GOVERNMENT OF MALAYSIA
MINISTRY OF WORKS
PUBLIC WORKS DEPARTMENT

THE STUDY ON THE MAINTENANCE AND REHABILITATION OF BRIDGES IN MALAYSIA

FINAL REPORT

VOLUME I

EXECUTIVE SUMMARY

DECEMBER 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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CURRENCY EQUIVALENTS
(As of 31 December 1991)

Currency Unit - Ringgit (M$)
M$ 1.00 =US$ 0.366=Yen 45.862

PREFACE

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

JICA sent to Malaysia a study team headed by Mr. Hisashi OHSHIMA from Nippon Koei Co., Ltd., three times between September 1990 and October 1992.

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

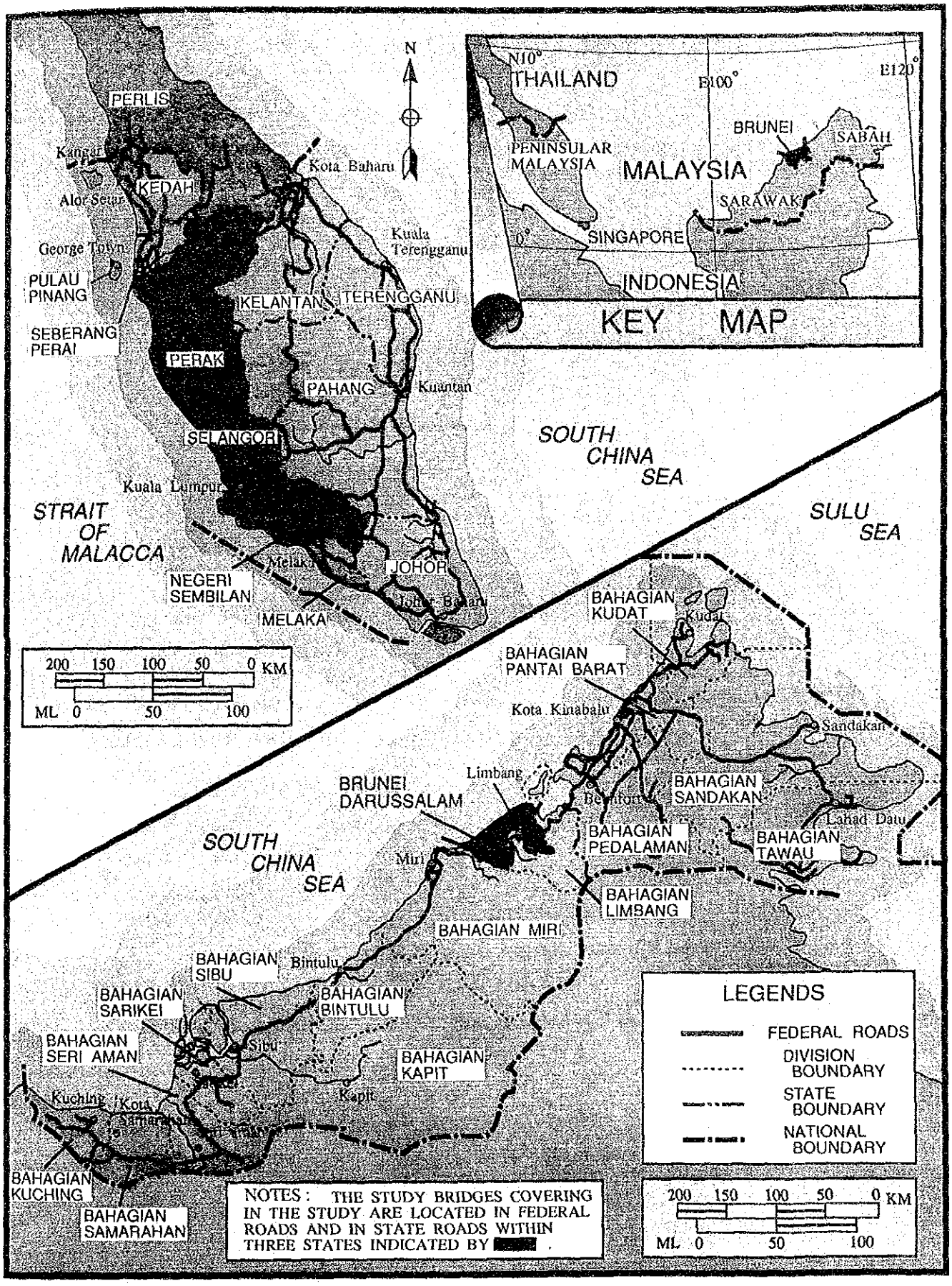
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

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

December 1992

Kensuke Yanagiya

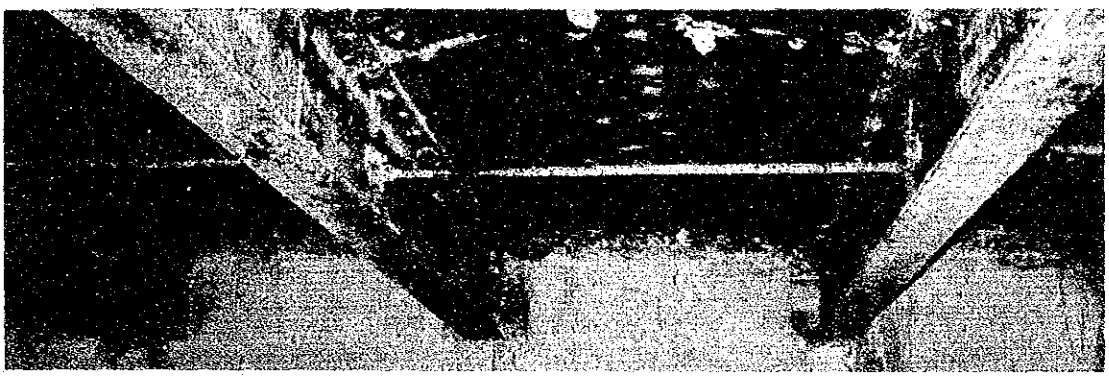
Kensuke Yanagiya
President
Japan International Cooperation Agency



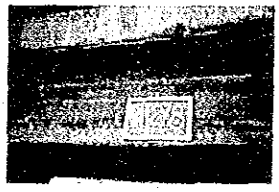
LOCATION MAP

Photos of Typical Construction Type and Defects

1. Steel Beam with Buckle Plate Bridge (SBB)



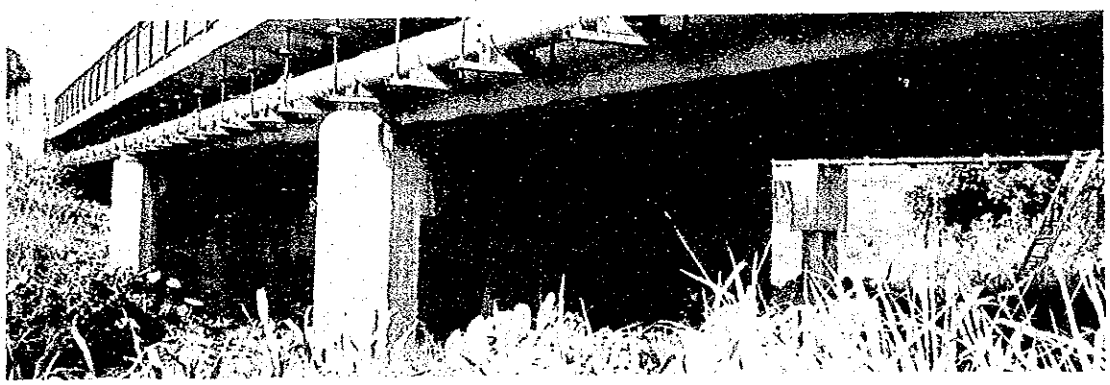
Cross Section



Lamination of Lower Flange

Corrosion of Web Plate and Sediment Accumulation on Lower Flange

2. Steel Beam with Concrete Deck Slab Bridge (SBC)



General View

Paint Deterioration

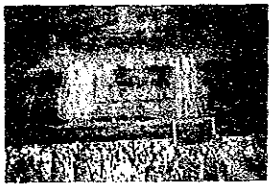
Two-Way Cracks on Deck Slab Soffit

Photos of Typical Construction Type and Defects

3. Reinforced Concrete Beam Bridge (RCB)

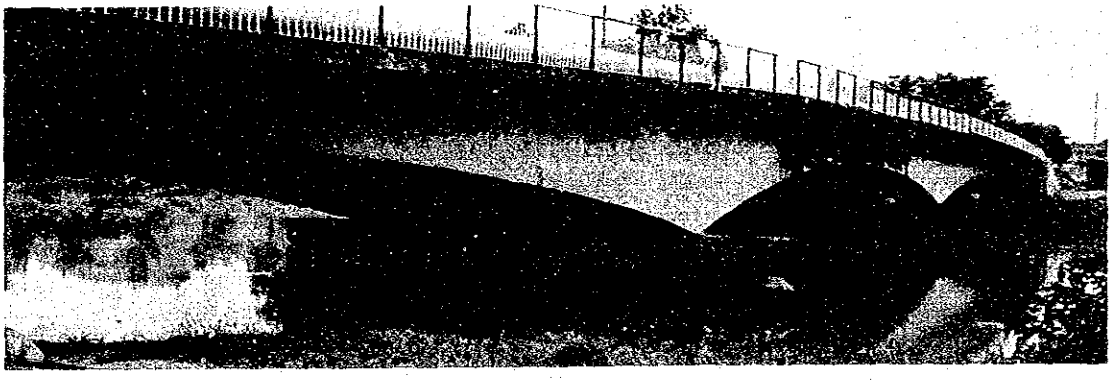
General View

Flaking and Rebar Exposure

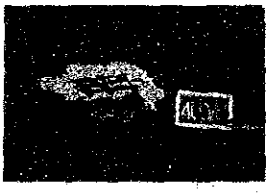


Free Lime

4. Reinforced Concrete Slab Bridge (RCS)



General View



Flaking and Rebar Exposure

Water Leakage and Flaking

Photos of Typical Construction Type and Defects

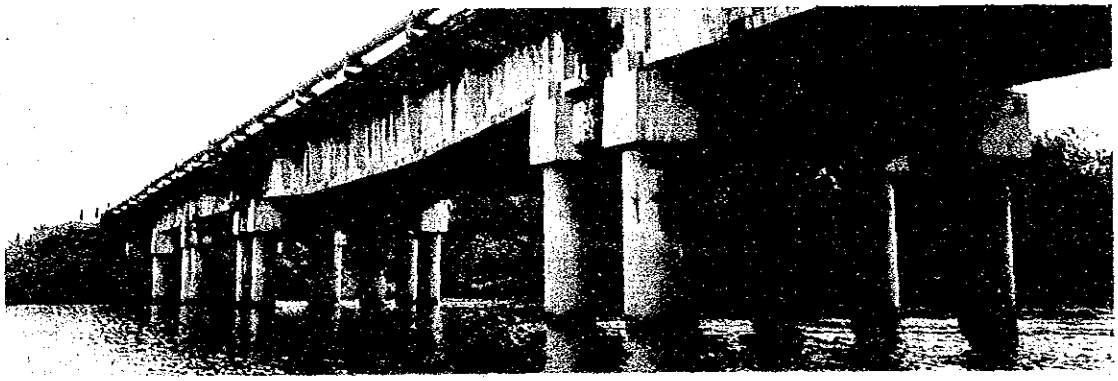
5. Precast Reinforced Concrete Beam Bridge (PRB)

General View

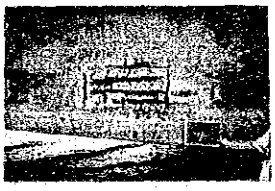
Free Lime and Water Leakage between Beams

Flaking and Rebar Exposure

6. Prestressed Concrete Beam Bridge (PCB)



General View

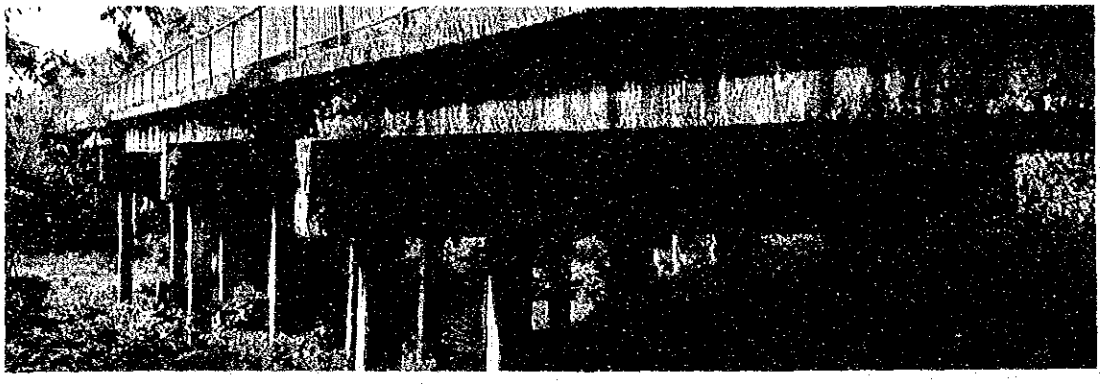


Exposed P.C. Tendon on Beam Web

Reber Exposure on Deck Soffit

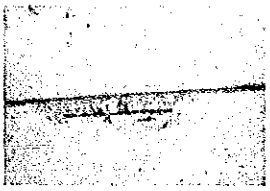
Photos of Typical Construction Type and Defects

7. Pretensioned Inverted Tee Beam Bridge (IT)



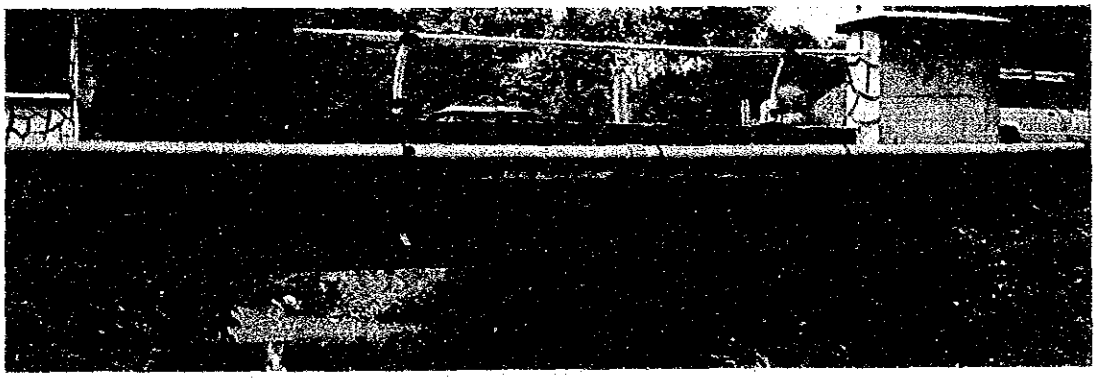
General View

Free Lime and Water Leakage between Beams



Exposed P.C. Tendon on Beam Soffit

8. Encased Steel Beam Bridge (SBE)



General View

Exposed Lower Flange of Steel Beam

Flaking and Rebar Exposure on Deck Soffit

Photos of Typical Construction Type and Defects

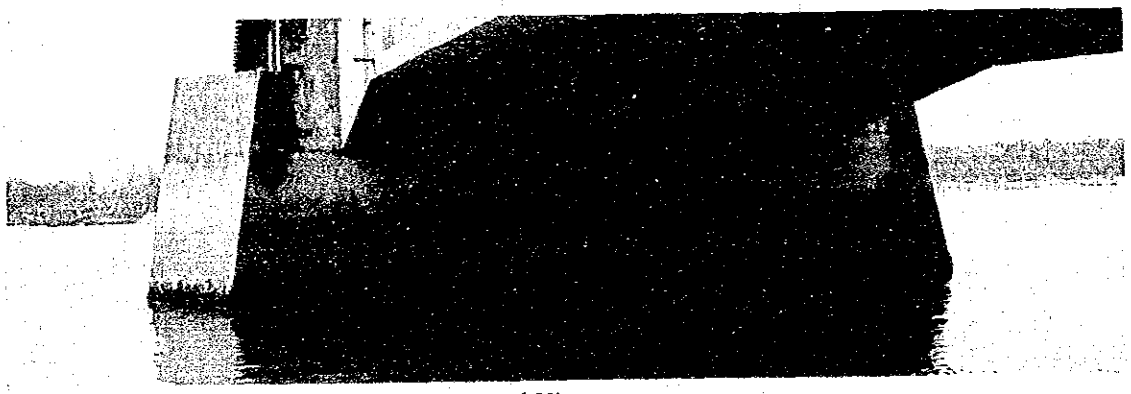
9. Pile Bent Type Abutment and Pier

General View

Abrasion due to Acid Attack

Longitudinal Cracks on Pier Column

10. Wall Type Pier



General View

Flaking and Rebar Exposure

Vertical Crack on Wall

PRINCIPAL EXECUTIVE SUMMARY

PART A: OUTLINE OF THE STUDY

In response to the request from the Government of Malaysia (GOM), the Government of Japan (GOJ) decided to conduct the Study on the Maintenance and Rehabilitation of Bridges in Malaysia (the Study). Accordingly, the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of technical cooperation programs of GOJ, organized a Study Team to implement the Study. The Study Team was dispatched to Malaysia in September 1990 and the Study officially commenced with the submission of the Inception Report. After twenty seven months, the Study was completed in December 1992 with the submission of the Final Report and the Bridge Inspection, Maintenance and Rehabilitation Manual.

The principal objectives of the Study are twofold:(1) To develop a systematic maintenance and rehabilitation program for bridges in Peninsular Malaysia, and (2) To establish a manual for inspection, maintenance and rehabilitation work covering all the typical bridges in Malaysia.

The Study covered 216 Federal bridges located along the Federal roads in Peninsular Malaysia with condition rating given by the National Axle Load Study (NALS) as 3 (defined as bridge with significant defect), 4 (in structurally dangerous condition) or study category of Substandard Axle Load (SSAL). The Study also included 30 selected Federal bridges in Sabah and Sarawak and 40 selected State bridges in the States of Perak, Selangor, and Negeri Sembilan with the aim of conducting visual inspection and reflecting the inspection results into the Manual.

In the Study, an extensive data collection exercise and field survey were carried out and the main field surveys undertaken were as follows:

- Visual inspection for 100 bridges consisting of 95 selected out of the above 216 bridges and 5 special bridges selected by GOM, and for 70 bridges selected by GOM which made up of 30 Federal bridges in Sabah and Sarawak, and 40 State bridges as mentioned above. Visual inspection carried out at each bridge site involved measurement survey, field interviews, damage condition rating, photographing, and assessment of possible rehabilitation plans.

- Detailed structural survey for 20 bridges consisting of 17 bridges out of the 95 selected bridges, 1 bridge out of the five special bridges and one bridge each in Sabah and Sarawak from the 30 bridges inspected. The detailed structural survey included topographic survey, subsoil and water investigation, and river hydrological survey. In addition to these field surveys, full scale bridge loading tests were carried out for a total of five spans at three different bridge sites.

- Supplemental bridge survey was also carried out for a total of 199 bridges since NALS did not cover the quantitative damage data of these bridges, as originally anticipated. These bridges consisted of 121 bridges which were discarded for the visual inspection and 78 bridges which were visually inspected but discarded for the detailed structural survey. The purpose of the supplemental survey was to obtain the bridge data for planning maintenance and rehabilitation programs covering all the study bridges, i.e. to measure the extent of damage, to identify rehabilitation method, and to estimate the work quantity. In the supplemental bridge survey, it was found that 11 study bridges have been replaced and 2 study bridges have no defects. Thus, the total number of the 216 study bridges was reduced to 203 bridges.

Based on the information collected through the above field survey, assessment works for the study bridges were carried out from structural, functional and hydraulic viewpoints to identify and diagnose all defects so that suitable rehabilitation methods can be selected to effectively rectify the cause of the defects.

Assessment from the structural viewpoint is divided into two categories; one is material deterioration and the other is load carrying capacity. The material deterioration assessment was carried out through the visual inspection, while the assessment of load carrying capacity was carried out through structural analysis for only 20 representative bridges to identify which structural member is inadequate or adequate in carrying "Long Term Axle Load (LTAL)" loading. The results of the structural analytic assessment for the respective bridge types were used to estimate adequacy of the load carrying capacity of structural members in the remaining same bridge types.

The bridge functional assessment was carried out in terms of traffic capacity, pedestrian flow capacity, and bridge opening capacity. Traffic capacity of each study bridge was evaluated by means of comparison between the calculated total service flow rate in both directions and the present total traffic volume at traffic count station near the bridge obtained from "Traffic Volume Malaysia". Pedestrian flow capacity on each study 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. Bridge opening capacity was also assessed to determine whether it can accommodate flood runoff discharge through interview surveys with residents living near the bridge site and also based on the flood information collected from each Drainage & Irrigation Department (DID) District office.

The assessment from hydraulic viewpoint for each study bridge was carried out through the visual inspection to identify flood marks and local scouring/bank erosion locations, to confirm the main water course and to evaluate whether the riverbed is rising or lowering. Furthermore, hydrological analysis for the selected major bridges was also carried out to theoretically estimate the magnitude of floods, the flow capacity of the river at bridge site and the flood level at the bridge site.

Based on diagnosis of all the defects identified through the above exercises such as structural, functional and hydraulic assessments, suitable rehabilitation methods were selected for each defective member or each defective bridge. Accordingly, the work quantity of each rehabilitation method was estimated on a bridge by bridge basis.

The rehabilitation methods selected in the Study were broadly divided into three categories; structural, functional and hydraulic. The structural rehabilitation work is to rectify a deteriorated bridge member or to strengthen a bridge member which has inadequate load carrying capacity, while the functional rehabilitation work is to improve the bridge function by widening carriageways, adding sidewalks, or raising bridge grades. The hydraulic rehabilitation method is mainly to protect river banks or river beds in the vicinity of abutments and river piers.

To estimate the project cost, which was broadly divided into direct cost and indirect cost, the multiplier factors for indirect cost items such as engineering, land acquisition, administration, and contingency were first assessed and determined referring to similar projects. Secondly, the unit price of each rehabilitation method was analyzed to estimate the direct construction cost. The project cost of each study bridge was then estimated by multiplying the estimated work quantity and the corresponding unit price analyzed. The total project cost covering the 203 study bridges was estimated at M$58.148 million.

The economic evaluation followed the project cost estimate. The trends model was applied to project the traffic volume based on the traffic count data available in "Traffic Volume Malaysia 1998", while the estimated project cost was converted to economic cost by using the authorized average conversion factor (CF) of related works published by the "Economic Planning Unit". The tangible benefits accrued from the bridge rehabilitation and considered in this Study are three categories; (1) saving in vehicle operation cost due to a reduction of traffic flow interruption period, (2) saving in vehicle operation cost due to an increase of vehicle speed, and (3) saving of maintenance cost between "with" and "without" project cases.

The economic evaluation was carried out using three parameters; Benefit/Cost Ratio (B/C), Net Present Value (NPV) and Internal Rate of Return (IRR),and assuming a project life of 20 years starting from 1994. The results indicated that the benefit which is mostly derived from the reduction of the traffic interruption period due to bridge failure is large enough as compared to the cost with a benefit cost ratio of 6.75 and an internal rate of return of 58 % as a whole project. Furthermore, the economic evaluation of individual study bridge revealed that the 197 study bridges, or 97 % of the 203 study bridges, are economically viable in 1994. The 6 remaining bridges are also substantially feasible in 1999 due to enhancing an internal rate of return by retarding the rehabilitation for 5 years.

PART B : CONCLUSION

B-1 Necessity of Bridge Maintenance and Rehabilitation

The growth of the transport and communication sector, especially the road network in the road transport subsector, has been playing an important part in the national growth and economic expansion of the country. On the road network, bridges are key elements because of their strategic location and the adverse consequences when their capacity is impaired.

Out of the 216 study bridges, 34 (15.7%) were constructed before 1945 and 180 (83.3%) were built between 1946 and 1974. On the type of construction, 76 (35.2%) are steel beam buckle plate (SBB) bridges which have major structural and maintenance problems. Hence, the aging and inadequate load carrying capacity of these bridges are one of the most potential problems. Moreover, the rapid growth of total traffic volume and increase in the traffic loads require bridge widening and an increase in the bridge load carrying capacity. To make matters worse as revealed in the Study, river water and air pollution have aggravated deterioration of the bridge materials due to chemical attack, chloride attack as well as carbonation.

In order to prevent the adverse consequences such as a loss of traffic safety and a reduction of structural safety, and to avoid an increase of the Government expenditure for bridge replacement, there is clearly a need to carry out bridge maintenance and rehabilitation in Malaysia as a matter of urgency.

B-2 Implementation of the Project

Based on the preliminary rehabilitation design and the economic evaluation carried out in the Study, it was concluded 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, in conforming with the Government policy emphasized in the "Sixth Malaysia Plan 1991-1995". The total project cost covering 203 bridges amounts to M$ 58.148 million, December 1991 price levels, as shown below:

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

PART C : RECOMMENDATIONS

C-1 Project Implementation

It is recommended that the bridge maintenance and rehabilitation covering a total of 203 bridges, defined as "A Project", shall be implemented based on the following reasons:

(i) All of the study bridges have suffered various distresses or damages and some of them are in critical condition;
(ii) Those bridges can be improved by mainly using standard rehabilitation or strengthening techniques;
(iii) The economic evaluation results indicate that the project is economically highly feasible;
(iv) The Government of Malaysia, presumably, has enough financial capability to prepare the total project cost.

With consideration of the Government's financial arrangement capability as well as urgency of the project implementation, the following key aspects are recommended.

(i) The project covering 203 bridges shall be divided into five packages;
(ii) The construction of the first package shall be commenced in early 1994; and
(iii) In principle, each package shall be completed within one Malaysian fiscal year and the project be completed by the end of 1998.

C-2 Technical and Institutional Recommendation

(1) Need to Eliminate Design and Construction Deficiencies in New Bridges

The study results revealed that various deficiencies observed in the study bridges included the deficiencies due to improper bridge design and construction. It is, therefore, obvious that these deficiencies should be eliminated in new bridge design and construction, otherwise the workload of the maintenance and rehabilitation will never be reduced in the future.

In order to eliminate those deficiencies, the following measures should be taken;

- Standard design of appropriate types of superstructures covering span length from 10m to 40m and typical design of several types of substructures shall be established, and application of these standard design shall be institutionalized nation wide.

- In new bridge planning, bridge type selection, span arrangement, determination of total bridge length and finish grade shall be carefully examined, especially from river hydrological and hydraulic viewpoints.

- A comprehensive bridge design manual including construction details and erection /construction methods shall be prepared.

- The Bridge Unit in JKR should be given the authority to review and to approve all the bridge designs under JKR jurisdiction.

- The JKR's management and supervision team for bridge construction should be strengthened and pay more attention to quality control of the work.

(2) Need to Establish a Solid Organization for Bridge Management and to Implement Systematic Bridge Inspection, Maintenance, and Rehabilitation

As stressed in Part B: Conclusion, there is clearly a need to carry out systematic bridge inspection, maintenance, and rehabilitation which are only part of a broad panoply of the measures from the moment a bridge is opened to traffic. A successful bridge inspection, maintenance, and rehabilitation, however, will to a considerable extent rely on the organizational, managerial, and training aspects of the operation. Therefore, the followings are recommended:

- The Bridge Unit in JKR should be given the authority to oversee all the activities related to bridge inspection, maintenance and rehabilitation and be responsible for bridge management under JKR jurisdiction.

- The State JKR should be responsible for management of the rehabilitation work, while each District Office is responsible for implementation of superficial and periodical bridge inspection and routine bridge maintenance.

- All the inspection results and the maintenance and rehabilitation records should be centralized in the JKR Bridge Management System.

- To enhance the JKR engineers and technician's capability which in turn directly affects the quality of work, a professional training should be carried out periodically.

- Qualified Bridge Inspectors Registration should be introduced in the national bridge inspection system so that they can maintain a professional mind.

- Frequent personnel turnovers must be avoided, so that working on a bridge inspection and maintenance team does not become merely a stepping stone to another job.

- A bridge inspection, maintenance, and rehabilitation budget should be separately allocated from the road maintenance.

EXECUTIVE SUMMARY

VOLUME - I

PREFACE
LOCATION MAP
PHOTOS
PRINCIPAL EXECUTIVE SUMMARY

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ABBREVIATIONS
(Alphabetical Order)

AAR	Alkaline-Aggregate Reaction
BCR	Benefit Cost Ratio
BMS	Bridge Management System
BS	British Standard
CF	Conversion Factor
Co., Ltd	Company Limited
DID	Drainage and Irrigation Department
EDM	Electronic Distance Measurement
GOJ	Government of Japan
GOM	Government of Malaysia
HPU	Highway Planning Unit
IT	Inverted Tee-Beam
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
JKR	Jabatan Kerja Raya
JSCE	Japan Society of Civil Engineering
KEL	Knife Edge Load
LTAL	Long Term Axle Load
MOT	Ministry of Transport
MTAL	Medium Term Axle Load
N/mm^2	Newton Per Square Millimeter
NALS	National Axle Load Study
NR	Natural Rubber
OECD	Organization of Economic Corporation and Development
PCB	Prestressed Concrete Beam
PC	Prestressed Concrete
RC	Reinforced Concrete
RCB	Reinforced Concrete Beam
RCS	Reinforced Concrete Slab
SBB	Steel Beam Buckle Plate Slab Bridge
SBC	Steel Beam Concrete Slab Bridge
SBE	Steel Beam Encased Bridge
SBR	Styrene Butadience Rubber
SPT	Standard Penetriation Test
SSAL	Substandard Axle Load
SV	Special Vehicle
TBM	Temporary Benchmark
UPV	Ultrasonic Pulse Velocity
UK	United Kingdom
UDL	Uniformly Distributed Load

CHAPTER I INTRODUCTION

CHAPTER I

INTRODUCTION

I-1 Background of the Study

It has been recognized that there is a necessity to strengthen the Bridge Management System (hereinafter called "BMS") and that bridge maintenance and rehabilitation works should be systematically carried out throughout Malaysia. In this regard, the Government of Malaysia (hereinafter called "GOM") requested the Government of Japan (hereinafter called "GOJ") to provide assistance for this purpose. In response to the request, GOJ decided to proceed with the Study on the Maintenance and Rehabilitation of Bridges in Malaysia (hereinafter called "the Study").

Accordingly, the Japan International Cooperation Agency (hereinafter called "JICA"), the official agency responsible for the implementation of technical cooperation programs of GOJ, dispatched a preliminary study team to Malaysia from 13 February 1990 to 24 February 1990. The agreement on the Scope of Works for the study was signed between GOM and JICA on 23 February 1990. Subsequently JICA organised an Advisory Committee consisting of three members and a Study Team consisting of 8 members in August 1990.

The Study Team was dispatched to Malaysia on 6 September 1990 and the Study officially commenced with the submission of the Inception Report to discuss and confirm with GOM on the approach and methodology of the study together with the study schedule.

The Study was completed in December 1992 with the submission of the Final Report.

I-2 Objective of the Study

The principal objectives of the Study were two fold:-

1. To develop a systematic maintenance and rehabilitation program for bridges in Peninsular Malaysia.

2. To establish a manual of inspection, maintenance and rehabilitation work covering all the typical bridges in Malaysia.

In addition to the above, the Study includes providing practical training to the Public Works Department (Jabatan Kerja Raya (JKR) in Malay) counterparts in the fields of inspection techniques, bridge loading test and assessment techniques on the required maintenance and rehabilitation methods for various types of defective structural members.

I-3 Scope of the Study

The Study covers 216 bridges located along federal roads in Peninsular Malaysia with condition rating given by National Axle Load Study (hereinafter called "NALS") as 3, 4 or SSAL which is defined as a bridge with significant defects detected, structurally dangerous condition and Substandard Axle Load respectively. The Study also includes 30 selected federal bridges in Sabah and Sarawak and 40 selected bridges in the States of Perak, Selangor and Negeri Sembilan.

The Study carried out on the federal bridges in Peninsular Malaysia includes; collection and review of available and related data, visual inspections on 100 typical bridges, detailed survey on 20 typical bridges including loading test on 5 of the selected bridges, preparation of rehabilitation and maintenance programs with cost estimate and economic analysis for all the study bridges, and preparation of the manual on bridge inspection, maintenance, and rehabilitation works.

The Study carried out on the federal bridges in Sabah and Sarawak includes; visual inspections on 15 bridges from each State and preparation of a visual inspection report, detailed survey on a few selected bridges and their rehabilitation design, and reflection of the results of inspection and design in the manual on bridge inspection, maintenance and rehabilitation works.

The Study carried out on 40 state bridges in the States of Perak (10 bridges), Selangor (20 bridges) and Negeri Sembilan (10 bridges) includes, visual inspection on the selected bridges and preparation of a visual inspection report, and reflection of the inspection results in the manual on bridge inspection, maintenance and rehabilitation works.

The Study was carried out in 3 phases from September 1990 to December 1992. Figure I-1 shows the major work items of the study and their interrelationship.

I-4 Composition of the Report

The final report consists of four volumes as listed below:

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

In addition to the above, a bridge inspection, maintenance and rehabilitation manual was prepared as a separate volume and submitted to GOM.

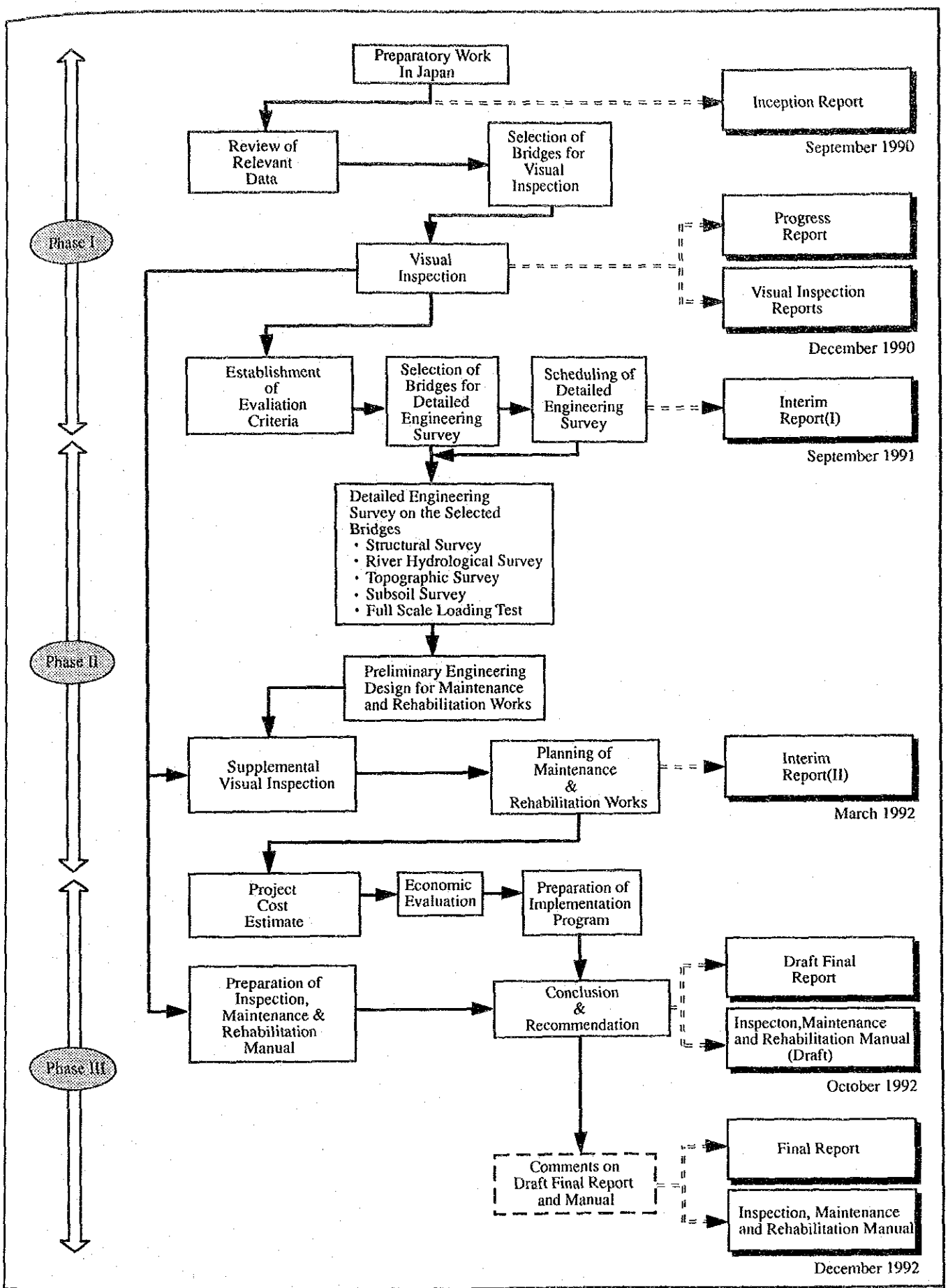

Figure I-1 Overall Work Flow of The Study

CHAPTER II

CONCLUSIONS AND RECOMMENDATION

CHAPTER II

CONCLUSIONS AND RECOMMENDATION

II-1 Conclusions

II-1-1 Necessity of the Bridge Maintenance and Rehabilitation

The growth of the transport and communication sector, especially the road network in the road transport subsector, has been playing an important part in the national growth and economic expansion of Malaysia. Up to date, a total of about 40,000km of roads has been built in the country and among those, the federal roads amounted to 13,000km.

On the road network, bridges are key elements because of their strategic locations and of the adverse consequences when they fail or when their capacity is impaired. It is estimated that there are about 4,500 bridges in Malaysia, out of which 2500 bridges are located on federal roads.

About 12% of these federal bridges were constructed before 1945 and 77% were built between 1946 and 1974. Hence, aging of these bridges is one of the most potential problems. Besides this, the rapid growth of total traffic volume and increase in traffic loads require bridge widening and an increase in the bridge load-carrying capacity respectively. To make matters worse, river water and air pollution aggravate deterioration of the bridge materials due to chemical attack, chloride attack as well as carbonation.

In order to prevent the adverse consequences such as loss of traffic safety, reduction of structural safety and increase of the Government expenditure for bridge replacement, there is clearly a need to carry out bridge inspection, maintenance and rehabilitation as stressed in the "Sixth Malaysia Plan 1991-1995", in which the emphasis has begun to shift from building new roads to maintaining and rehabilitating existing facilities in road transport network.

II-1-2 Assessment Results of Study Bridges

Out of 2500 federal bridges, the bridges which were classified with condition rating "3", "4" or study category of Substandard Axle Load (SSAL) by NALS are defined as the study bridges and amounted to 216.[1]

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(1) After commencement of the study, 11 bridges have been replaced and 2 bridges have no defects; thus a total of 216 bridges was reduced to 203 bridges.

Assessment methods applied in the Study are broadly divided into two categories consisting of visual inspection covering a representative 100 out of the 216 study bridges and detailed field survey for 20 typical bridges selected from those 100 bridges.

The findings from the visual inspection results are as follows:

- **Member Condition of Each Main Structure**

  - Steel and concrete beams have suffered advanced deterioration as compared to other members such as concrete decks, abutments. Especially the deterioration of steel beams is quite remarkable.

  - Concrete deck slabs are the most sound members.

- **Bridge Condition of Each Bridge Type**

  - Steel beam with buckle plate (SBB) is the most defective bridge among the other bridge types.

  - Reinforced concrete slab (RCS) and inverted "T" beam (IT) are in relatively worse condition than others such as steel beam with concrete slab (SBC), steel beam encased (SBE) and precast concrete beam (PRB).

  - Prestressed concrete beam (PCB) bridges are, generally, in good condition.

As part of the detailed field survey, topographic survey, subsoil and water investigation, river hydrological survey and detailed structural survey were carried out for 20 selected bridges. The major findings through those surveys are as follows:

- **From Subsoil and Water Investigation**

  - The chemical attack on concrete piles identified during NALS is not due to sulphates as originally anticipated, but more likely to be caused by a combination of acid attack and high water-cement ratio in the concrete. As a precautionary measure, it is concluded to apply rich mix concrete with unit portland cement content more than 300 kg/m^3 in the rehabilitation design.

  - The foundation failure at Bridge No.00546980 is probably due to a combination of inadequate bearing capacity of the piles in the original design, negative friction due to consolidation settlement and lateral soil movement. It is therefore prudent to consider urgent rehabilitation measures to support the superstructure by constructing new rigid framed abutments close to the existing abutments.

From River Hydrological Survey

- At Endau Bridge (No.00317000), the hydrological analysis has proven that the beams at both end spans which were found to have the flood marks during the field inspection have been submerged. Thus, the submerged spans should be rehabilitated using an appropriate method such as raising the bridge grade.

- The assessment result proved that the channel capacity at Dungun Bridge site (No.00346740) is slightly less than that required. Therefore, excavation of the right side bank, provision of revetment for both side banks, provision of river-bed protection and spur dikes are selected so as to increase the channel capacity at the bridge site.

From Detailed Structural Survey

- Based on the concrete cover measurement survey, the cover of slab soffits varied from 25 to 50mm and was found to be adequate. While, the concrete cover for beam soffit averaged about 30mm is slightly inadequate and the concrete cover of 40mm in piles and in substructure is too low. It was therefore decided that the minimum cover of slabs and beams should be 30mm and 40mm respectively, and a minimum cover of 70mm should be applied for all substructures in the rehabilitation design.

- Based on the strength measurement results, the applicable strength of each material in the structural assessment are as follows:

(Unit : N/mm²)

Concrete(1)				Steel(2)	
Superstructure		Substructure		Structural Steel	Rebar
Beam	Slab	Abut/Pier	Pile		
20-25	20	20	25	230	230

Note: (1) Cube strength at 28 days

(2) Yield strength

- From the carbonation test results, it was revealed that all the deck slabs tested except for 2 bridges have been heavily carbonated with carbonation depth varying from 11mm to greater than 75mm. In the rehabilitation work, the carbonated parts of the concrete which indicate inadequate alkalinity shall be removed or scarified.

- From the chloride test results, it can be concluded that most of the piles have been badly attacked by chloride which far exceeds the critical value (0.4%) at

the rebar position. Chloride attack to the beams and slabs at bridge No.00317000 is quite serious and it has reached a depth of more than the cover. It was decided that rich mix concrete and adequate concrete cover should be applied to prevent chloride attack in the rehabilitation design.

- From the sulphate test results, it was revealed that the percentage of sulphate by weight of cement is within acceptable level.

- From the formation analysis of bearing pads, the rubber polymer in bearing pad of Bridge No.00701801 is a blended type consisting of natural rubber (NR) and styrene butadience rubber (SBR). Therefore, it is conclusive that the main reason for deterioration is due to inadequate ozone resistance of both NR and SBR. In this regard, it is recommended that natural rubber coated by chlorophene shall be applied as elastomeric bearings in the rehabilitation design.

- From the alkaline-aggregate reaction test, it is apparent that cracks on the pile head of Bridge No.00319110 are due to alkaline aggregate reaction (AAR). Taking into account the extent of damage, epoxy injection together with surface coating is suitable for the rehabilitation method.

From Full Scale Bridge Loading Test

- The assessment of the loading test results has proven that each bridge tested has some reserved residual load carrying capacity (RRLC) of a certain percentage against maximum design stress resulting from bridge behavior difference between in design and in actual, i.e mitigating actual working stress due to several effects such as composite action, built up action, lateral load distribution action and so on. Following are RRLC values to the corresponding type of bridge.

Bridge Type	Member	RRLC Value
SBC	Main Beam	20%
RCB	Main Beam	20%
PCB	Main Beam	20%
RCS	Main Slab	10%

It should be noted that the above RRLC values are only applicable to analytic assessment of the existing bridges for rehabilitation design.

II-1-3 Results of Preliminary Rehabilitation Design

In the preliminary rehabilitation design, analytic assessment applying the Long Term Axle Load (LTAL) was carried out for each of the 20 representative bridges. The assessment results revealed that among those bridges, steel buckle plate, main beams supporting the

buckle plate and concrete main beams of 2 girders type bridge were inadequate to carry LTAL loading. Based on the those findings as well as the inspection results and the assessment results of the detailed survey, all defects detected in each study bridge were diagnosed from viewpoints of material deterioration, load carrying capacity, bridge function and hydraulic adequacy. Thereafter, a suitable rehabilitation for each or combined defect(s) was selected to effectively rectify the cause of the defect(s).

The rehabilitation plans in the study are divided into three categories: structural rehabilitation work, functional rehabilitation work and hydraulic rehabilitation work. The structural rehabilitation works are to rectify a deteriorated bridge member and to strengthen or replace a bridge member which has inadequate load carrying capacity and/or has active or critical defect. The functional rehabilitation work is to improve the bridge function by widening carriageways, adding sidewalks or raising bridge grade, while hydraulic rehabilitation work is mainly to protect riverbanks or river beds in the vicinity of abutments and river piers.

As a planning result of maintenance and rehabilitation works covering all the study bridges, the rehabilitation works required on the defective members or bridges which have inadequate bridge function were identified at each of the study bridges. The dominant rehabilitation works and the percentage of bridge members or bridges affected against all the study bridges are shown in Table II-1.

Table II-1 Summary of Dominant Rehabilitation Work

Structural and Hydraulic Rehabilitation Plans		
Bridge Type or Superstructure type	Three Most Dominant Rehabilitation Methods Required	% of Bridge Members Affected
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	17.0%
	– Protection of abutment foundation by revertments	14.1%
Piers	– Pier reinforcement by partial concrete lining	9.2%
	– Pier reinforcement by total concrete lining	6.8%
	– Pier protection by patching	5.8%
Functional Rehabilitation Plans		% of Bridges Affected
– Widening of Carriageway		2.0%
– Adding of Sidewalk		8.3%
– Raising of Grade		3.9%

II-1-4 Project Cost

The total project cost obtained by adding each project cost of the 203 study bridges amounts to M$58.148 million based on December, 1991 price levels as shown below:

Description		(Million M$)
Construction Cost		45.428
Engineering Cost	Detailed Design	2.726
	Supervision	1.817
Administration		1.363
Contingency		6.814
Total		58.148

II-1-5 Economic Evaluation Results

The economic evaluation using three economic parameters: Benefit Cost Ratio (BCR), Net Present Value (NPV) and Internal Rate of Return (IRR), was carried out for individual bridge and for the whole project covering the 203 study bridges.

■ Whole Project

As a whole, most of the benefit is derived from the reduction of the duration of traffic interruption. 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%. It is then concluded that the project is feasible as a whole.

■ Individual Bridge

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

It is concluded that the project should 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 in this study can be added due to the service level and reliability of nation-wide road network improved by the proposed rehabilitation project.

II-2 Recommendation

II-2-1 Project Implementation

It is recommended that the bridge maintenance and rehabilitation covering a total of 203 bridges defined as "A Project" shall be implemented based on the following reasons:

(i) All of the study bridges have suffered various distresses or damages and some of them are in a critical condition.

(ii) Those bridges can be improved mainly using standard rehabilitation or strengthening techniques.

(iii) The economic evaluation results indicates that the project is economically highly feasible.

(iv) The Government of Malaysia presumably has enough financial capability to arrange the total project cost.

With full consideration of the Government's financial arrangement capability as well as urgency of the project implementation, the following key aspects are recommended for the project implementation.

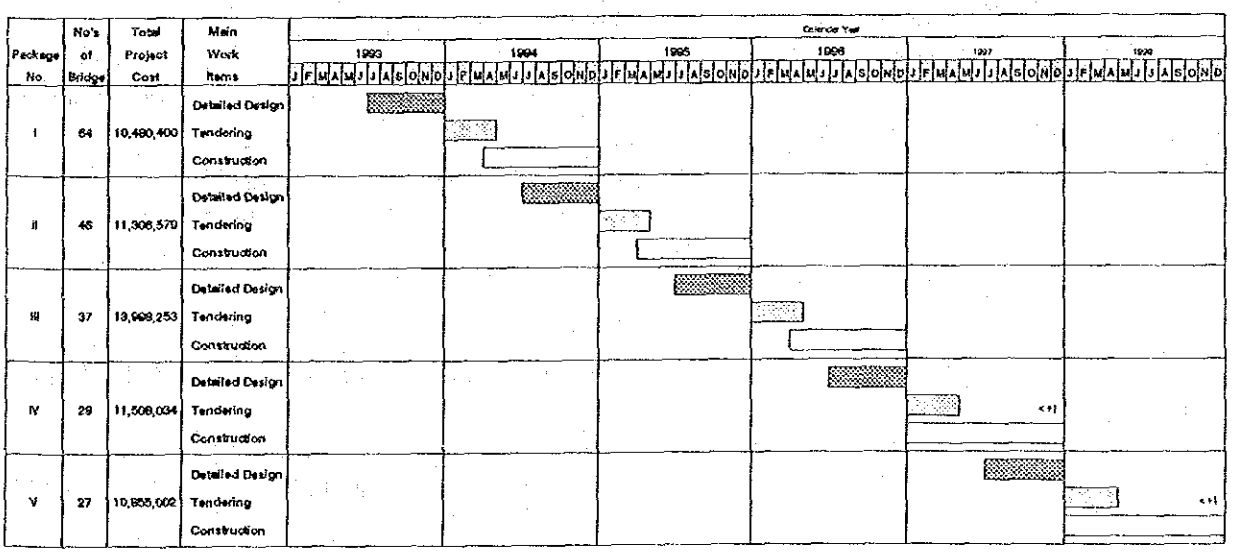
(i) The project covering 203 bridges shall be divided into five packages,

(ii) The construction of the first package shall be commenced in early 1994, and

(iii) In principle, each package shall be completed within one Malaysian fiscal year and the project be completed by the end of 1998.

The overall implementation schedule is depicted in Figure II-1.

Figure II-1 Overall Implementation Schedule



Note : : ☐ indicate rainy season from November to February.
<+1>: Rehabilitation works for Bridge No. 317000 and 339550 are carried out continuously during the two or three years from 1996 to 1998
: Fiscal year in Malaysia from January 1 to December 31

II-2-2 Technical and Institutional Recommendation

(1) Need to Eliminate Design and Construction Deficiencies in New Bridges

The study results revealed that various deficiencies observed in the study bridges included the deficiencies due to improper bridge design and construction. It is therefore, obvious that these deficiencies should be eliminated in new bridge designs and construction otherwise the workload of the maintenance and rehabilitation will never be reduced in the future.

In order to eliminate those deficiencies, the following measures shall be taken;

- Standard design of appropriate types of superstructure covering span length from 10m to 40m and typical design of several types of substructure shall be established and application of these standard design shall be institutionalized nation wide.

- In new bridge planning, bridge type selection, span arrangement and determination of total bridge length and finish grade shall be carefully examined, especially from river hydrological and hydraulic viewpoints.

- A comprehensive bridge design manual including construction details and erection /construction methods shall be prepared.

- The Bridge Unit in JKR should be given the authority to review and to approve all the bridge design under JKR jurisdiction.

- The JKR's management and supervision team for bridge construction should be strengthened and pay more attention to quality control of the work.

(2) Need to Strictly Control Overloaded Trucks

The study results revealed that some of the existing bridges especially steel beams with buckle plate slab have inadequate LTAL local carrying capacity unless rehabilitation is provided. It was reported that overloaded or overheightened trucks are passing on the bridges or under the overbridges, which are susceptible to fatigue or impact damage. Therefore, it is recommended that the Government takes the following action within the earliest possible time.

- Weigh bridges should be installed at selected locations along the major federal roads to control the overloaded trucks.

- Strict enforcement is required in collaboration between the Police Department and Roads Transport Department.

(3) Need to Establish A Solid Organization for Bridge Management and to Implement Systematic Bridge Inspection, Maintenance, and Rehabilitation

As stressed in Section II-1, there is clearly a need to carry out systematic bridge inspection, maintenance and rehabilitation which are only part of a broad panoply of the measures from the moment it is opened to traffic and ending with its replacement. A successful bridge inspection, maintenance and rehabilitation will, to a considerable extent, rely on the organizational, managerial and training aspects of the operation. Therefore, the following aspects are recommended:

- The Bridge Unit in JKR should be given the authority to oversee all the activities related to bridge inspection, maintenance, and rehabilitation and be responsible for bridge management under JKR jurisdiction.

- The State JKR should be responsible for management of rehabilitation work, while each District Office is responsible for implementation of superficial and periodical bridge inspections and routine bridge maintenance.

- All the inspection results and the maintenance and rehabilitation records should be centralized in the JKR Bridge Management System.

  Figure II-2 shows the responsibilities of each structure, flow of bridge documents, etc. as described above.

- To enhance the JKR engineers and technician's capability which in turn directly affects the quality of the work, a professional training should be carried out periodically.

- Qualified Bridge Inspectors Registration should be introduced in the national bridge inspection system so that they can keep a professional mind.

- Frequent personal turnovers must be avoided so that working on a bridge inspection and maintenance team does not become merely a stepping stone to another job.

- A bridge inspection, maintenance, and rehabilitation budget should be separately allocated from road maintenance.

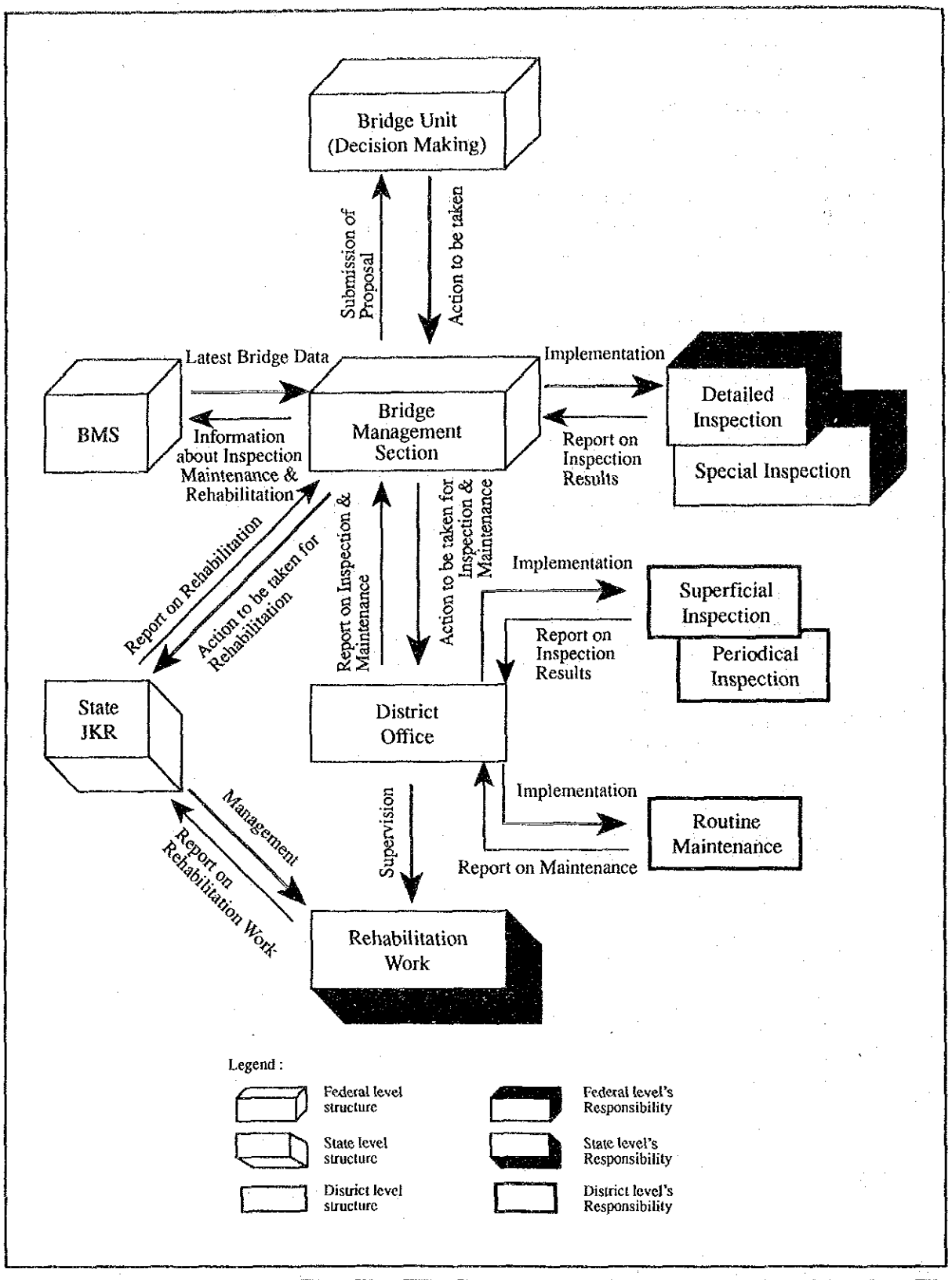


Figure II-2 Schematic Flow of the Link Between Inspection and Bridge Management