reinforced Concrete Beam
11	00546980	SELANGOR	K.SELANGOR	1969	3	STAL	10.64	3	30.94	Reinforced Concrete Slab (Hollow)
12	00563880	PERAK	MANJUNG	1972	3	STAL	14.07	3	41.59	Pretensioned Inverted Tee Beam
13	00567840	PERAK	KINTA	1960	3	STAL	6.06	2	12.12	Precast Reinforced Concrete Beam
14	00834850	KELANTAN	KUALA KRAI	1960	3	STAL	4.63	3	13.71	Reinforced Concrete Slab
15	05001070	JOHOR	BATU PAHAT	1919	2	SSAL	4.77	1	4.77	Steel Beam Buckle Plate
16	05803340	PERAK	BTG PADANG	1950	3	STAL	4.97	1	4.97	Steel Beam Buckle Plate
17	05903120	PERAK	BTG PADANG	1950	3	STAL	10.88	3	23.18	Steel Beam R.C.Slab

17 Bridges

<< SPECIAL Bridges >>

NO.	KEY	STATE	DISTRICT	YEAR BUILT	STUDY CATE-GORY	CAPA-CITY	MAX. SPAN (M)	NO. OF SPAN	BRIDGE LENGTH (M)	TYPE OF BRIDGE
1	–	SABAH	PENAMPANG	1964	–	–	25.70	3	50.10	Steel Beam R.C.Slab
2	–	SARAWAK	SAMARAHAN	1965	–	–	19.80	5	71.60	Steel Beam R.C.Slab
3	00371000	KELANTAN	KOTA BHARU	1962	–	–	30.00	29	840.00	Reinforced Concrete Beam

3 Bridges

Grand Total 20 Bridges

In addition to the above, the Study Team is requested to investigate reason of the defects and countermeasure if required for the following bridges.

NO.	KEY	STATE	DISTRICT	YEAR BUILT	STUDY CATE-GORY	CAPA-CITY	MAX. SPAN (M)	NO. OF SPAN	BRIDGE LENGTH (M)	TYPE OF BRIDGE	DETECTED DEFECTS
1	00512960	JOHOR		1965	3	STAL	11.30	3	30.22	RCB	Crack on Abutment
2	00701810	KEDAH		1970	3	STAL	30.52	3	48.60	PCB	Deteriorated Rubber Bearing

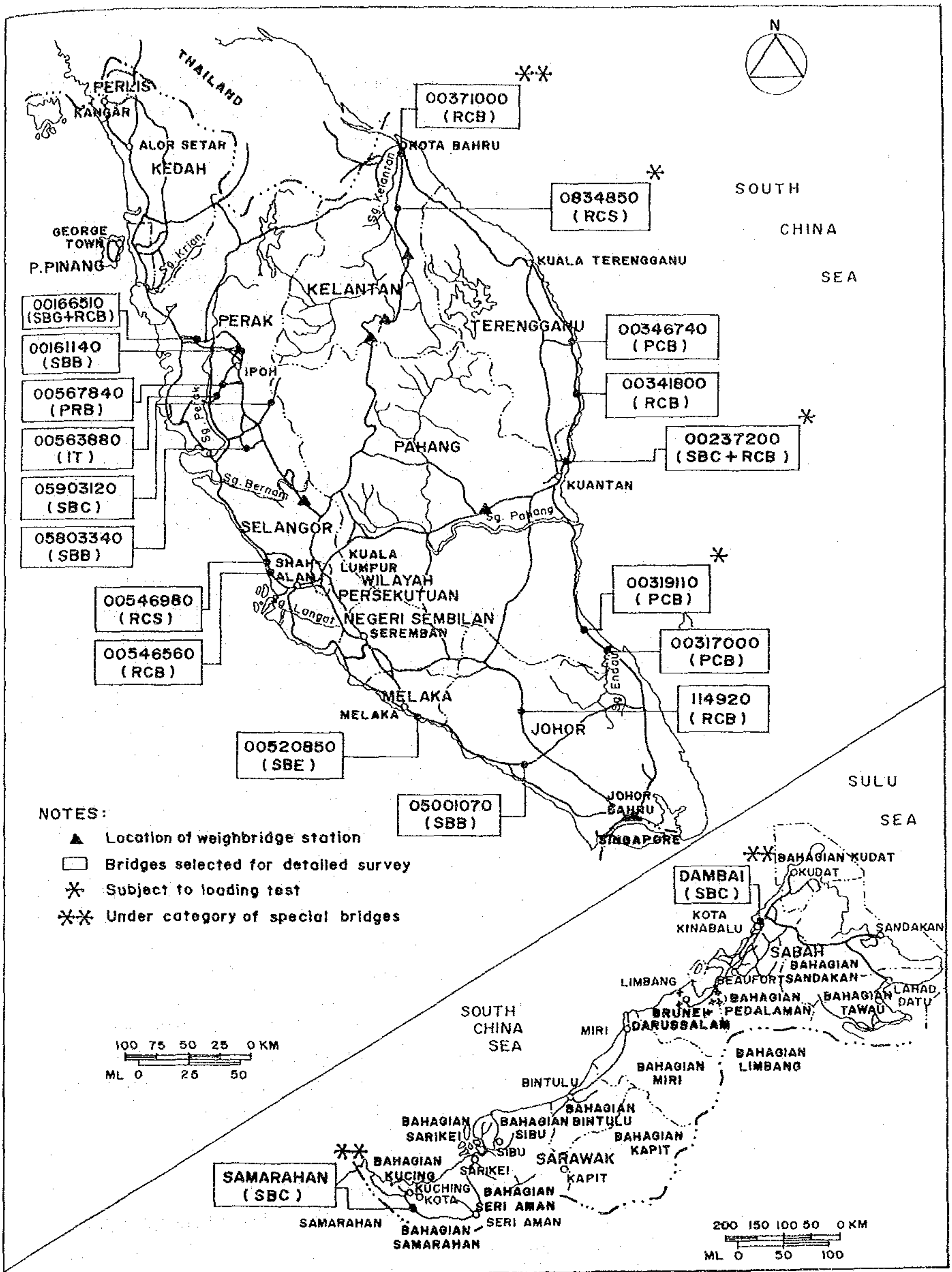


Figure III-6 Location Map of the 20 Bridges Selected

The above selection results showed that loading tests would be conducted at the 3 bridge sites for the 5 bridges consisting of 1-steel beam with R.C. slab, 1-reinforced concrete beam, 2-prestressed concrete beam and 1-reinforced concrete slab.

III-4 Detailed Field Survey

The detailed field survey covering 20 representative bridges carried out in the Study includes topographic survey, subsoil and water investigation, river hydrological survey, detailed structural survey, and full scale bridge loading test.

III-4-1 Topographic Survey

Although an enormous volume of data had been gathered, topographic survey data for the selected 18 bridge sites in Peninsular Malaysia were not available. However, simple bridge site plans and river cross-sectional profiles were available for the 2 selected bridges in Sabah and Sarawak. This available topographic data can be utilized in conjunction with the supplemental field survey conducted by the Study Team. As such, topographic survey was carried out only at the 18 selected bridges located in Peninsular Malaysia.

The primary purpose of the topographic survey is to visualize and illustrate the levels and contours of the surrounding land and river relative to the bridge. This topographic survey is essential since it provides the basic data for the following works:

* Hydraulic analysis.
* Determination of local scour and the extent of rehabilitation and maintenance required for the river bank and scour protection.
* Structural analysis of the substructure.
* Stratigraphy of the subsoil relative to the topography of the land.

The topographic survey work was subletted to a local licensed surveyor and commenced on the 26th September, 1991 for a contract period of 45 days. Up to six surveying parties were mobilized at different stages during the survey works. The field operations were divided into reconnaissance, traversing, leveling, EDM tachometry and echo sounding.

All the field works were completed by the 31st October 1991. The field books were checked and the recorded data were processed by a computer. The X, Y, Z coordinates of all recorded points were plotted using a flatbed plotter. The results of the survey were prepared in the following form:-

* Topographic Drawings (18 nos)
* River Crossings (42 Sections)
* Bridge Profile along the center line including river cross-section below the bridge center-line (18 sections)

III-4-2 Subsoil and Water Investigation

A total of 5 out of the 20 bridges, bridge number 00161140, 00346740, 00546560, 00546980 and 00567840, were found to require subsoil investigation. This is in view of the possibility of future rehabilitation plans such as the addition of sidewalks, widening of carriageway and raising of grade as well as the reinforcement of foundations. One deep borehole was sunk at each of the selected bridge sites.

The principal objective of subsoil investigation was to determine the representative stratigraphy of the subsoil and ground water conditions at the selected bridge locations. Important subsoil engineering parameters are obtained from this investigation and are adopted for use in the analysis, design, and selection of foundation types.

In addition to the subsoil investigation, a river water quality survey and topsoil sampling with regard to possible sulphate attacks were also being carried out. This exercise was carried out to confirm the NALS findings concerning the possibility of sulphate attacks at a number of bridges. Ten of these bridges were finally shortlisted for the sulphate survey, involving hand auger holes, river water samplings, and chemical analysis of pH value and sulphate content.

Those chemical test results will help to scrutinize the NALS findings and possibly unravel some of the causes of chemical attacks on the concrete. This will in turn help to determine the appropriate course of rehabilitation works to be taken. Immunity against further deterioration can then be given to a varying degree by protective measures.

The subsoil and water investigation carried out involved rotatory wash boring on land to a maximum depth of 45.5m, SPT, collection of disturbed and undisturbed samples, ground water and river water sampling, soil test to obtain soil index properties, chemical analysis of soil and water samples, pressiometer test and pile length investigation using P/S wave logging method.

The subsoil engineering parameters obtained were used in the structural assessment and selection of foundation types and design. The subsoil investigation revealed that the foundation failure at bridge 00546980 was caused by a combination of the following three factors:-

- The piles had inadequate bearing capacity in the original design.

- This condition is aggravated by negative skin friction due to consolidation settlement of soft marine clay.

- This settlement induces lateral soil movement, and this lateral force results in the bending of piles.

The result of water and top soil investigation contradicts the NALS hypothesis regarding sulphate attack on concrete. The sulphate content was found to be negligible at most bridge sites. The distress in concrete piles could have been caused by the presence of acids in the vicinity of the bridge sites and high water-cement ratio in the concrete. It is therefore proposed that low water-cement ratio using ordinary portland cement content of more than 300 kg/m^3 should be applied in the remedial work.

III-4-3 River Hydrological Survey

The river hydrological study as part of the detailed engineering survey was carried out to prepare hydraulic rehabilitation plans for the selected 20 bridges and to derive basic criteria for bridge rehabilitation from a hydraulic viewpoint.

To achieve the above objectives, the river hydrological study is broadly divided into two fold; field inspection from hydraulic viewpoint and hydrological analysis.

(1) Field Inspection from Hydraulic Viewpoint

The field inspection was carried out referring to the topographic maps of the 20 study bridges in order to clarify the cause of the hydraulic defects observed. Principal inspection items are listed below.

- Identification of flood marks at bridge sites during the past major floods.
- Confirmation of the main water course of the river.
- Observation of river bank condition.
- Confirmation of the tendency of riverbed whether raising or lowering.
- Identification of the local scouring locations.

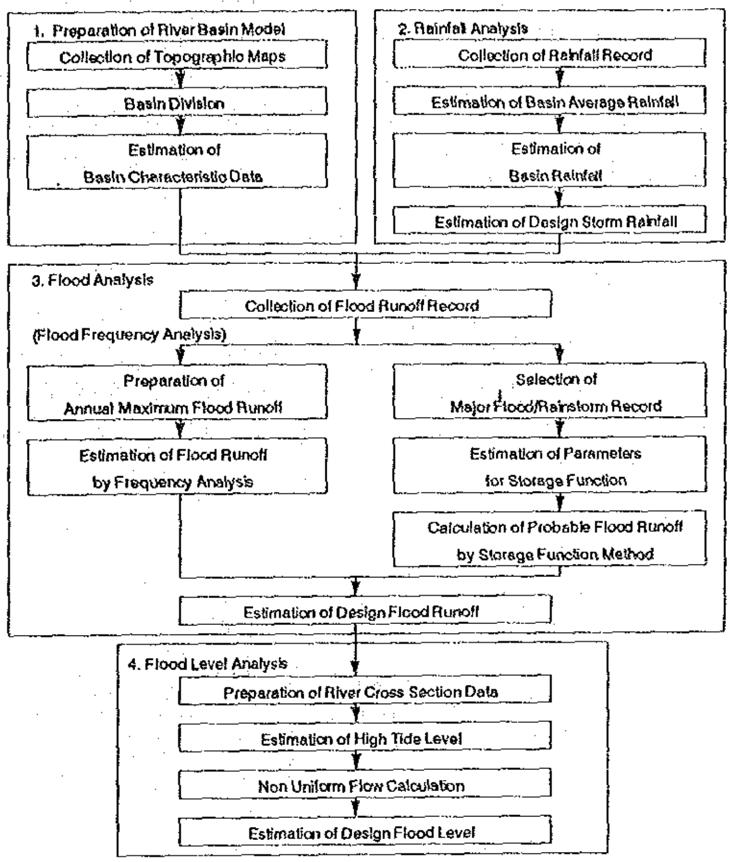
(2) Hydrological Analysis

The objective of the hydrological analysis is to assess the river hydrological conditions, as listed below, around the bridge sites of the respective major bridges: 0037100 on the Kelantan river, 00346740 on the Dungun river, 00319110 on the Pontian river and 00317000 on the Endau river.

- Magnitude of flood
- Flow capacity of river at bridge site
- Flood level

In the hydrological analysis, the storage function method and thiessen method were applied for runoff calculations and rainfall analysis, respectively. Non-uniform flow method was adopted to analyze the flood level of the river which is affected by tidal levels. The overall flow diagram for hydrological analysis is depicted in Figure III-7.

Figure III-7 Overall Flow for Hydrological Analysis



(3) Summary of Hydraulic Defects and Rehabilitation Plans

The hydraulic defects which were not only detected based on the field inspection but also proven by the hydrological assessments for major rivers are tabulated together with the corresponding rehabilitation plans in Table III-4.

Table III-4 Summary of Hydraulic Defects and Rehabilitation Plans

Key	Defect	Cause	Rehabilitation Plan
001/611/40	– Exposed pier footing	– Local scouring	– Installation of river bed protection
	– Exposed abutment footing	– Local scouring	– Installation of abutment protection
001/665/10	– Decreasing bridge opening	– Sedimentation	– Widening river channel with slope protection
	– Exposed footing	– River bight	– Realignment
	– Riverbank erosion	– River bight	– Realignment
002/372/00	– Failure of abutment protection	– Insufficient depth of slope toe	– Reconstruction of abutment protection
003/170/00	– Submergence of both end spans	– Inadequate bridge clearance at both end spans	– Raising of girders
	– Exposed footing of concrete wall	– Local scouring	– Installation of foot protection
003/418/10	– Failure of abutment protection	– Insufficient depth of slope toe	– Reconstruction of abutment protection
003/467/40	– Inadequate free board	– Insufficient capacity of river channel	– Excavation of river channel
	– Riverbed degradation	– Local scouring	– Installation of riverbed protection
	– Riverbank erosion	– River bending in upstream	– Installation of riverbank protection
003/710/00	– Failure of abutment protection	– Local scouring	– Reconstruction of abutment protection
	– Riverbank erosion in both upstream and downstream		– Construction of slope protection
Dambai	– Riverbank erosion	– River bending in upstream	– Construction of slope and abutment protection

Based on observations made during the field inspection, it was found that very low emphasis has been given on river hydrological and hydraulic aspects of bridges in Malaysia. It was therefore recommended that the River Structure Standard in Japan would be applied, after some modification was made, for future bridge design in Malaysia. The standard stipulated desirable bridge length, minimum span length required, minimum free board, desirable location of river piers and abutments as well as minimum embedded depth of footings of the river piers.

III-4-4 Detailed Structural Survey

The objective of the detailed structural survey is to obtain detailed engineering information so as to enable preliminary rehabilitation design covering the 20 bridges. Detailed structural survey work includes structural details measurement, material strength measurement and material deterioration degree measurement.

(1) Structural Detail Measurement

Structural detail measurement included conventional dimension measurement, crack/corrosion mapping, concrete cover and rebar size measurement, and steel thickness and pile length measurement. The objective of the structural detail measurement is to prepare as-measured drawings for each bridge and all the measurement results were compiled in a drawing form.

(2) Material Strength Measurement

Material strength measurement carried out in the Study included concrete coring, ultrasonic pulse velocity (UPV) test and schmidt hammer test for concrete strength, while steel strength measurement was carried out by using a Hardness tester (Echo-Tip).

Based on the test results as well as referring to relevant British Standard (BS) code and old engineering reference books, the following are the strength of each material to be applied in the structural assessment.

(Unit: N/mm^2)

Concrete(1)				Steel(2)	
Superstructure		Substructural		Structural Steel	Rebar
Beam	Slab	Abut/Pier	Pile		
20(3) or 25(4)	20	20	25	230	230

Note: (1) Cube strength at 28 days
(2) Yield strength
(3) For R.C. structure
(4) For P.C. structure

(3) Measurement of Material Deterioration Degree

Type of the material deterioration measurement carried out in the Study included; chloride test, carbonation test, rebar corrosion test by half-cell potentialmeter and alkali-aggregate reaction (AAR) test. The formation analysis of bearing pads was also carried out. A summary of the test results is presented in Table III-5.

Table III-5 Summary of Test Results of Material Deterioration Degree

Type of Test	Summary of Results/Findings
Carbonation Test	- Most substructures are not carbonated. - For superstructure: . Most PC beams are not carbonated . Insite RC and encased steel beams have been carbonated to depth varying from 2 to 60mm . Quite a number of deck slabs have been carbonated with depth varying from 11 - 70 mm.
Chloride Test	- Most piles are badly attacked by chloride. - For superstructure only beams and slabs of bridge 00317000 have been badly attacked by chloride.
Sulphate Test	- All the bridges tested for sulphate show that the percentage of sulphate is within the acceptable limit. - Therefore the defect observed could have been caused by other aggressive agents.
Rebar Corrosion Test	- All the bridges tested indicated that all the rebars have not corroded yet or that corrosion is not serious yet.
Formation Analysis of Bearing Pads	- 2 samples were taken from Bridge 00701810 and Dambai bridge. - The test result of sample at Bridge 00701810 shows that it is made from NR and SBR which are less resistance to ozone. Thus this characteristic is the cause of defects observed. - Main reason for defect at Dambai is due to load concentration at lower flange edge.
Alkali-Aggregate Reaction Test	- Cracks on pile head at Bridge 00319110 are caused by Alkali Aggregate Reaction (AAR).

III-4-5 Full Scale Bridge Loading Test

In most cases, actual load carrying capacity of bridges is higher than that obtained by theoretical calculation. This phenomena is caused by the difference between design and actual bridge behavior due to a result of material properties deviation, degree of difference in lateral load distribution, extent of composite action, etc. Most of bridges therefore have such reserved residual loading capacity (RRLC), the value of which depends on type of structure, construction materials and extent of defects or deterioration.

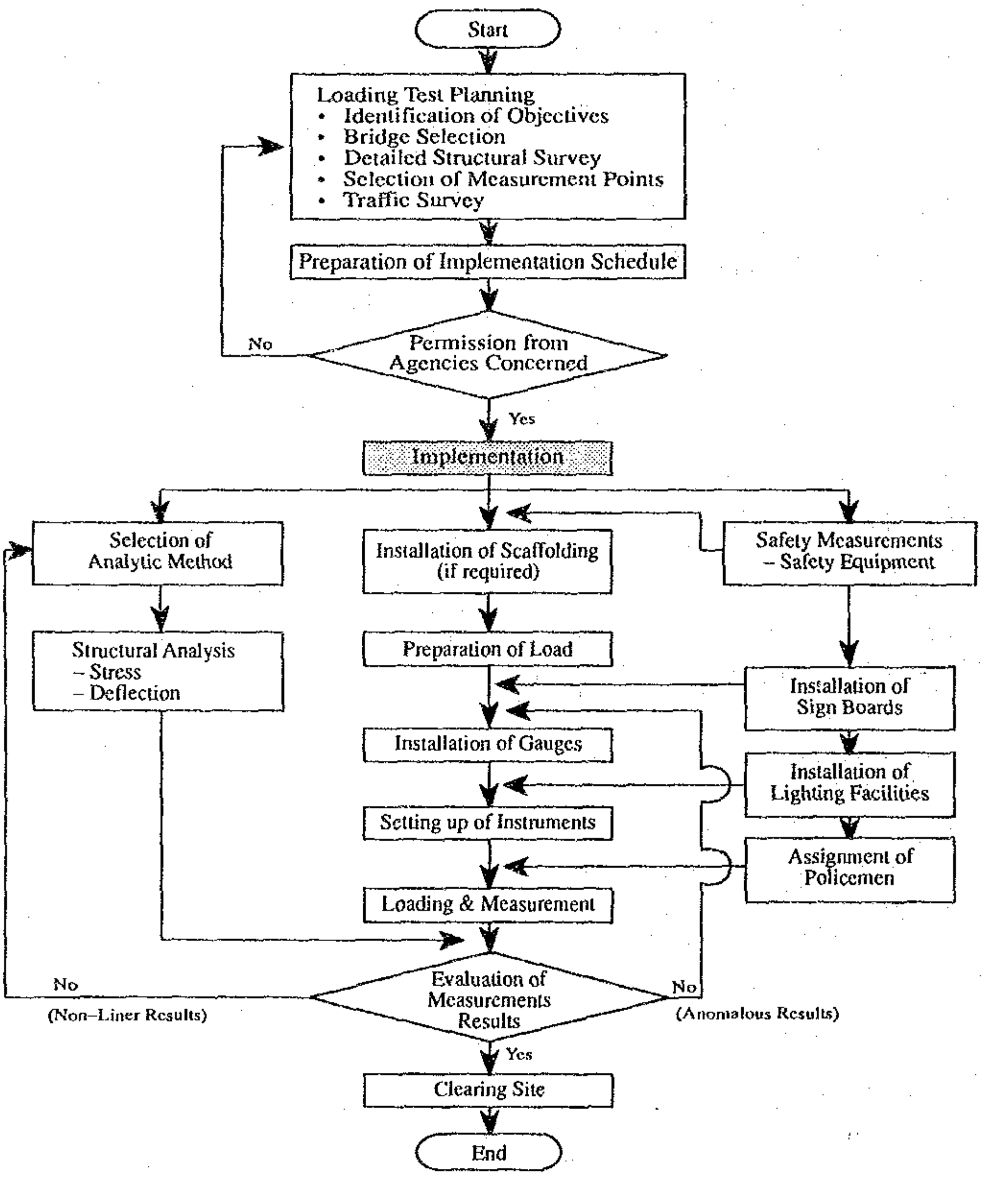
It is, however, difficult to estimate RRLC by analysis alone, particularly on the effects of defects or deterioration to the overall performance of an existing bridge, but it is of importance to make it a requisite in assessment of the existing bridges. In order to overcome the difficulty, a full scale loading test could prove to be useful to determine RRLC of the bridges instead of analysis.

The primary purpose of full scale loading test in the Study is therefore to estimate RRLC of main component part of the bridge. To achieve this, comparison of stress and deflection is made between theoretically calculated values and those empirically measured. The other secondary purpose of the test is to ensure that structural theories and assumptions applied in the calculation are correct and suitable for use in the structural bridge assessment work.

Out of the 20 bridges for the detailed survey, a total of five spans at three different bridge sites were selected for a full scale bridge loading test.

The type of loading test carried out in the study is divided into two; static and dynamic loading tests. A static loading test was carried out at all selected bridges to measure deflections and strains of main component part under a known load using loaded vehicles. A dynamic loading test was carried at bridge 00237200 which is located on the heaviest traffic route among others. In this test the actual working strain of the members under the existing traffic load was measured. The loading test procedure is presented in Figure III-8

Figure III-8 Loading Test Procedure



Results of the full scale loading test indicated that the main beams of SBC, RCB and PCB bridges have RRLC of about 20% in terms of the design stress. A summary of the assessment result for static and dynamic loading tests is tabulated in Table III-6 and III-7 respectively.

Table III-6 Summary of Assessment Results of Static Load Tests

Bridge No	Bridge Component/ Member	Summary of Assessment Results
00237200 (SBC & RCB)	Main beam of SBC	. Rigidity of the steel beam is considerably less than that used in design. . Effect of composite action in SBC is suspicious. Hence it is recommended for beams in SBC bridge assessment work should be considered as an non-composite beam. . The test result indicates that beams in SBC have reserved residual loading capacity of about 20%.
	Main beam of RCB	. Little variation between load test result and theoretical calculaton. . Othotropic plate theory in lateral load distribution could be applied to the assessment. . The test result indicates that the beams in RCB have about 20% reserved residual strength.
	Deck slab of SBC and RCB	. Concrete deck slab is more than adequate to take design wheel load of 10 tonne.
00319110 (PCB) & (PCB)	Main beam of centre span	. Little variation between load test result and theoretical calculation. . Beams are working as an elastic body and the prestressing force is still effective. . The test result indicates that this type of beam has reserved residual loading capacity of about 20% of the design stress.
	Main beam of approach span	. The beam is working as an elastic body and the prestressing force is working effectively. . The result tally with theoretical calculation. . This type of beams has reserved residual loading capacity of about 20% in term of the design stress.
	Deck slab of approach span	. Concrete deck slab is more than adequate to take wheel load of 10 tonne.
00834850 (RCS)	Main slab	. Longitudinal construction joint provided along the centre line has no distribution rebar installed, but has connector which function for transfering shear only. . Deflections from load test are higher than those theoretically calculated. This causes by non-uniform or low quality of concrete in the bridge, attest by large honey comb on soffit of the bridge. . This type of bridge has reserved residual loading capacity of about 10% in term of design bridge.

Table III-7 Summary of Assessment Results of Dynamic Load Test

Type of Test	Summary of Assessment Results.
Dynamic Test under Existing Traffic During Peak Hour	. Maximum stress recorded is 2.28 and 2.31 times compared to those in static test for SBC and RCB beams respectively. . Hence it was presumed a vehicle of gross weight of about 40 tonne passed on the bridge during the test period. . Since a single 40 tonne vehicle produces an equivalent to 40% of HA load in SBC and 57% in RCB, it was concluded that the bridge has adequate durability to take live load derived from the existing traffic at this specific location.
Dynamic Test under Known Load at Different Running Speed	. Impact stress was known to be related to the smoothness of the surface and the running speed and hence the test result was not conclusive. . Discordance was caused by wheel position being not coincidence with wheel locus as those under static load test.

III-5 Determination of Applicable Live Load

The study bridges are known to have been built or designed using the prevalent British Standard of the time the bridge was built. On the other hand, in 1990 JKR introduced and enforced a new bridge loading standard based on the recommendation made by NALS. Thus the assessment of applicable live load was carried out for the purpose of determining the most appropriate live load to be applied in the study.

To this end, thorough examination of historical transition of live loads in Malaysia was firstly carried out. Secondly, a comparative study in terms of sectional forces due to the several design live loads applied and the present JKR live load was carried out to reveal the extent of difference in sectional forces. Finally, based on the assessment of those differences, an applicable live load in the Study was determined.

III-5-1 Past and Present Design Live Load Application in Malaysia

Although there was no record with regard to bridge loading application for bridges built before 1942 in Malaysia, the evidence, such as steel manufacturer marking embossed on the steel beams, indicated that the bridges have been designed in UK. Therefore, these bridges were presumed to have been designed to BS 153 with similar live load specified as the Ministry of Transport (MOT)'s bridge loading standard train in 1922. Bridges built after 1942 were certain to have been designed in accordance with HA loading in the BS 153 Part 3A and it was derived from the previously applied MOT's standard loading train. After 1975 it was certain that bridges were designed to HB loading with the guided condition.

In 1990, JKR introduced "JKR Bridge Loading Standard" in which all bridges on Federal Roads shall be designed to the worst effect of the Long Term Axle Load (LTAL), 20 Units of Special Vehicle (SV) controlled or 7 Units SV uncontrolled, while bridges on State Roads shall be designed to the Medium Term Axle Load (MTAL).

LTAL consists of a Uniformly Distributed Load (UDL) in association with a Knife Edge Load (KEL) of 100 KN per a Notional Lane of 2.5m. It was derived based on the loading model used in the derivation of BD21/84 loading curve with slight modification. SV load is an abnormal vehicle unit loading and consists of a tractor and a multi-axle trailer with total weight of 430 tons in case of 20 units of SV. MTAL consists of UDL and KEL with the intensity of UDL being lower than those of LTAL. MTAL was derived from consideration of bending moment and shear effects from, whichever is higher, either BS 153 HA load or 45 unit HB vehicle guided along the centerline.

III-5-2 Comparison of Sectional Forces

Based on the above study, it was concluded that the possible applicable live load should be either HA, MTAL, LTAL or SV load. Further assessment was then made by comparing sectional forces due to these design loads to reveal the extent of differences.

(1) Typical Bridge Configuration

To ensure comparisons is made under the same condition, a representative or typical bridge configuration was obtained from statistical analysis of all the study bridges. The span length of the study bridges varies from 1.8 to 45.78 meters, while the average carriageway width is 7.05 meters. Therefore the comparison of sectional forces was carried out to cover bridges with span length up to 50m and carriageway width of 7.05m, without considering lateral load distribution.

(2) Comparison of Sectional Forces due to Live Loads

In the comparative analysis, it was found that the bending moment and shear force due to SV load at span length longer than 35.0m is almost double that due to HA load. Thus, the comparative study on sectional forces due to 20 Unit SV loading and HA loading indicates that most of the study bridges will not be able to carry SV loading and thus SV load was discarded. While maximum sectional forces due to MTAL and LTAL were found to be 26.1% and 35.3% higher than HA loading respectively.

This percentage was found to be high, hence further assessment was made by taking into account the effect of dead load because the magnitude of the contribution in live load depends on the weighted ratio of dead load against total load.

(3) Comparison of Sectional Forces due to Total Load

Typical bridges considered in this exercise were SBB with span range from 5 to 15m, SBC from 5 to 15m, RCB from 5 to 15m, RCS from 5 to 15m, IT from 10 to 20m and PCB from 25 to 50m. The width of carriageway in this exercise was fixed at 7.05m.

The percentage differences in case of applying MTAL as a live load compared with HA including dead load are all within 20% and the maximum percentage difference is 19.89% in SBB with a span length of 6 meters. While, in case of LTAL, the maximum percentage difference is 26.9% in SBB with a span length of 6 meters and the bridges of which the percentage difference compared with HA exceeding 20% are SBB, SBC, RCB and RCS having a span length between about 6 meters and 9 meters. These bridges amount to about 28% of all the study bridges.

(4) Conclusion

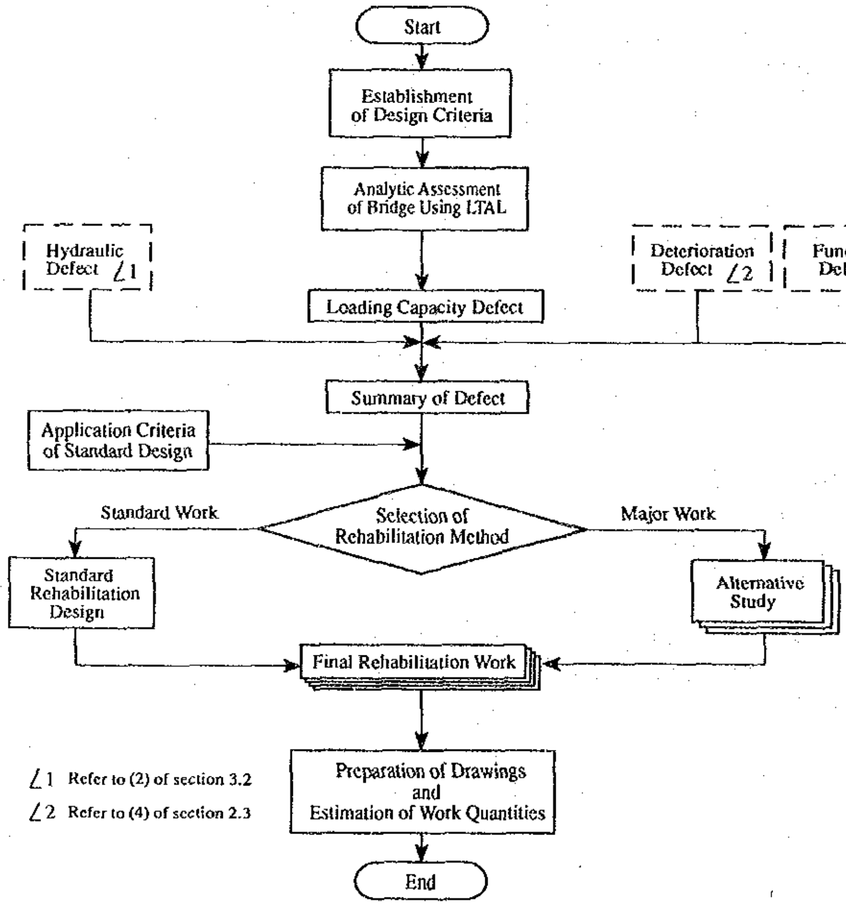
Based on the above assessment results, it is concluded that LTAL shall be applied as the live load standard in this Study with due consideration of the following aspects:

- LTAL is the present JKR live load standard applicable to the federal bridges.
- The average percentage difference between LTAL and MTAL is only 7%.
- The percentage difference within 20% could be covered by the reserved residual loading capacity as proven in the loading test.
- The bridges of which the percentage difference on sectional force due to LTAL compared to HA exceeding 20% are only 28% of all the study bridges. Some of these could have LTAL loading capacity, if effects of the lateral load distribution and the reserved residual loading capacity are considered or could be rehabilitated by applying standard strengthening methods.

III-6 Preliminary Rehabilitation Design

The purposes of preliminary rehabilitation design covering the 20 bridges including the 3 special bridges are to assess the bridges using LTAL loading, to prepare standard rehabilitation design, to carry out an alternative study for possible major rehabilitation work and to estimate the work quantities. The preliminary rehabilitation design was carried out based on all the results obtained from detailed survey. The design flow is depicted in Figure III-9 which also indicates interrelationship of the above work items.

Figure III-9 Flow Chart of Preliminary Design



III-6-1 Structural Assessment Criteria

The structural assessment criteria to be applied in the Study is in principle based on the JKR Design Practice except where the specification is not clear then the Bridge Design Specification in Japan was applied. The assessment criteria covers the following aspects of assessment design:

- Geometric Design Standard
  JKR "ARAHAN TEKNIK (JALAN) 8/86" is applied.

- Bridge Width
  R5 is applied in accordance with Article 5.11 of JKR "ARAHAN TEKNIK (JALAN) 8/86".

- Free Board
  River Structure Standard in Japan is adopted after some modification was made considering Malaysian river conditions.

- Bridge Loading
  The loads to be considered shall be dead load, live load (LTAL), pedestrian load, tractive/braking force and earth pressure.

- Assessment Method
  - o Analytic assessment and rehabilitation design on existing bridge members were carried out using the elastic design method (allowable stress design) based on BE 1/73 and BS 153 Part 3B.

  - o For adding sidewalks which are not attached to the existing bridge or a new bridge construction, the design shall be carried out based on BS 5400 and BS 4360 using limit state design methods.

- Applicable Design Standard

  In deriving the assessment criteria, the JKR Bridge Design Manual was refered. In addition, reference were made to Design Specification for Highway Bridge published by the Japan Road Association and BS 153, BE1/73, BS 5400 Part 1, 2, 3 and 4.

III-6-2 Analytic Assessment of Bridges

In selecting the most appropriate rehabilitation plan, it is essential to diagnose all defects in terms of material deterioration, load carrying capacity, bridge function and hydraulic adequency together with the corresponding cause of the defect so that the rehabilitation is selected to effectively rectify the cause of the defects.

To this end, all of 20 bridges for the detailed survey have been assessed from hydraulic, material deterioration and functional viewpoints in the previous sections. Therefore, in this section, the remaining item analytic assessment from load carrying capacity viewpoint is carried out to identify which bridge member is inadequate or adequate to carry LTAL loading.

(1) **Method of Assessment**

The assessments were carried out based on the available structural data taken from the detailed structural survey. The loading test results were also utilized in the assessments where the comparisons of allowable stress with the working stress were made by deducting the latter by a certain percentage of RRCL value, depending on the type of structure outlined as follows;

- **Steel Beam and R.C. Bridges**

In the assessment of steel beams, the maximum working stress theoretically calculated due to the most severe LTAL loading including dead load is compared with the allowable stress of the structural steel. If the working stress after a reduction of 20% is within the allowable stress, then the steel beams are considered adequate.

The same method described above was also applied in the assessment of R.C. beams and R.C. slabs. However the mitigating factor of working stress, 20% for R.C. beams and 10% for main slabs were applied.

- **Prestressed Concrete Bridges**

On all the P.C. beams except Endau bridge (00317000), effective prestressing forces are unknown. Due to this lack of data, the assessment method applied is by comparison of the difference between sectional forces (bending moment and shear force) due to the assessment total load (LTAL + Dead Load) and those due to the design total load (HA + Dead Load). Then if the difference is not more than 20% which is reserved residual loading capacity of P.C. beams, the P.C. beam is considered adequate.

- **Substructures**

Subsoil profile, pile length data and size of footing are requisite data in the assessment of substructures. However, due to a lack of these data, the assessment method applied is also by comparison of the difference between reaction forces due to the assessment total load and those due to the design total load. If the difference is not more than 20 - 30%, then the substructure is considered adequate.

(2) Results of the Assessment

Summary of the assessment results is tabulated in Table III-8. The result of assessment indicates that in general most of the bridge types can be rehabilitated without major strengthening works except for steel beams with buckle plates, buckle plates and two-girder type of P.C. beams.

Table III-8 Summary of Analytic Assessment on Existing Bridges

Bridge No.	Bridge Type	Ratio (%) <1			Assessment Results
		Slab	Beam	Substructure	
114920	RCB	−77.5	−2.8	+23.6	
161140	SBB	+34.2	+66.2	+12.6	Steel buckle plates and beams have inadequate capacity.
166510	SBG	−38.8	−43.7	+7.5	
	RCB	−	+86.7	−	R.C Beams have inadequate capacity.
237200	SBC	−26.7	+2.1	+20.4	
	RCB	−27.5	−27.1	−	
317000	PCB	−28.0	−20.0	+5.0	
319110	PCB	−6.6	+8.4 (−3.4) <4	+10.3	Main beams of 2−girder type bridge have inadequate capacity
341800	RCB	−80.4	−6.8	+13.5	
346740	PCB	−	<2	−	Main beams of 2−girder type bridge have inadequate capacity
520850	SBE	−55.3	−7.7	+0.8	
546560	RCB	−4.3	+19.7	+14.3	Main beams have inadequate capacity.
546980	RCS	+138.7	−	+9.4	R.C Slab has inadequate capacity.
563880	IT	−	−12.4	+0.5	
567840	PRB	−	−14.9	+24.4	
834850	RCS	−2.1	−	+7.0	
5001070	SBB	<3	+105.8	+7.9	Steel buckle plate and beam have inadequate capacity.
5803340	SBB	<3	+20.6	+18.8	Steel buckle plate and beam have inadequate capacity.
5903120	SBC	+73.9	+0.7	+16.0	Slab has inadequate capacity.
Dambai	SBC	+6.3	+34.5	+12.1	Slab and beams have inadequate capacity.
Samarahan	SBC	+99.9	+24.4	+3.6	Slab and beams have inadequate capacity.
	RCB	−	−12.8	−	
371000	RCB	−7.3	−7.6	−0.9	

Notes : <1 Percentage increase (+) or decrease (−) against allowable stress or design force.
<2 The assessment results of Bridge No. 319110 is utilized to this bridge.
<3 The assessment results of Bridge No. 161140 is utilized to this bridge.
<4 Figure in ( ) means the result of 4−girder type bridge.

III-6-3 Summary of Selected Rehabilitation Method

Based on the assessments carried out in the previous sections, all the types of defects were diagnosed together with the corresponding causes. From these data, an appropriate rehabilitation method was selected on a member by member basis and a summary of the selected rehabilitation methods covering the 20 bridges is shown in Table III-9.

Table III-9 Summary of Selected Rehabilitation Methods

Classification			Steel Material	Concrete Material
STRUCTURAL REHABILITATION	SUPERSTRUCTURE	Protection	o Repainting	o Exposy Injection o Protective Coating o Patching o Guniting o Installation of water proof layer
		Reinforcement	o Installation of Additional Beam o Provision of Cross Beam o Attachment of steel plate	o Prepacked concrete lining with additional rebar o Concrete Lining by guniting w/rebar o Steel plate bonding
		Replacement	o Replacement by R.C slab	– None –
	Incidental facility		o Extension of drainage pipe o Installation of water drop o Replacement of Expansion Joint o Replacement of bearing <2 o Replacement of railing <2	
	SUBSTRUCTURE	Protection	o Repainting o Concrete lining	o Concrete lining (Brick Abutment) o Concrete lining o Patching
		Reinforcement	o Concrete lining	o Underpining by additional pile <3
		Replacement	– None –	o Replacement of abutment by rigid flame
Hydraulic Rehabilitation			o Slope protection o Foot protection o River bed protection o Spur dikes	
Functional Rehabilitation			o Adding sidewalk o widening carriageway o Raising grade	

Note <1 In principal, steel bearing to a steel beam while rubber bearing to a concrete beam
<2 This item is included in replacement of deck slab
<3 This item is included in raising grade

III-6-4 Standard Rehabilitation Design

Referring to the selected rehabilitation methods, standard rehabilitation methods which are relatively well known techniques in bridge maintenance and rehabilitation were designed together with the respective corresponding application criteria.

The standard rehabilitation design was divided into seven categories comprising of; Protection work to concrete, Reinforcement work to concrete, Protection/reinforcement to steel material, Protection/reinforcement to substructure, River training work, Incidental facilities and Temporary works.

Protection work to concrete materials is applicable to a concrete member whose defect is not active. The method includes epoxy injection, patching, protective coating, guniting and water proofing.

Reinforcement work to concrete members is in principle applicable to a bridge member which has inadequate load carrying capacity or has active structural defects. The method applied includes steel plate bonding, prepacked concrete lining with additional rebars and guniting with additional rebars.

Protection to steel materials is applicable to a steel member which has no active defects. The method includes repainting steel piles, repainting steel beams and concrete lining.

Reinforcement to steel materials is applicable to a steel member with inadequate load carrying capacity. The method applied includes attachment of steel plates for superstructure and concrete lining for steel piles.

Protection/reinforcement to substructures is applicable to a concrete or masonry substructure and the method applied includes concrete lining to abutment and concrete lining to piles.

River training work consists of slope protection, foot protection, river bed protection and river realignment works. Slope protection works are applicable to the river bank around abutments where erosion was detected. Foot protection works are applicable to footings of slope protection to prevent slope failure caused by a scouring action on the river bed. River bed protection works are applicable to the river bed around river piers where local scouring of the river bed was detected. River realignment works are applicable to extremely eroded banks of meandering rivers.

III-6-5 Alternative Study

All the 20 bridges can be rehabilitated using the standard rehabilitation method, except for three of the bridges where various possible methods are involved such as total bridge replacement for bridge 00166510, raising bridge grade for bridge 00317000 and replacement of buckle plate slab for bridge 00161140.

For those cases, 3-alternatives were prepared for each bridge mainly from an engineering viewpoint and each alternative was evaluated from structural aspect, construction cost, maintenance cost, construction period and aesthetic viewpoints to select the most optimum rehabilitation plan.

Finally, for bridge 00166510 which requires total replacement, prestressed invert "T" beams supported by R.C. inverted "T" abutment with R.C. piles was selected as a new bridge type, while for bridge 00317000 which was found to be submerged at both end spans, replacement of P.C. beams at both end spans to new P.C. beams and raising the bridge seat by 1.4 m was selected. For bridge 00161140 requiring the buckle plate replacement, replacement by R.C. slab was selected as an optimum rehabilitation plan.

III-6-6 Results of Preliminary Design

The bridge maintenance and rehabilitation methods for each bridge were finally decided based on the standard rehabilitation design and the alternative study of the major work items described above. In the rehabilitation design, strengthening design was also carried out for the bridge member which has inadequate LTAL load carrying capacity as revealed by the analytical assessment of the bridges. Subsequently preliminary design drawings for the 20 bridges were prepared and work quantities of the work items for each bridge were also computed. The work sequence for major works, such as raising of grade, replacement of steel buckle plate, etc. was itemized in the general arrangement drawing, while the standard rehabilitation sequence applied in the preliminary design was presented in the standard drawings. The specification for bridge maintenance and rehabilitation works is, in principle, based on JKR Standard Specification for Road Works (JKR/SPJ/1988) wherever applicable. However, for some work items not covered in JKR Specification, a brief specification for each special item was described in the Standard Drawings.

III-7 Planning of Maintenance and Rehabilitation Works

Planning of the maintenance and rehabilitation works covering all the study bridges was carried out based on a supplemental bridge survey and the results of preliminary rehabilitation design.

The supplemental bridge survey covering 199 bridges was carried out based on the criteria for selecting rehabilitation methods derived from the result of preliminary design. The purposes of the survey are to measure the extent of damage, to identify the rehabilitation method and to estimate the work quantity, since the NALS data did not cover the quantitative damage data which are requisite in formulating the rehabilitation program, as originally planned.

The bridges covered in the supplemental survey are divided into 2 groups: one group is the 121 bridges which were discarded for the visual inspection and the other group is the 78 bridges which were visually inspected but discarded for the detailed structural survey. The purpose of the supplemental bridge survey thus depend on the above two bridge categories, i.e. for 121 bridges the purposes are to rate type, degree and extent of damage, to select rehabilitation plans and to estimate the work quantities, while for the other 78 bridges the purposes are to select rehabilitation plan and to estimate the work quantities.

III-7-1 Methodology of Supplemental Survey

Taking into account the enormous number of bridges, a criteria for selecting a suitable rehabilitation method was setup based on the results of the preliminary design in order to ensure that the rehabilitation method selected could be uniform and standardized.

The selection criteria of rehabilitation methods was broadly divided into three categories; structural, functional and hydraulic rehabilitation criteria:

- **Selection Criteria for Structural Rehabilitation Methods**

The structural rehabilitation works are broadly divided into three categories comprising of protection, strengthening and replacement. Thus, the criteria are also subdivided into the following three categories.

- Selection Criteria of Protection Work

Protection work is applicable to a bridge member which has adequate load carrying capacity but which has minor material deterioration defects including inactive cracks due to shrinkage, creep or temperature or some construction deficiencies such as honeycomb, flaking, water stain, etc. The work involves epoxy injection, patching, guniting, protective coating, water proofing and concrete lining for concrete members, and repainting and concrete lining for steel members.

The specific rehabilitation method depends on type of defect, its extent and degree as well as the cause of defect. Each type of rehabilitation method is defined together with the corresponding application criteria.

- Selection Criteria of Strengthening Work

Strengthening work is applicable to a bridge member which has major material/structural defects or which has inadequate LTAL load carrying capacity judged by the analytic assessment results of 20 bridges. Major defects requiring the reinforcement works include active cracks due to bending or shear force, live or progressing settlement and serious section loss.

The works include steel plate bonding, prepacked concrete lining with additional rebars and guniting with additional rebars for concrete members, and attachment of steel plate and concrete lining with additional rebars for steel members.

The specific rehabilitation method depends on construction material used, extent of excess stress, and type of associated damage together with its extent and degree. Each type of the rehabilitation method is defined together with the corresponding application criteria.

- Selection Criteria of Replacement Work

Replacement work is applicable to a bridge member or a whole bridge of which rehabilitation work(s) is beyond economic repair.

A bridge member which has major structural/potential defects and which has inadequate load carrying capacity was designated to be replaced with an appropriate bridge member. Furthermore, a bridge which has combined rehabilitation plans not only from structural defect but also from functional defect and/or hydraulic defect was designated to be replaced by a new bridge.

- **Selection Criteria for Functional Rehabilitation Methods**

Functional rehabilitation methods are divided into three categories consisting of widening carriageway, adding sidewalk and raising grade. Criteria for applying these rehabilitation plans is discussed below:-

- Widening Carriageway

Necessity for widening carriageway on all the study bridges was assessed by means of comparison with traffic capacity on the bridge and current traffic volume at the same bridge location. Basically these assessment results carried out in the previous stage were utilized in determining the necessity for widening carriageway.

- Adding Sidewalk

The criteria for adding sidewalk is based on whether a bridge without sidewalk is located in an urban area or otherwise and its proximity with institutional public facilities such as schools, hospitals, mosques and other landmarks to the bridge. Applying the criteria, the surrounding area of each bridge site within about one km was surveyed to identify whether the bridge is located within the above specified conditions. If a bridge without sidewalk is located in the above condition, it was determined that sidewalk should be provided.

- Raising Grade

Based on interview surveys with local residents living in the vicinity of the bridge site, information on whether the study bridge has been submerged during flood was obtained. If the bridge has been submerged, additional information was also obtained such as approximate flood frequency per year and flood duration time.

If a bridge is found to have been submerged, it was then determined that raising grade is required or the bridge length has to be extended to cater for flood flow.

- **Selection Criteria for Hydraulic Rehabilitation Methods**

Hydraulic rehabilitation plan includes slope protection, foot protection, river bed protection and river alignment depending on the extent and nature of the hydraulic problem encountered such as scour, erosion, flood flow at bridge site.

- Slope protection is applicable to river banks adjacent abutments where erosion is observed.

- Foot protection is applicable to the footings of slope protection in order to prevent slope failure caused by scouring action on the river bed.

- River bed protection is applicable to river bed surrounding the river piers where local scouring or river bed lowering is observed,

- River alignment (rechanneling) work is applicable to extremely eroded banks of a meandering river located in the vicinity of the bridge upstream.

Selection of a specific rehabilitation method depends on the stream type, river scale, flood flow velocity, foundation type and geology of each site. Type of rehabilitation method of each plan is defined together with the corresponding application criteria.

III-7-2 Planning Results of Maintenance and Rehabilitation Works

During the supplemental bridge survey covering 199 bridges, it was found that 11 bridges have been replaced, hence the total number of study bridges was reduced to 205 bridges including 17 bridges in which detailed survey was carried out.

Assessment was then made on the 205 bridges for the purpose of highlighting the most dominant rehabilitation work required to be carried out on the component of each particular bridge type. A summary of the assessment results from structural and functional viewpoint is tabulated on Table III-10 and Table III-11 respectively.

Table III-10 Summary of Assessment of Rehabilitation Methods from a Structural Viewpoint

Bridge Type or Superstructure type	Three Most Dominant Rehabilitation Methods Required	% of Bridge Member Effected
Steel Beam with R.C. Slab Bridges (SBC)	– Steel beams protection by repainting	94.0%
	– Deck slab protection by patching	50.0%
	– Deck slab protection by water proofing	27.8%
Steel Beam Encased Bridges (SBE)	– Encasing concrete protection by patching	33.3%
	– Encasing concrete protection by lining	22.2%
	– Deck slab protection by patching	22.2%
Steel Beam Buckle Plate Bridges (SBB)	– Total replacement of buckle plate by RC slab	100.0%
	– Total replacement of steel bearings	97.1%
	– Steel beam protection by repainting	87.1%
RC Beam Bridges (RCB)	– Deck Slab protection by patching	25.8%
	– RC beam protection by patching	22.6%
	– RC beam reinforcement by bonding steel plate	22.6%
RC Slab Bridges (RCS)	– RC slab protection by injection	43.5%
	– Deck slab protection by guniting	30.4%
	– Deck slab protection by water proofing	26.1%
Precast RC Beam Bridges (PRB)	– Deck slab protection by water proofing	75.0%
	– RC beam protection by patching	15.0%
	– RC beam reinforcement by bonding steel plate	5.0%
Precast RC–Beam Bridges (PRB)	– RC beam reinforcement by bonding steel plate	23.1%
	– RC beam protection by coating	23.1%
	– Deck slab protection by patching	15.4%
Inverted T Beam Bridges (IT)	– Deck slab protection by water proofing	66.7%
	– Beam protection by patching	22.2%
	– Beam protection by injection	11.1%
Abutments	– Abutment protection by injection	28.5%
	– Abutment protection by partial concrete lining	17.1%
	– Protection of abutment foundation by revertments	14.2%
Piers	– Pier reinforcement by partial concrete lining	9.3%
	– Pier reinforcement by total concrete lining	6.8%
	– Pier protection by patching	5.8%

Table III-11 List of Study Bridges which Require Rehabilitation Work Based on a Functional Viewpoint

Type of Rehabilitation Work	No's of Bridges	List of Bridges
Widening of Carriageway	4	00567840 (PRB), 00838100 (RCS), 01800060 (RCS), 01800670 (SBC)
Adding of Sidewalk	17	00113760 (RCB), 00161140 (SBB), 00161290 (SBB), 00303890 (RCS) 00313150 (SBE), 00313520 (RCS), 00336310 (RCB), 00341800 (RCB) 00519700 (PRB), 00521710 (RCB), 00700660 (PCB), 05102670 (SBB) 06406260 (SBB), 06702060 (SBE), 07604020 (SBB), 07604160 (SBB) 08604640 (SBB)
Raising of Grade	8	00304390 (SBC), 00317000 (PCB), 00700750 (RCS), 00834950 (RCS) 00838100 (RCS), 02305970 (RCS), 05102380 (SBB), 05300960 (SBB)

III-8 Cost Estimate

The study objective is to estimate maintenance and rehabilitation project costs of each of the study bridges amounting to 203[(1)] bridges.

To achieve the above objective, the following procedures were applied.

- Assessment of the indirect cost items and project cost composition, and determination of multiplier factors of these items.
- Review of main work items derived from the preliminary design of 20 bridges and identification of the associated subsidiary work items.
- Analysis of the unit price of each pay item (or each rehabilitation method) covering 20 bridges.
- Establishment of standard unit prices applicable to all the bridges based on the assessment of the unit prices analyzed.
- Estimate of the maintenance and rehabilitation project cost covering all the study bridges.

III-8-1 Unit Price Analysis for the 20 Bridges

(1) Basic Condition

Following basic conditions were applied in the cost estimate:

- Price level of labour, material and equipment is based on December, 1991 figures.
- The unit rates of the above items are derived from market investigation and some from JKR.
- The unit rates are in and around Kuala Lumpur and the local deviation of the rates is not considered in the estimate.

Note (1) Two bridges were found in good condition in the supplemental survey. Thus total number of the study bridges is reduced to 203 bridges.

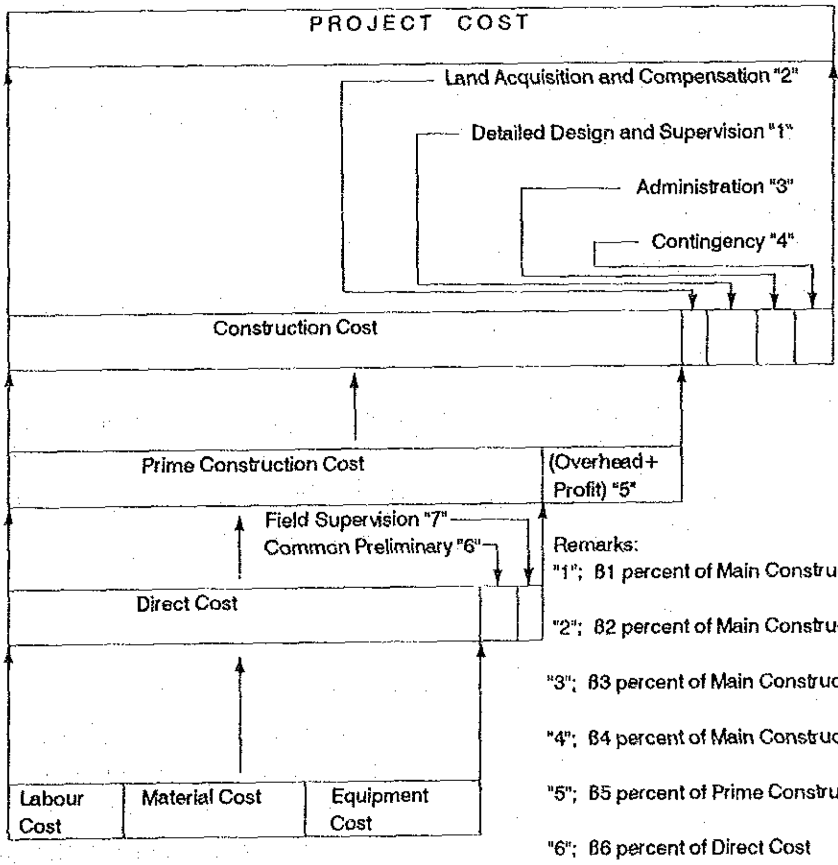
- Except for the direct cost, other costs such as contractor's overhead and profit, detailed design and supervision cost, etc. are computed using the multiplier factors.

(2) Structure of Project Cost

Project cost consists of construction cost, land acquisition and compensation, engineering cost, administration cost and contingency. The construction cost is divided into prime construction cost and contractor's overhead and profit. The prime construction cost is further subdivided into direct costs comprising of labour cost, material cost and equipment cost, and indirect costs such as field supervision cost and common preliminary work cost.

Structure of the project cost is depicted in Figure III-10.

Figure III-10 Structure of Project Cost



Remarks:
"1"; β1 percent of Main Construction Cost
"2"; β2 percent of Main Construction Cost
"3"; β3 percent of Main Construction Cost
"4"; β4 percent of Main Construction Cost
"5"; β5 percent of Prime Construction Cost
"6"; β6 percent of Direct Cost
"7"; β7 percent of Direct Cost plus Common Preliminary Works

The multiplier factors for respective indirect items applied in the Study are tabulated in Table III-12.

Table III-12 Applicable Multiplier Factors for Indirect Items

Factor	Description	Multiplier Factor (%)	Parameter
β 1	Detailed Design and Supervision	6 4	Construction Cost
β 2	Land Acquisition and Compensation	0	N/A
β 3	Administration	3	Construction Cost
β 4	Contingency i) Physical Contingency ii) Price Contingency	15 -	Construction Cost
β 5	Overhead + Profit	20	Prime Construction Cost
β 6	Common Preliminary Works	5	Direct Cost
β 7	Field Supervision	4	Direct Cost

Consequently the project cost is given by the following equation based on the structure of project cost and is the one hundred sixty eight (168) percent of the Direct Cost.

Project Cost = Direct Cost x $\{1+\beta6+(1+\beta6)\cdot\beta7\}$ x $(1+\beta5)$ x $(1+\beta4+\beta3+\beta2+\beta1)$
= Direct Cost x $\{1+0.05+(1+0.05)x0.04)x(1+0.20)x(1+0.15+0.03+0+0.10)$
= Direct Cost x 1.68

(3) Unit Price Analysis

In the unit price analysis, the following procedures were taken so as to ensure that the analysis results are as precise as possible.

- The production rate stated in the Cost Estimate Manual published by the Ministry of Construction in Japan are modified taking into account labours' skillfulness, unit material usage, efficiency of equipment, operator's capability and so on in Malaysia as well as based on those in the similar projects in ASEAN countries.

- Applying the modified production rates of various items, the unit prices are calculated.

- The production rate applied in the above calculation is calibrated based on comparison with unit prices obtained from JKR and market research.

- Finally the unit price of each work item is recalculated using the calibrated production rate.

Based on the above exercise, all the unit prices for respective work items covering 20 bridges were analyzed.

III-8-2 Standard Unit Prices of Respective Rehabilitation Methods

Standard unit prices which should be applicable to the remaining bridges for the purpose of the total project cost estimate were analyzed based on the assessment of the unit prices for the 20 bridges.

(1) Classification of Unit Prices for the 20 Bridges

The unit prices analyzed for 20 bridges were reviewed from applicability viewpoint to the other bridges and were classified into the following four categories.

Category A : These are not affected by job site condition and thus applicable to the rehabilitation method in other bridges without any modification.

Category B : These are slightly affected by the job site condition but the work sequences are similar in every bridge. Thus, average unit price of those of 20 bridges is considered as the standard unit price.

Category C : These are for functional rehabilitation works. Thus, these are only applicable to the other bridges provided that rehabilitation method, the work scale and bridge type of the other bridge are the same as those in the original unit price.

Category D : Where the unit prices are considerably affected by the job site condition and size of the bridge member to be rehabilitated. These are not applicable to other bridges without standardization of these unit prices.

(2) Standard Unit Price Analysis

Based on the classification of unit prices, the unit prices under Category C require to be analyzed individually on a case by case basis, while the unit prices under Category D involving those for concrete pile lining and hydraulic rehabilitation plan require to be standardized.

For unit prices for various sizes of concrete pile lining, standard unit price of the pile lining for different size of piles was obtained after calibration of those unit prices by interpolation methods.

For standard unit prices of hydraulic rehabilitation plans, standard unit quantities of each rehabilitation method were estimated referring to the standard design, and standard unit price of each method was estimated.

Consequently, based on the above mentioned exercises, the standard unit price of each individual method is prepared and is used to estimate project cost of each of the remaining bridges.

III-8-3 Project Cost Estimate

In the supplemental bridge survey covering 199 bridges, rehabilitation methods of each bridge were identified and the corresponding work quantities were also estimated accordingly. While standard unit prices applicable to most of the rehabilitation methods of those bridges were analyzed in the previous section based on the assessment of the unit prices covering various rehabilitation methods of the 20 bridges for the detailed survey.

However, some of these standard unit prices are not applicable to several rehabilitation methods such as widening of carriageway, adding sidewalk, raising of bridge grade as well as total replacement, the unit price of which depends on the bridge type and configuration of the bridge. Those unit prices were individually estimated after referring to a breakdown of unit prices of the similar rehabilitation methods.

The project cost of each bridge was obtained by adding each rehabilitation amount assigned in the bridge and the total project cost covering 203 bridges was estimated at M$58.148 million while the cost breakdown of each cost item is shown in Table III-13.

Table III-13 Breakdown of Project Cost

Cost Item	Amount (Million M$)
Construction Cost	45.428
Engineering Cost	4.543
Administration Cost	1.363
Contingency	6.814
Total	58.148

III-9 Economic Evaluation

The purposes of the economic evaluation are to evaluate the economic viability of each of the 203 bridges and to provide information for the preparation of an implementation program.

The study methodology was determined based on the following principles:

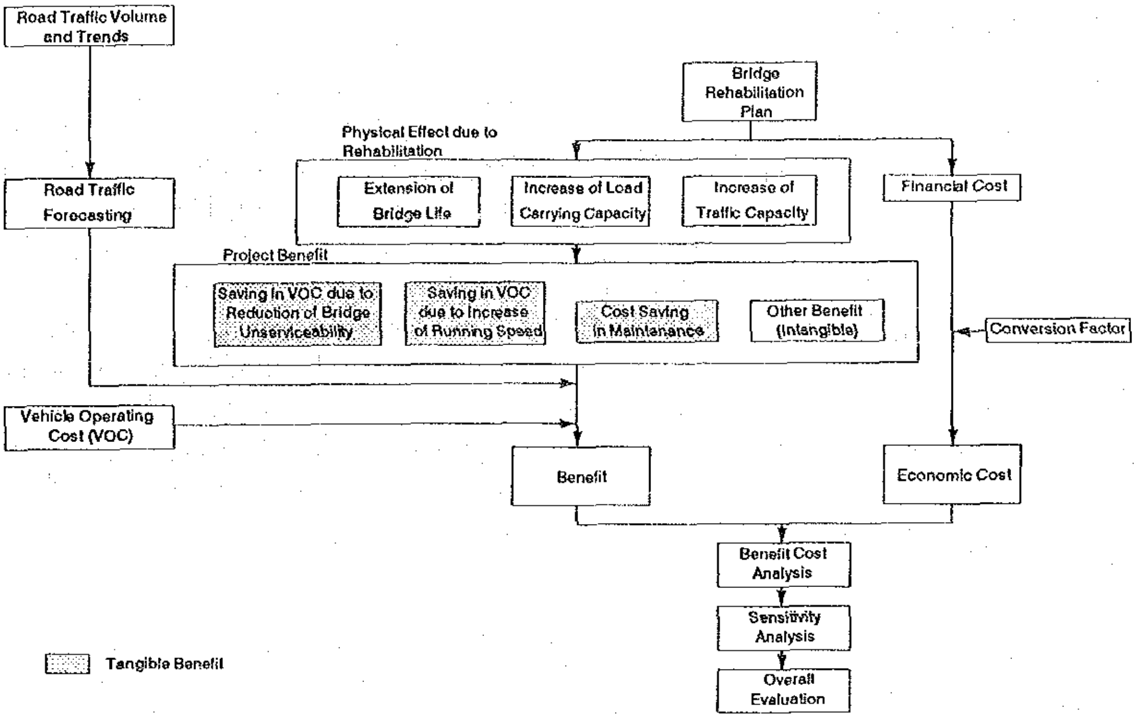
- The method of evaluation shall be simplified due to the large number of bridges to be evaluated and to the relatively small cost of individual bridge rehabilitation work.

- Future traffic volume shall be estimated by utilizing existing traffic data to the maximum extent.

- The result of economic evaluation shall be easily reviewed by JKR corresponding to the possible changes in the future traffic situation.

In accordance with the above principles for the evaluation, the following procedure was taken as shown in Figure III-11.

Figure III-11 Flow Chart of Economic Evaluation



III-9-1 Traffic Projection

The procedure applied in traffic forecast using the trends model is as follows:

- Identify a traffic count station corresponding to each bridge.
- Determine traffic volume (16 hours) by vehicle type and growth rate for each bridge.
- Convert 16-hour traffic volume to vehicle per day (VPD).
- Set growth rate at zero if it is calculated negative.
- Calculate future traffic volume using the growth rate.
- Break down daily traffic volume into vehicle type using the present model shares.

In this study, "Traffic Volume Malaysia 1989" issued by Highway Planning Unit (HPU) was referred to for traffic count data.

III-9-2 Economic Cost

Cost components considered in the analysis consist of rehabilitation cost which is the investment cost needed to improve the bridge durability and to enhance bridge function, and maintenance cost which is continuously required to keep the bridge in service condition after it has been rehabilitated.

Those financial costs were converted to economic cost by using authorized average conversion factor (CF) of related works published by the "Economic Planning Unit" in the Prime Minister's Department. CF in this analysis was taken to be 0.8, hence the economic project cost for the bridge rehabilitation project was then evaluated to be M$46,518,614 (derived from financial cost of M$58,148,267 x 0.8).

Since maintenance cost varies depending on the environment and socio-economic condition of area, and in the absence of maintenance cost standards in Malaysia, those standards used in OECD countries were studied and the values were adjusted for Malaysian conditions. Based on this study it was then proposed that the maintenance cost after rehabilitation by reconstruction and widening, reinforcement, and protection shall be taken as 2.5%, 5% and 10% of rehabilitation cost over a 5-year period respectively.

III-9-3 Benefit Measurement

The following three kinds of tangible benefits accrued from bridge rehabilitation were considered in this Study:

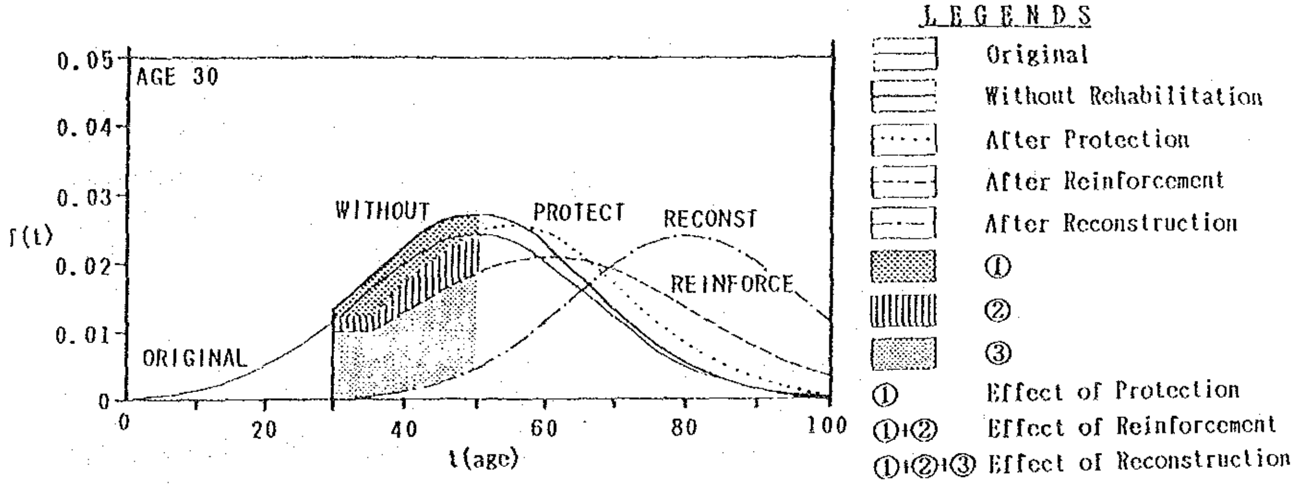
(i) Savings in vehicle operation cost due to a reduction of interruption to traffic flow. Improvement of bridge durability reduces number of days of traffic interruption (i.e. extending bridge life), and therefore saves operation cost due to detours.

(ii) Saving in vehicle operating cost due to an increase in vehicle speed. Bridge widening makes it possible for vehicles to keep at constant speed on and near the bridge.

(iii) Maintenance Cost Savings
The maintenance cost savings can be expected on the bridge administrator side. The benefit comes from the difference in maintenance cost between "with" and "without" project cases.

In order to quantify the saving in vehicle operation cost due to a reduction of interruption to traffic flow, a probability model for traffic interruption due to bridge failure was incorporated based on the assessment of "Statistical Analysis on Bridge Life" (H.Iizuka, JSCE, 1988) in Japan. The benefit is quantified as the difference of the probability for traffic interruption between "without rehabilitation" and "with rehabilitation" cases as depicted in Figure III-12.

Figure III-12 Probability Density of Bridge Unserviceability, With and Without Rehabilitation



In calculating the above three tangible benefits, vehicle operation cost and equivalent bridge age applied are shown in Table III- 14 and Table III-15 respectively.

Table III-14 Vehicle Operating Costs by Vehicle Type

(M$/km)

Vehicle Type	M'cycles	Cars & Taxis	Buses	S. Vans & Utilities	Medium Lorries	Heavy Lorries
Normal Route	0.046	0.184	1.517	0.498	0.785	1.059
Detour Route	0.055	0.220	1.859	0.632	0.911	1.147
Before Widening	0.066	0.266	2.761	0.867	1.248	1.579

Table III-15 Assumed Equivalent Bridge Age

Overall Rating from Safety Viewpoint (R)	Traffic Volume (AADT : Vehicle/day)	Year Built	
		Before 1945	After 1945
$4.0 \leq R$	Regardless of Traffic Volume	45	40
$3.5 \leq R < 4.0$	AADT $\geq$ 9,000	45	40
	AADT < 9,000	40	30
$R < 3.5$	AADT $\geq$ 9,000	40	30
	AADT < 9,000	30	20

Based on the above assumptions, the equations for calculating tangible benefits were developed based on two options; (1) bridge rehabilitation (with project); and (2) do nothing (without project).

III-9-4 Economic Evaluation

In this analysis, the three parameters as listed below were used for economic evaluation.

- Benefit/Cost Ratio (B/CR)
- Net Present Value (NPV)
- Internal Rate of Return (IRR)

In the above calculation, a discount rate of 11% per annum was taken and the project life was assumed to be 20 years starting from 1994.

III-9-5 Economic Evaluation Results

(1) Entire Project

As a whole project, most of the benefits are derived from the reduction of the duration of traffic interruption due to bridge failure. The benefit is large enough as compared to the cost with a benefit cost ratio of 6.75 and an internal rate of return of 58%. The project is considered to be feasible as a whole.

(2) Individual Bridge Basis

The internal rate of return exceeds 11% for 197 bridges out of 203. For the remaining 6 bridges, it was also observed that the benefit grew by retarding rehabilitation for 5 years and the internal rate of return was improved; 3 bridges became feasible with an internal rate of return of more than 11% and the other 3 bridges gained an internal rate of return of at least 6%.

The project is considered to be implemented for all the bridges including the above 6 based on the following reasons:

- The entire project is considered to be fully justified because 97 % of the bridges are feasible for rehabilitation in 1994 and 99 % in 1999.
- For the 3 bridges with an IRR of less than 11% for rehabilitation in 1999, intangible benefits not included in the calculation can be added due to the service level and reliability of a nation-wide road network improved by the proposed rehabilitation.

(3) State Basis

Economic evaluation results were compiled by State basis. The IRR by State ranges between 26 and 99%, indicating that the project packaged by State is also feasible. The reason of the highest IRR of 99 % in Perak State is the lack of a detour route if the federal road No. 59 becomes impassable. Pahang State also has a high IRR at 82% due to the low density of arterial roads. For Trengganu State, the lowest IRR at 26% can be attributed to 2 bridges that need reconstruction and large-scale rehabilitation.

(4) Conclusion

The following is concluded as a result of the economic evaluation for the 203 bridges (13 bridges were excluded from the 216 bridges).

(i) Implementation of the project for the 203 bridges is well justified because 97% of the bridges are feasible for rehabilitation in 1994 and 99% in 1999.

(ii) 6 individual bridges have an IRR less than 11% for rehabilitation in 1994. Due, however, to possible intangible benefits including to keep entity of the road network, these bridges should be incorporated in the proposed project. Moreover, the IRR of these bridges can be easily improved by retarding rehabilitation work.

(iii) If implementation program is formulated by route or by State basis only based on the calculated IRR or other parameters, some problems including work concentration can be anticipated as described below. These problems should be avoided by careful arrangement of the program.

- o Traffic flows in and around a particular route will be largely hindered.
- o Work capacity of local contractors could be exceeded.
- o JKR State and District local engineers who manage and supervise the work may be in shortage.

III-10 Rehabilitation Program

It was concluded based on the economic evaluation that all the study bridges are technically and economically viable and the implementation of a bridge rehabilitation project covering all the bridges should be carried out within the earliest possible time according to the Government policy as emphasized in the "Sixth Malaysia Plan 1991-1995". However, all the study bridges totaling 203 numbers are extensively scattered over the whole Peninsular and the extent of rehabilitation work required for each bridge also widely varies from only a simple protection work to total bridge replacement. Therefore, a proper rehabilitation program is required to ensure that the project will be implemented effectively and smoothly.

III-10-1 Framework for Programming

(1) Implementation Period

The critical elements to decide the implementation period in this project have been identified to be mainly the Government's financial arrangement capability and technical aspects that mean gradually increasing risk of the loss of structural safety and traffic hazards in the study bridges.

From the financial viewpoint, it is fact that the Government has allocated M$5,577.6 million for the federal roads and bridges development in the "Sixth Malaysia Plan" covering five years from 1991 to 1995. On the other hand, the total project cost was estimated at M$58 million, which is equivalent to about 1.0% of the development funds allocated in the "Sixth Malaysia Plan", assuming a five year implementation period. Therefore, it is concluded that the Government presumably has enough capability to allocate the required project funds. It should be noted that the 1.0% is an acceptable level compared with that in Japan, considering the accumulative maintenance and rehabilitation bills resulted from almost no practical maintenance and rehabilitation works being undertaken since the bridges were built in Malaysia.

From the technical viewpoint, the Study results revealed that some of the study bridges have been critically deteriorated/damaged and all of them have suffered various advanced defects. Accordingly, it is strongly recommended that the rehabilitation work is required to eliminate loss of traffic safety and to decrease risk of bridge failure within the earliest possible time.

Consequently, it is recommended that five years is suitable as an implementation period mainly from the Government's financial arrangement capability and the technical aspects.

(2) Packaging

The economic evaluation results pinpointed various adverse effects if the packaging is done on roadlink basis or on a state basis. To overcome this problem, the concepts in packaging are as follows:-

- Priority of each bridge implementation is basically determined by the economic index of IRR.
- In a package, the bridge arrangement within a certain stretch or area shall not be concentrated in order to prevent any hindrance of the present smooth traffic flow, to overload contractors' resources and to overcome shortage of the government staff for the management and supervision.

- It is essential to transfer the maintenance and rehabilitation technology from the federal JKR to the state and district JKRs in the project implementation to enhance the JKR engineers and technicians' capability as well as to train a sufficient number of staff. Therefore, in order to create the project participation opportunity at every project year, the project bridges within a State or District shall be allocated equally in terms of number of bridges throughout the five year implementation period.

Based on the above concepts, the 203 bridges are divided into five packages and a summary of each package is shown in Table III-16 together with overall economic index of each package.

Table III-16 Summary of Each Package

Package No.	No's of Bridges	Total Project Cost (M$)	Overall Economic Index	
			IRR	BCR
I	64	10,480,400	94.9%	12.03
II	46	11,306,579	77.7%	10.01
III	37	13,998,253	45.3%	5.14
IV	29	11,508,034	38.7%	4.13
V	27	10,855,002	28.6%	2.82
TOTAL 5	203	58,148,268	57.8% /1	6.75 /1

Note : /1 Index showing the whole project

III-10-2 Implementation Schedule

In principle, it is assumed that construction including tendering of each package shall be completed within one Malaysian fiscal year (which is from January 1st to December 31) because the project will be financed by the Government of Malaysia.

Main work items for the scheduling consist of detailed engineering design, tendering activities and construction.

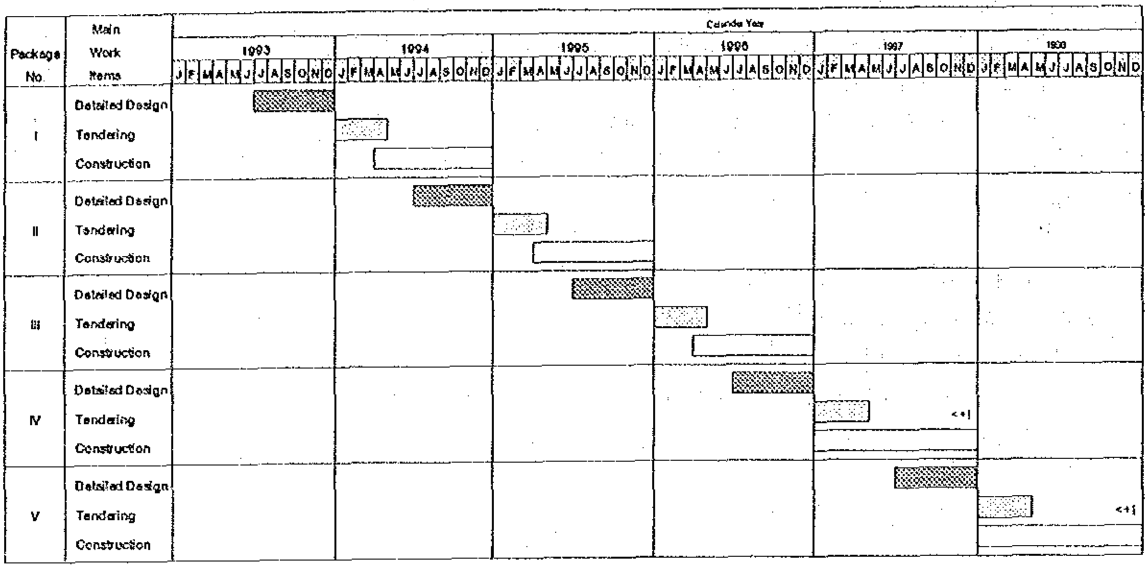
The detailed design should be carried out one year in advance of the construction and it will take about six months to complete the design of each package.

The tendering activities shall commence on the first week of January of each fiscal year and will take four months to complete.

The construction of each package shall commence on the first week of every April and be completed by the end of every December in principal.

Assuming commencement of the package I in 1994, the project will be completed by the end of 1998. The overall implementation schedule is depicted in Figure III-13.

Figure III-13 Implementation Schedule



Note : : ⬚ Indicate rainy season from November to February.
<+|: Rehabilitation works for Bridge No. 317000 and 308080 are carried out continuously during the two or three years from 1996 to 1998
: Fiscal year in Malaysia from January 1 to December 31

III-10-3 Funding Schedule

The total project cost is 58.148 million Malaysian ringgit at the December 1991 price level. In light of the implementation schedule, the project funding schedule of each year is shown below.

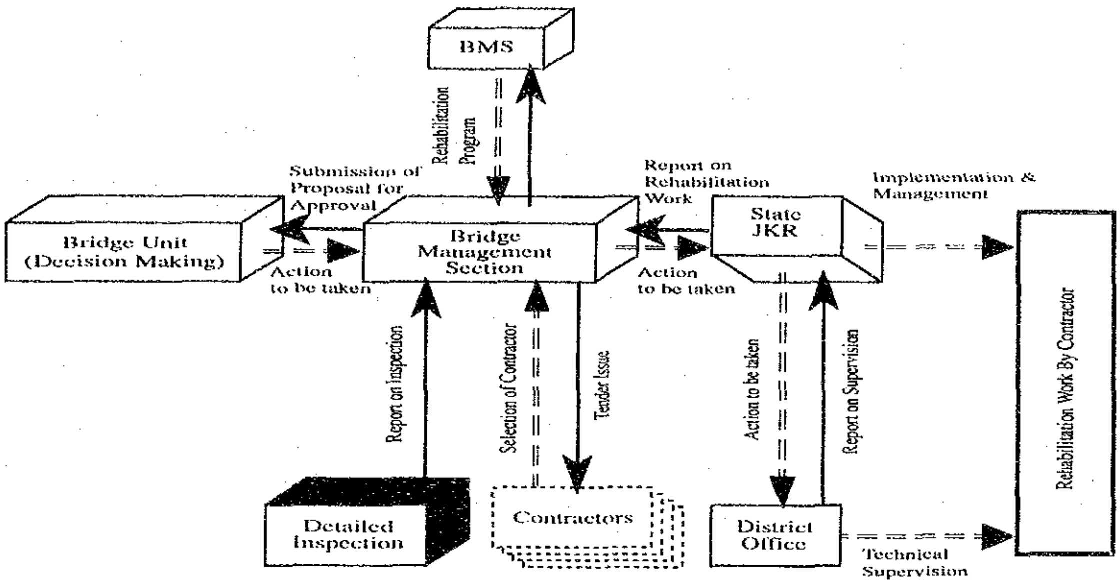
YEAR	FUNDS REQUIRED FOR EACH YEAR M$ MILLION
1993	0.678
1994	10.333
1995	11.851
1996	13.646
1997	11.295
1998	10.345
TOTAL	58.148

III-10-4 Project Management and Organization

The Bridge Unit in JKR is an executing agency for the implementation of the project. The responsibilities of the agency are to carry out the detailed rehabilitation design and tendering activities. While the State JKR and the District JKR are responsible for construction management and monitoring of the project, and the direct construction supervision respectively.

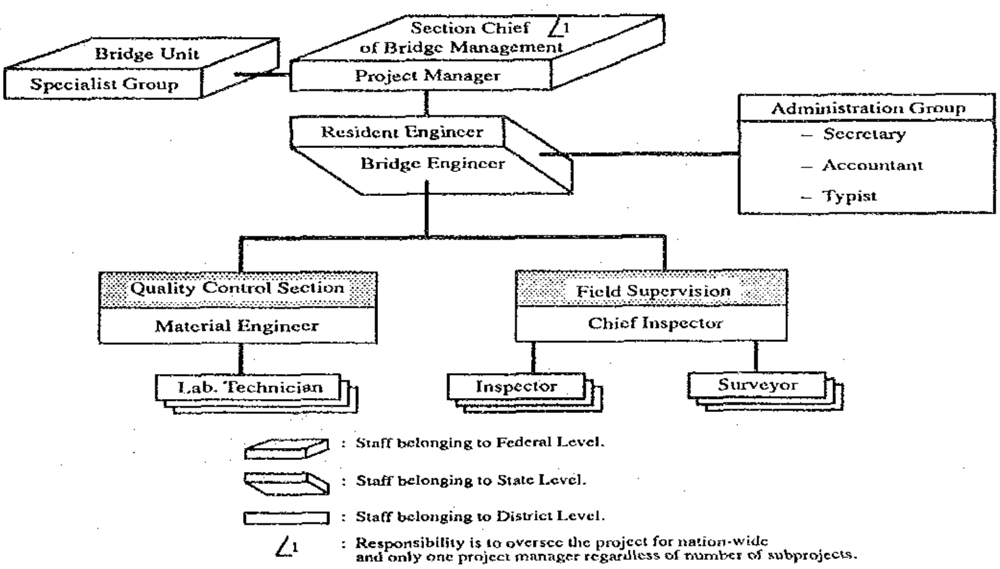
Schematic interrelationship between those agencies is depicted in Figure III-14 which indicates the direction flow, responsibility and function of the agencies concerned.

Figure III-14 Schematic Interrelationship between the Agencies



In principle, the project shall be executed on a contract basis by contractors selected through competitive biding. Therefore the Government must organize a construction supervision team(s) to manage and supervise the contractors' field works but the size and staffing of the organization depend on number of the bridges to be rehabilitated, their locations and scale of the respective rehabilitation works. For reference purpose, a typical organization is shown in Figure III-15 assuming it is required to manage and supervise a subproject covering about 15-20 bridges at a time.

Figure III-15 Typical Organization for Construction Supervision



JICA