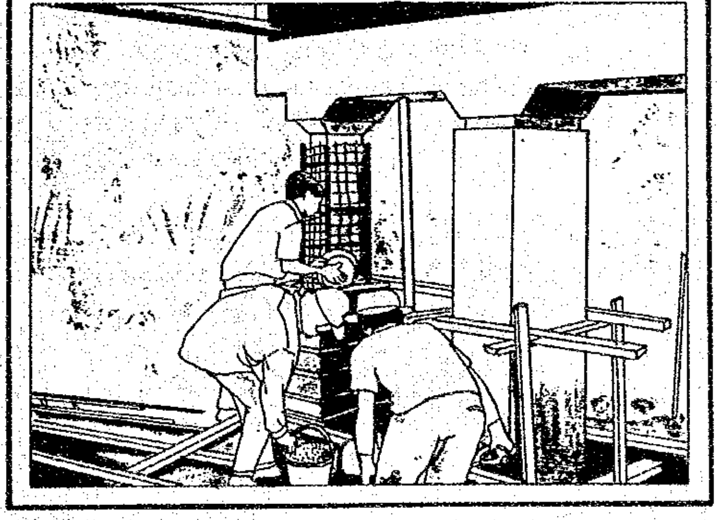
CHAPTER 17

CONCLUSIONS AND RECOMMENDATION



CHAPTER 17

CONCLUSIONS AND RECOMMENDATION

17.1 General

The conclusions and recommendation presented in this chapter were made not only after thorough evaluation of all the study results such as visual inspection, detailed field survey, preliminary design, cost estimate and economic evaluation but also after referring to the contents stated in the "Bridge Inspection, Maintenance, and Rehabilitation Manual" which was prepared and submitted as a separate booklet.

17.2 Conclusions

17.2.1 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 national growth and economic expansion of the country. Up to date, a total of about 40,000km of roads has been built in Malaysia 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 the federal roads.

Out of the 216 study bridges which are equivalent to about one twelfth of these federal bridges, 34 bridges (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, aging and inadequate load carrying capacity of these bridges are 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 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 a loss of traffic safety, a reduction of structural safety and an increase of the Government expenditure for bridge replacement, there is clearly a need to carry out bridge inspection, maintenance and rehabilitation, as stressed in "Sixth Malaysia Plan 1991-1995" in which the emphasis has begun to shift from building new roads to maintaining and rehabilitating existing facilities in the road transport network.

17.2.2 Assessment Results of Study Bridges

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

Assessment methods applied in the Study are broadly divided into two categories consisting of visual inspection covering a representative 100 bridges 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 slab is the most sound member among others

  - Piers are in slightly worse condition even though there is not much difference in condition between abutments and piers

- **Bridge Condition of Each Bridge Type**

  - Steel beam with buckle plate (SBB) bridge was found to be the most defective bridge.

  - Reinforced concrete slab (RCS) and inverted "T" beam (IT) were found to be in relatively worse conditions than the others such as steel beam with concrete slab (SBC), steel beam encased (SBE) and precast concrete beam (PRB).

  - Prestressed concrete beam (PCB) bridges were, 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 the 20 selected bridges. The major findings through those surveys are as follows:

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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 is reduced to 203 bridges.

- **From Subsoil and Water Investigation**

  - The chemical attack on concrete piles identified during NALS are 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 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 riverbed protection and spur dike 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 soffit varied from 25 to 50mm and was found to be adequate. While, the concrete cover for beam soffit which averaged about 30mm is slightly inadequate and the concrete cover of 40mm in piles and in substructure is too low. It was decided that 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 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.

17.2.3 Results of Preliminary Rehabilitation Design

In the preliminary rehabilitation design, at first 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 main concrete beams of 2 girders type were inadequate to carry LTAL Loading.

Based on above 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 broadly divided into three categories comprising of 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, 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 17-1.

Table 17-1 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 – Deck slab protection by patching – Deck slab protection by water proofing	94.0% 50.0% 27.8%
Steel Beam Encased Bridges (SBE)	– Encasing concrete protection by patching – Encasing concrete protection by lining – Deck slab protection by patching	33.3% 22.2% 22.2%
Steel Beam Buckle Plate Bridges (SBB)	– Total replacement of buckle plate by RC slab – Total replacement of steel bearings – Steel beam protection by repainting	100.0% 97.1% 87.1%
RC Beam Bridges (RCB)	– Deck Slab protection by patching – RC beam protection by patching – RC beam reinforcement by bonding steel plate	25.8% 22.6% 22.6%
RC Slab Bridges (RCS)	– RC slab protection by injection – Deck slab protection by guniting – Deck slab protection by water proofing	43.5% 30.4% 26.1%
Precast RC Beam Bridges (PRB)	– Deck slab protection by water proofing – RC beam protection by patching – RC beam reinforcement by bonding steel plate	75.0% 15.0% 5.0%
Precast RC–Beam Bridges (PRB)	– RC beam reinforcement by bonding steel plate – RC beam protection by coating – Deck slab protection by patching	23.1% 23.1% 15.4%
Inverted T Beam Bridges (IT)	– Deck slab protection by water proofing – Beam protection by patching – Beam protection by injection	66.7% 22.2% 11.1%
Abutments	– Abutment protection by injection – Abutment protection by partial concrete lining – Protection of abutment foundation by revertments	28.5% 17.0% 14.1%
Piers	– Pier reinforcement by partial concrete lining – Pier reinforcement by total concrete lining – Pier protection by patching	9.2% 8.8% 5.8%
Functional Rehabilitation Plans		% of Bridges Affected
	– Widening of Carriageway – Adding of Sidewalk – Raising of Grade	2.0% 8.3% 3.9%

17.2.4 Project Cost

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

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

17.2.5 Economic Evaluation Results

The economic evaluation using three economic parameters: BCR, NPV and IRR was carried out for individual bridge and for the whole project covering 203 study bridges.

- **Whole Project**

As a whole, most of the benefit is 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.

- **Individual Bridge**

The internal rate of return of each of 197 bridges out of 203 exceeded a 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.

17.3 Recommendation

17.3.1 Project Implementation

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

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

(ii) Those bridges can be improved mainly by 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 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.

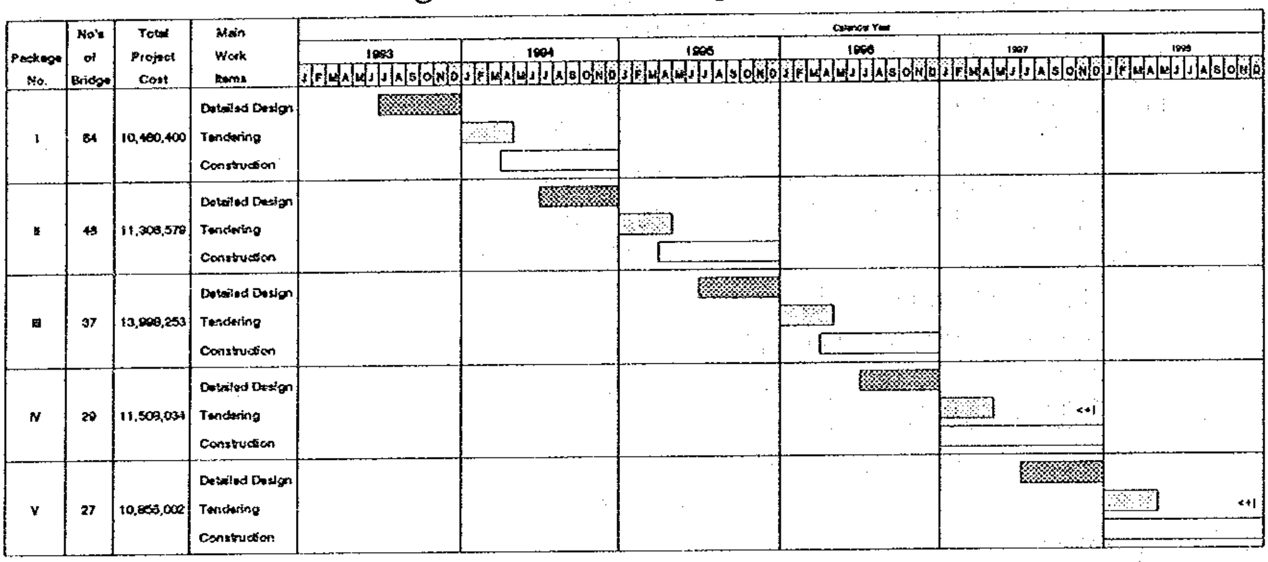
(i) The project covering 203 bridges shall be divided into five packages,

(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 17-1.

Figure 17-1 Overall Implementation Schedule



Note : : [ ] Indicate rainy season from November to February.
<+|: Rehabilitation works for Bridge No. 317000 and 339560 are carried out continuously during the two or three years from 1996 to 1999
: Fiscal year in Malaysia from January 1 to December 31

17.3.2 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, 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 method 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 trucks in terms of weight or height are passing on or under the bridges, which are susceptible to fatigue or impact damage. Therefore, it is recommended that the Government take the following actions within the earliest time.

- Weigh bridges should be installed at selected locations along major Federal roads to control 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 17.2 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 it is opened to traffic and ending with its replacement. 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 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 maintenance and rehabilitation records should be centralized in the JKR Bridge Management System.

It should be noted that the responsibilities of each structure, flow of bridge documents, etc. mentioned above are shown in Figure 17-2.

- To enhance the JKR engineers and technician's capability which in turn directly affect 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.

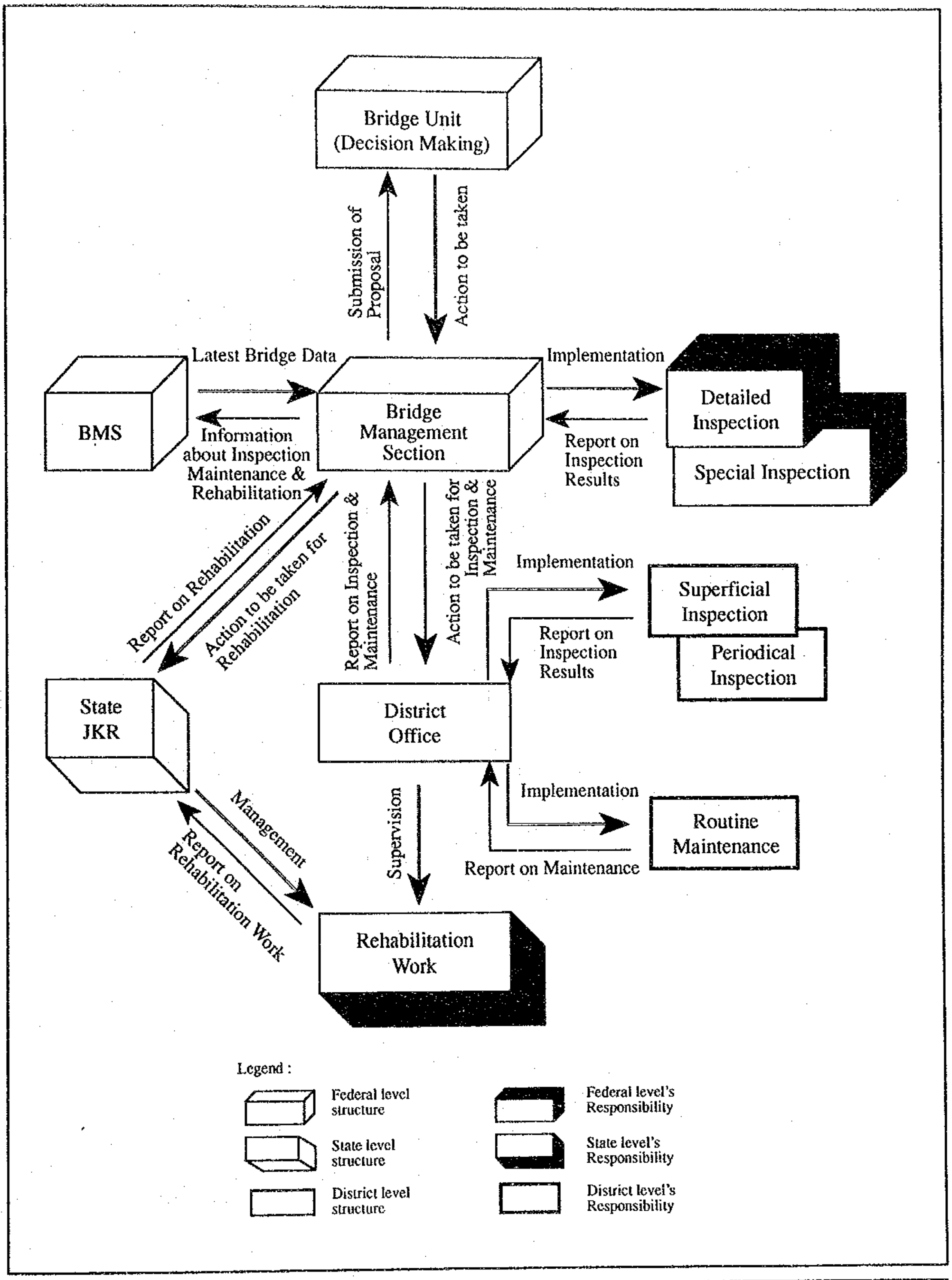


Figure 17-2 Schematic Flow of the Link Between Inspection and Bridge Management

JICA