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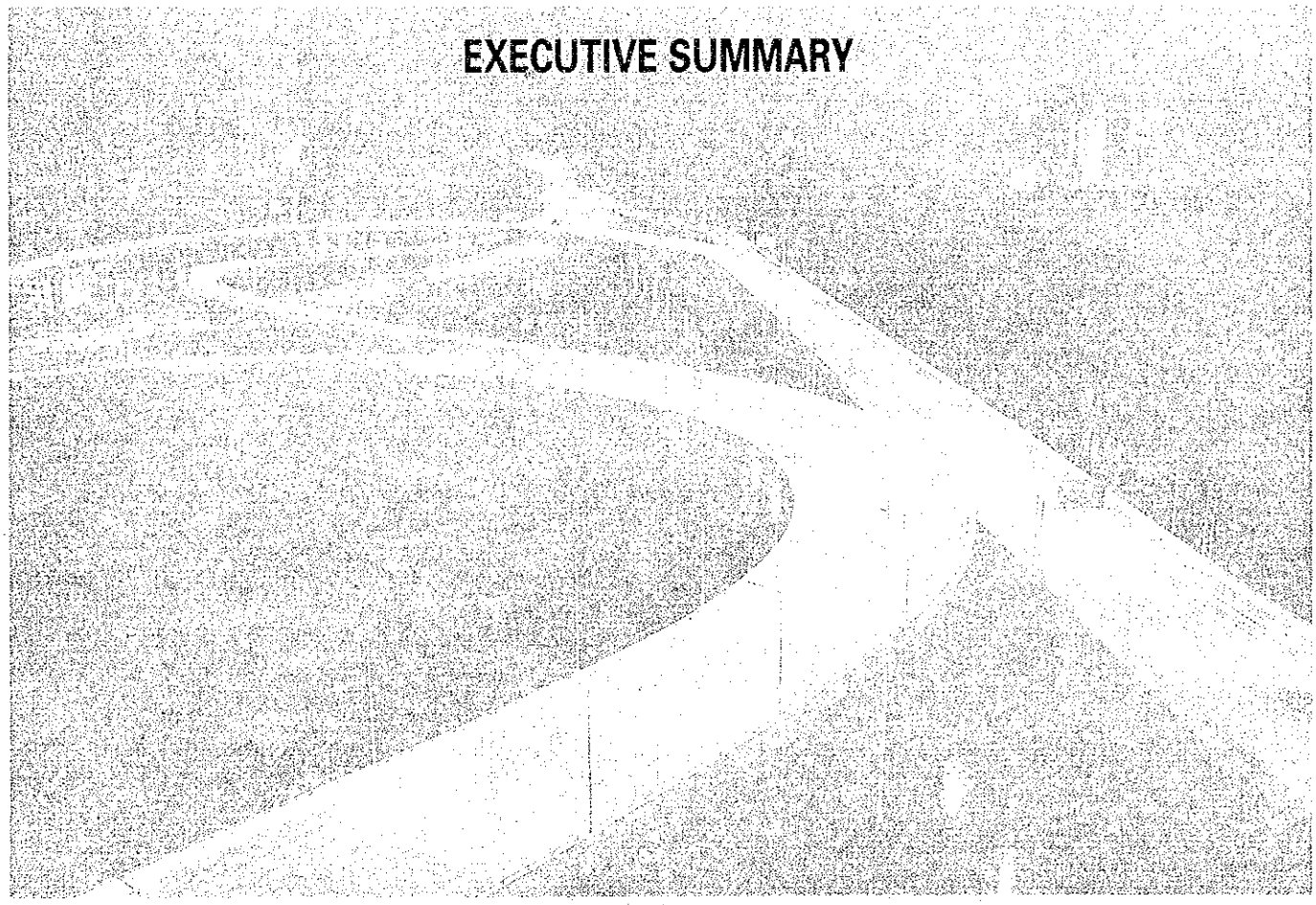
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
THE EXPRESSWAY AND RAPID TRANSIT AUTHORITY OF THAILAND
KINGDOM OF THAILAND

THE STUDY ON INSPECTION AND MAINTENANCE SYSTEM FOR THE EXPRESSWAY IN THE KINGDOM OF THAILAND

EXECUTIVE SUMMARY



DECEMBER 1994

ORIENTAL CONSULTANTS
PACIFIC CONSULTANTS INTERNATIONAL

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PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Government of Japan decided to conduct 'The Study on Inspection and Maintenance System for the Expressway in the Kingdom of Thailand', and entrusted the study to the Japan International Cooperation Agency (JICA).

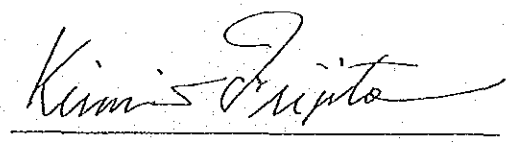
JICA then sent to Thailand a study team headed by Mr. Kazuro Yanagida, and composed of members of Oriental Consultants and Pacific Consultants International, from July 1993 to September 1994.

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

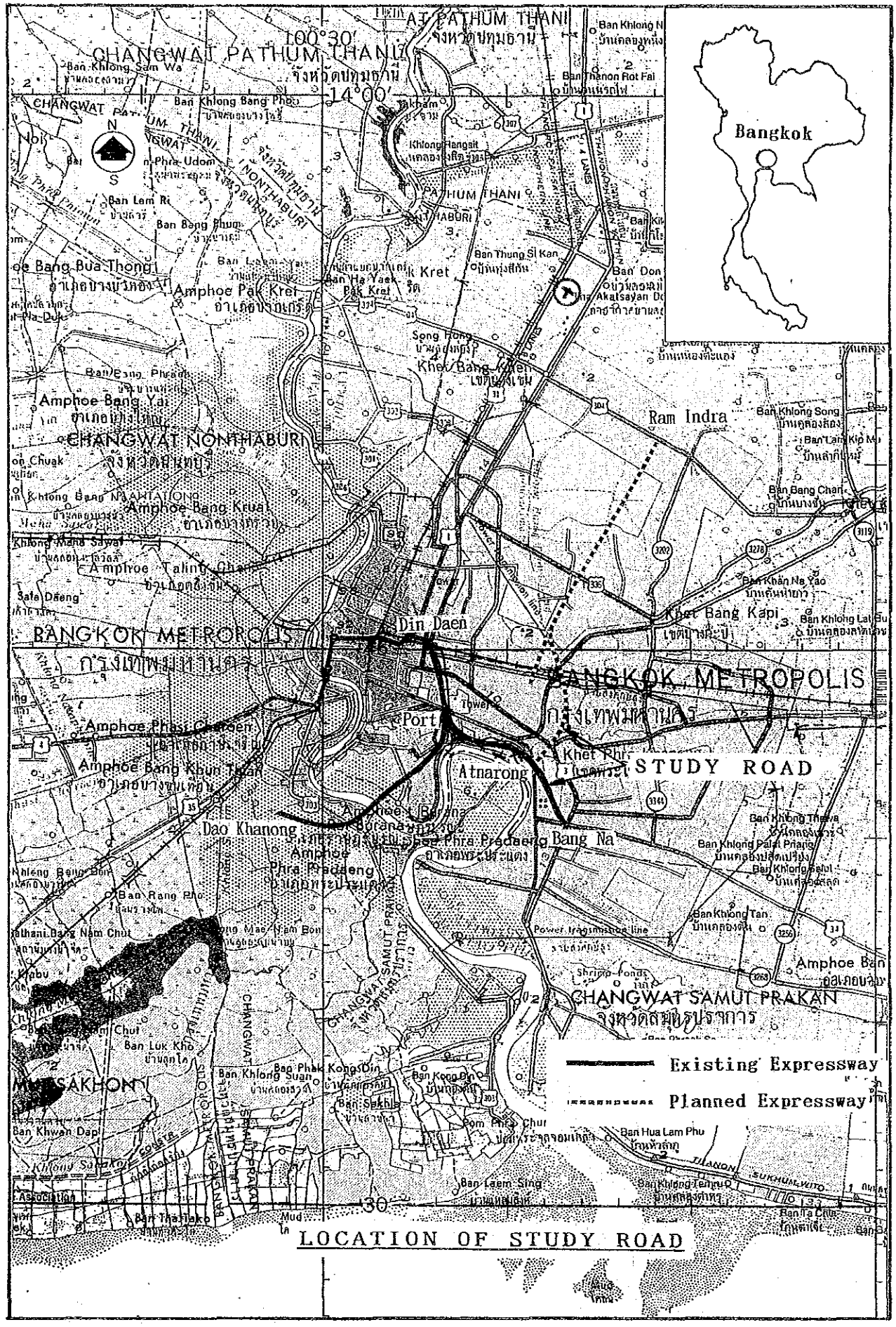
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

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

December 1994



Kimio Fujita
President
Japan International Cooperation Agency


Bangkok
100°30'
14°00'
CHANGWAT PATHUM THANI
จังหวัดปทุมธานี
CHANGWAT NONTHABURI
จังหวัดนนทบุรี
BANGKOK METROPOLIS
กรุงเทพมหานคร
CHANGWAT SAMUT PRAKAN
จังหวัดสมุทรปราการ
Amphoe Pak Kret
Amphoe Bang Yai
Amphoe Bang Kruai
Amphoe Talingchan
Amphoe Phasi Charoen
Amphoe Bang Khun Thian
Amphoe Phra Pradaeng
Amphoe Bang Na
Amphoe Bang Phli
Ram Indra
Din Daen
Khet Bang Kapi
Khet Phra Khanong
Atnarong
Dao Khanong
Port
Tower
STUDY ROAD
Existing Expressway
Planned Expressway
LOCATION OF STUDY ROAD

BRIEF OF EXECUTIVE SUMMARY

1. Background

The existing expressway system in Bangkok, which is operated and managed by the Expressway and Rapid Transit Authority of Thailand (ETA), has at present a total service length of 27.1 km. The first portion of the expressway that was opened to the public was in October 1981. Since then expressway traffic volume has risen sharply (by approx. 100 times) due to rapid economic growth and the increase in vehicle ownership in the Bangkok Metropolitan Area. It is predicted that damage to the existing road structures and facilities of the expressway will escalate with the rise in traffic volume, as well as the rise in the ratio of heavy vehicles and the extension of the expressway itself. Therefore, in order to manage the expressway systems adequately and carry out timely remedial work, it is necessary to systematize inspection and maintenance.

2. Objectives of the Study

The objectives of the study are as follows:

1) to formulate an inspection and maintenance system for the ETA expressway by doing the following:
   - developing a database system with the aid of a microcomputer,
   - preparing inspection manuals and a repair manual,
   - compiling a road inventory database,
   - making recommendations on the organization of maintenance, and
2) to transfer technology to ETA counterparts in the course of the implementation of the study.

3. Study Road

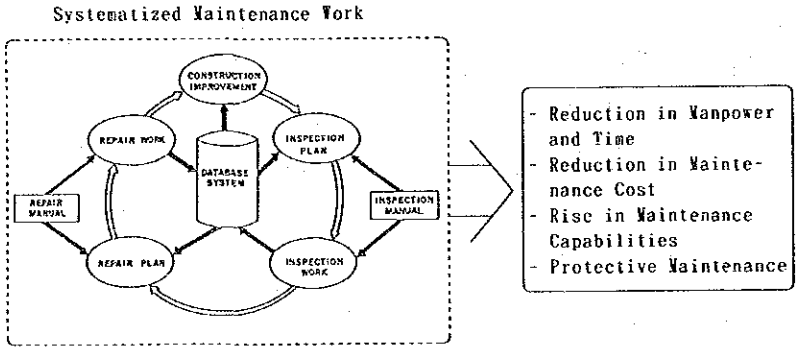
The study road covers the whole existing ETA expressway network (total length equals 27.1 km). In addition, the proposed database system was designed to compile information on the Ramindra-Atnarong Expressway, whose construction has been undertaken by ETA. The inspection and maintenance system covers visually observable items such as expressway superstructure, bridge piers, pavement, traffic safety devices, and part of the street lighting facilities.

4. Outline of Inspection and Maintenance System

4-1 Objectives of System

The inspection and maintenance system focuses on upgrading and rationalizing maintenance work by systematizing information and standardizing work methods. The system will provide a broad base of support for maintenance and management work by using inspection and repair manuals and computer databases. This will improve work procedures and methods that will result in higher efficiency and less incidental damage to structures.

This system will result in assisting social and economic growth of the Thailand with improvement in maintenance capabilities of the expressway.



4-2 Objective Structures and Facilities

In order to systematize information necessary for maintenance, road structures and facilities are subdivided into the following 11 components for the Land and Rama IX Bridge Section, taking into consideration structural, damage and repair characteristics:

	Land Section	Rama IX Bridge Section
Traffic Obstacle	Obstacles on road	Obstacles on road
Road Structures	Concrete structures Expansion joints Embankments Pavement Bearings	Steel structures Expansion joints Cables, Pavement Concrete structures Bearings
Road Facilities	Drainage Steel facilities Lighting Traffic signs Noise barriers	Drainage Maintenance facilities Lighting Traffic signs Dampers

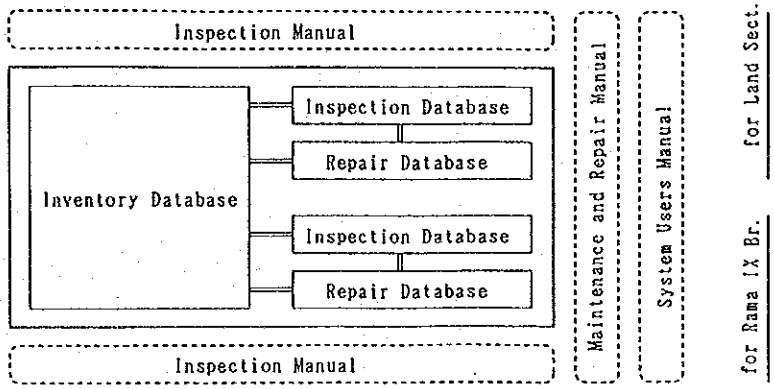
4-3 Damage and Inspection

Damage sustained by the above components are classified into 4 to 7 types to standardize damage information, taking into consideration a component's material, structure, function, and damage. Also, in order to judge the necessity of repair work, observations of damage or deterioration are categorized into four ranks from A to D.

Inspection work is categorized into four types in terms of purpose, frequency, inspection objects and methodology; i.e., daily inspection, routine inspection, special inspection, and emergency inspection.

4-4 System Framework

This system comprises of database which manage information necessary for expressway maintenance, manuals which describes standardized work procedures, and system users manual for database operation, as shown below.



4-5 Database System

The database system is divided into 9 databases that contain a total of 19 database files. A brief description of these databases are as below.

The database system is designed to operate in the interactive mode, and can be utilized by anyone by following messages displayed on the screen. A NEC Powermate 466i microcomputer is used to load the database system, which is in dBASE4 (Ver. 1.0) into a MS-DOS environment. The size of the program for the database system is 2,100 kilobytes.

Database	Database Files
Road Inventory	Superstructures, Piers, Expansion joints Bearings, Embankments, Guard-rail, Fence Pavement, Lighting, Traffic signs, Noise barriers
Inspection Database	Daily inspection and a Routine inspection database for both the Land Section and the Rama IX Bridge
Repair Database	Repair database for both the Land Section and the Rama IX Bridge
Other Databases	Member Database for the Rama IX Bridge members and Code Database

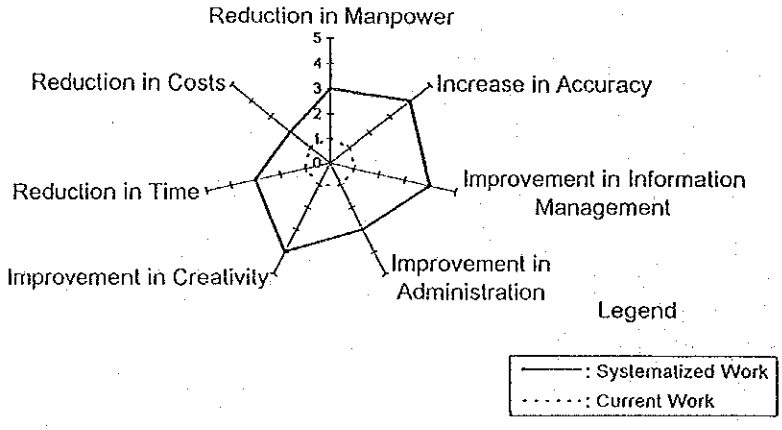
4-6 Manuals

Inspection manuals are subdivided into two manuals for both Land Section and the Rama IX Bridge Section, taking an exclusive maintenance section for the Bridge into accounts. However, the maintenance and repair manual has been drawn up so it can be applied to the whole expressway. System users manual describes database operation methods for operators.

The manuals cover all items essential to maintenance work from execution methods including input data coding sheets.

5. System Evaluation

It is expected that the developed system will be able to reduce manpower in approximately 80% for maintenance information management. If all other site and office work, such as inspection and design, is considered together with maintenance information management, there would be a decrease in manpower of approximately 30 to 50%.



According to an evaluation of the system using a scoring model, the system will produce both qualitative and quantitative benefits in costs and time. And this will be effective in rais ing work efficiency, dispersing information, and reinforcing work capabilities for expressway maintenance.

6. Recommendations for Efficient System Utilization

In order to utilize the developed inspection and maintenance system efficiently and raise the level of maintenance work, the following recommendations are proposed.

- Preparation of Documents and Equipment for Maintenance Work
  Route maps, markings or plates on kiloposts and piers, and the upkeep of documents and vehicles for maintenance work are proposed to achieve efficient and safe maintenance work.

- Reinforcement of Maintenance Staffing
  Allocation of engineers and operators to utilize the developed system, hiring of additional maintenance staff, establishment of sub-governmental organization for efficient execution of maintenance work, and establishment of a new branch office for the Ramindra-Atnarong Expressway are recommended to improve and reinforce maintenance engineering capabilities.

- Improvement of Maintenance Work System
  Improvement in regulations for maintenance work safety, implementation of unit price contract system to simplify contracting, and inventory data collection by contractors are proposed to upgrade maintenance work.

- System Expansion of System Use
  Conversion methods and procedures are proposed so that the developed inspection and maintenance system can be used on ETA's existing workstation (RISC/6000) network.

7. System Application Plan

In order to apply the developed system to actual maintenance work, a tentative application was carried out on a pilot road section between Petchburi Road and Rama IV Road (3,075 m), and the Rama IX Bridge Section, and its applicability confirmed. Technology transfer to ETA counterparts was also carried out in

the course of this application.

According to the above application and technology transfer, ETA can use and apply the system to actual maintenance work immediately after completion of the study.

8. Work Results

The study team submitted the final version of the following:

- Database System Program (dBASE4/MS-DOS)
- Road Inventory Database
- Inspection Manual for the Land Section (Thai and English)
- Inspection Manual for the Rama IX Bridge Section (do.)
- Maintenance and Repair Manual (do.)
- Database System Users Manual (English)
- Final Report (Executive Summary and Main Volume)

In addition to the above results, Workshop was held to demonstrate the developed system on March, 1994.

Table of Contents

1. Introduction

1.1 Background

The existing expressway system in Bangkok, which is operated and managed by the Expressway and Rapid Transit Authority of Thailand (ETA), was constructed and opened to traffic in three phases: the 8.9 km Din Daeng-Port section in October 1981, the 7.9 km Bang Na-Port section in January 1983, and the 10.3 km Dao Khanong-Port section in November 1987. The present total service length is thus 27.1 km.

However, compared to 1981, the Bangkok Metropolitan Area is 2.5 times more productive, has 1.4 times the population, and has 2.6 times the number of registered vehicles. Nowadays, the average daily number of vehicles using ETA's expressway exceeds more than 400,000 while it was less than 1 million for the entire year of 1981. Based on this, it can be said that the existing expressway system plays an important role as a main artery for vehicular traffic in the Bangkok Metropolitan Area. On the other hand, its road structures and facilities are being damaged by the large traffic volume.

It is predicted that damage to the existing road structures and facilities of the expressway will escalate with the increase in traffic volume, as well as with the rise in the ratio of heavy vehicles and the extension of the exposed itself. Therefore, in order to manage the expressway system adequately and carry out timely remedial work, it is necessary to systemize inspection and maintenance.

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The objectives of the study are as follows:

1) to formulate an inspection and maintenance system for the ETA expressway by doing the following:

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2) to transfer technology to ETA counterparts in the course of the implementation of the study.

1.3 Study Road

The study road covers the whole existing ETA expressway network (total length equals 27.1 km). In addition, the proposed database system was designed to compile information on the Ramindra-Atnarong Expressway, whose construction has been undertaken by ETA. Fig. 1.1 shows the study road network.

The inspection and maintenance system covers visually observable items such as superstructure, bridge piers, pavement, traffic safety devices, and part of the street lighting facilities (see Fig. 1.2).

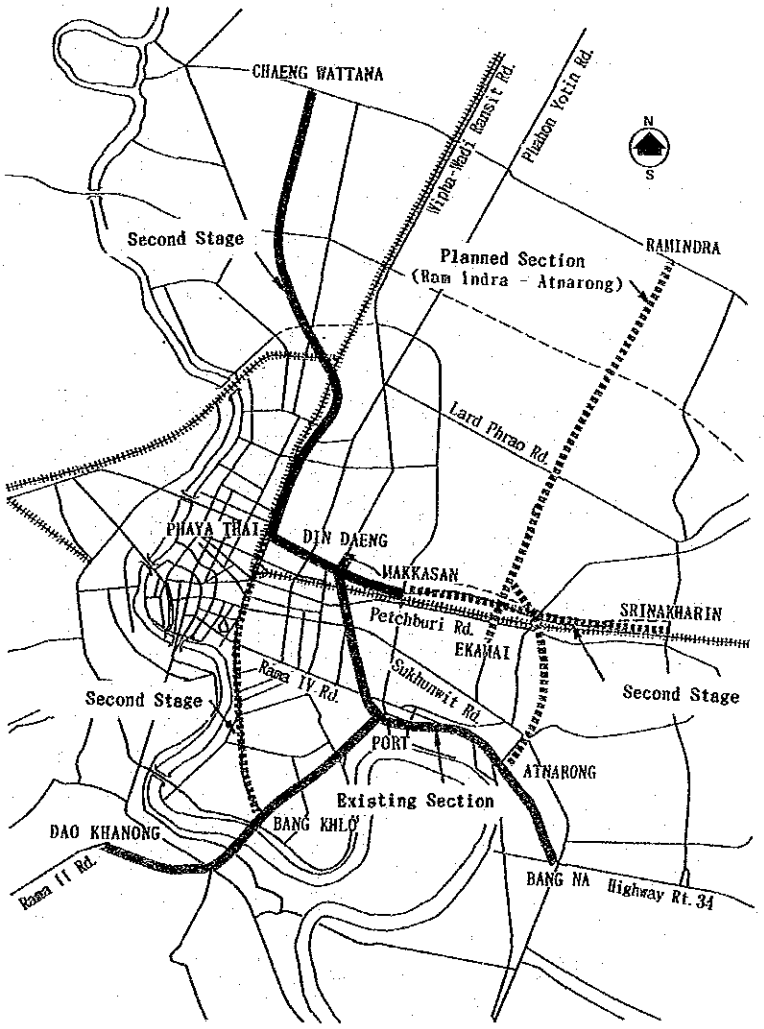
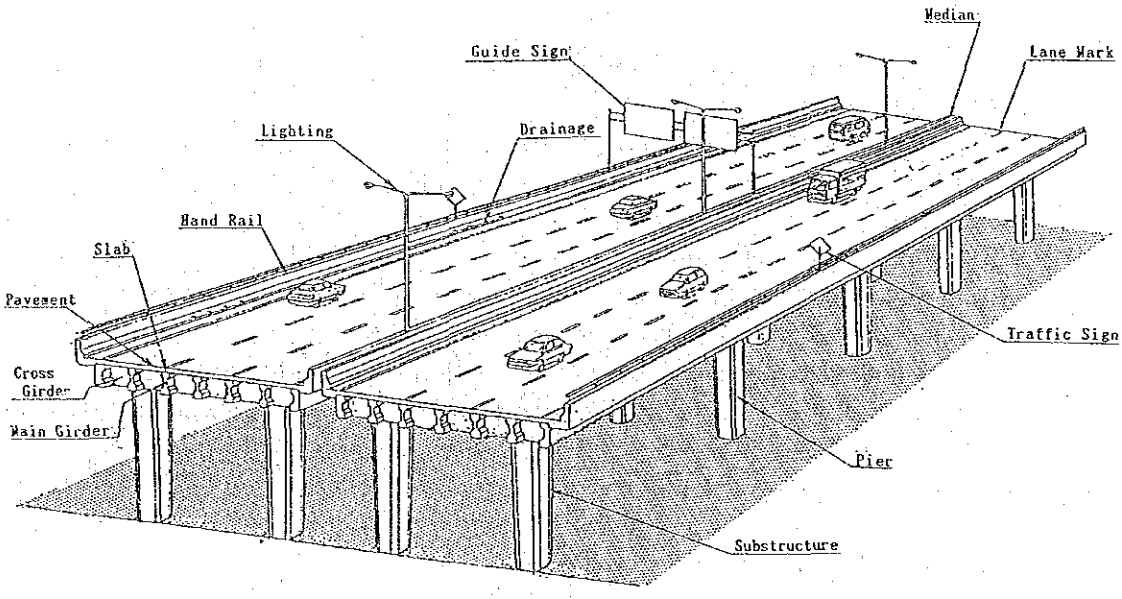
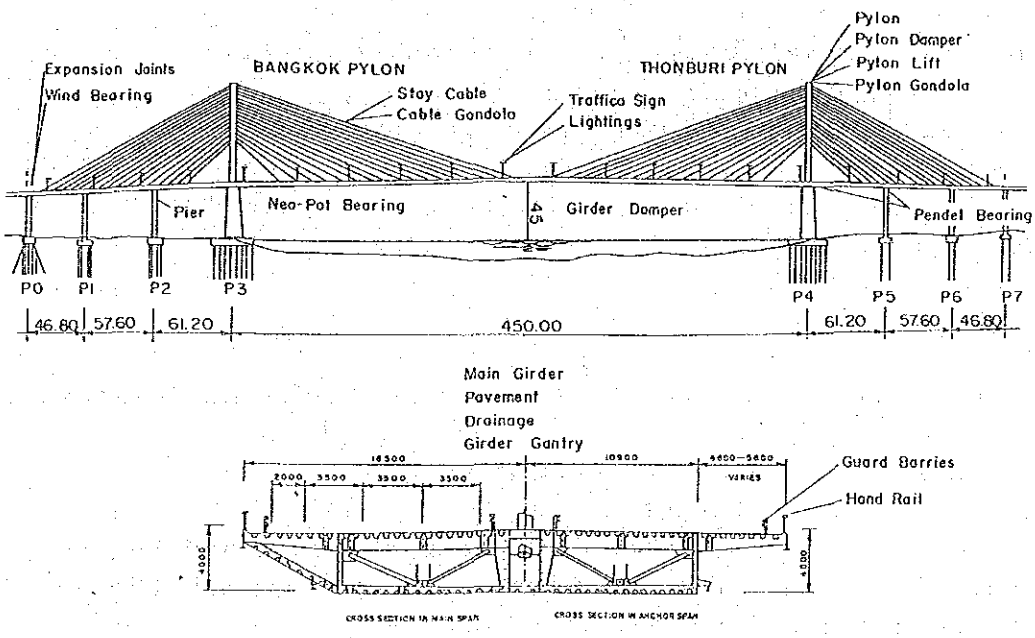


Fig. 1.1 Study Road Network



Land Section



Rama IX Bridge Section

Fig. 1.2 Objective Road Structures and Facilities

1.4 Study Flow

Fig. 1.3 shows the general work flow of the study which comprises of the following two phases.

- Phase 1 (June 1993 - March 1994)

  The study commenced in June 1993 and been carried out the following work items:

  Study on system concepts
  Submission of the Progress Report (November 1993)
  Design and formulation of database system
  Survey and Formulation of road inventory database
  Submission of Inspection/Repair Manuals (draft) (March 1994)
  Submission of the Interim Report (March 1994)
  Workshop to demonstrate the system (March 1994)

- Phase 2 (March 1994 - December 1994)

  Tentative application of the system to the expressway, as well as technology transfer to counterparts, and recommendations on expressway maintenance were carried out.

  Tentative application and technology transfer
  Review and evaluation of the system
  Recommendations on the expressway maintenance
  Submission of Inspection/Repair Manuals (September 1994)
  Submission of the Draft Final Report (September 1994)
  Submission of the Final Report (December 1994)

1.5 Work Results

The study team submitted the final version of the following:

- Database System Program (dBASE4/MS-DOS)
- Road Inventory Database
- Inspection Manual for the Land Section (Thai and English)
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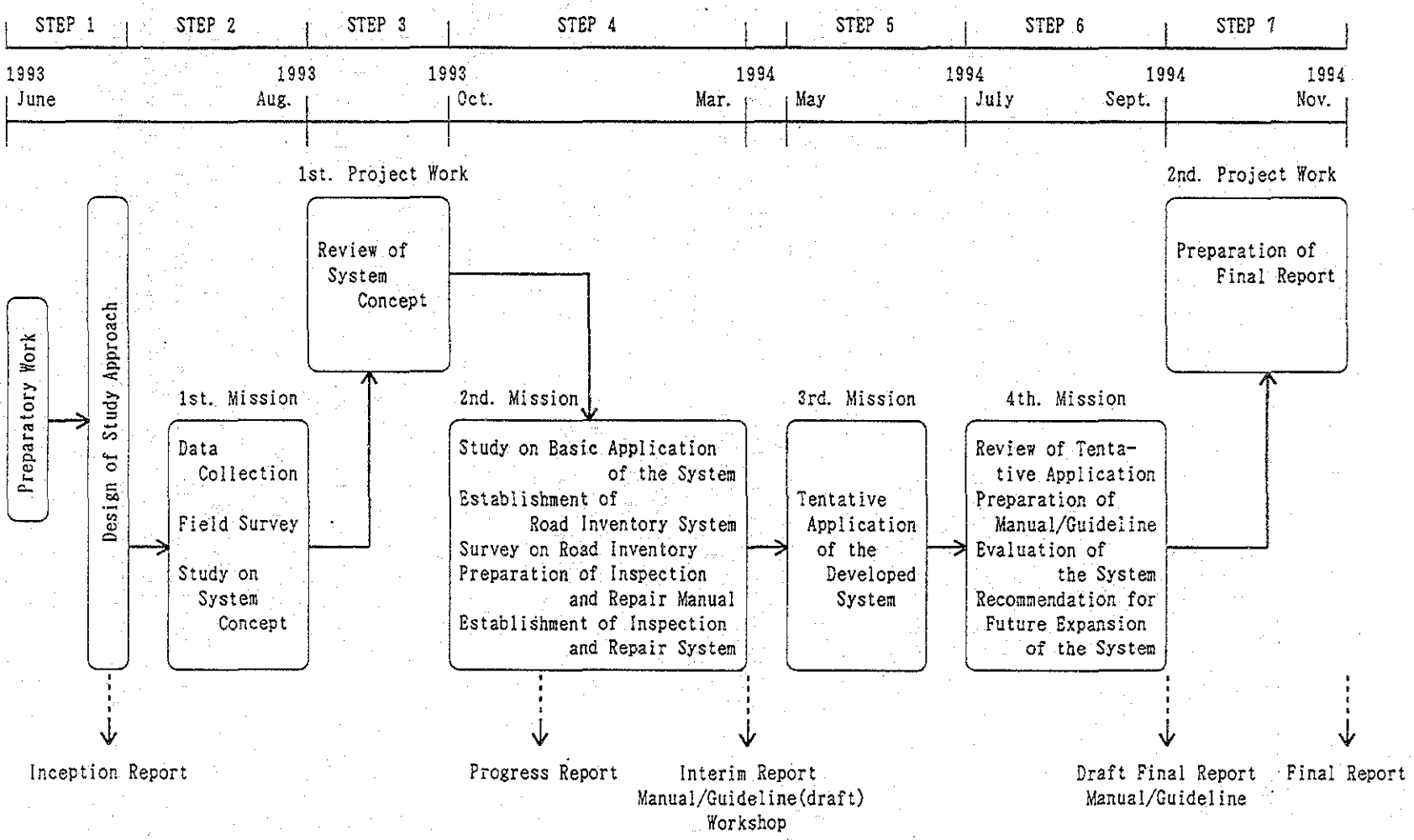


Fig. 1.3 General Flow of the Study

2. Outline of the Expressway

2.1 Road Structures and Facilities

ETA was established to plan, construct, and operate the expressway and mass transit system in the country under the Ministry of Interior in 1972.

The expressway system in Bangkok has been planned and constructed by ETA since 1978. A total of 27.1 km of expressway are currently in service and are known as the First Stage Expressway (FSE). FSE was constructed in 3 sections with Port junction as the center. The first section, Din Daeng to Port (8.9 km), was opened in January 1982 and leads to Don Muang International Airport and national highways No.1 and No.2, which extend to the north and northeast of Thailand. The second section, Bang Na to Port (7.9 km), was opened in January 1983 and joins two highways at Bang Na. One leads to the heavily industrialized area of Samut Prakarn, while the other ultimately leads to Trat and also links up with a highway that goes to the deep-sea port of Sattahip on the eastern seaboard. The last section, which connects Dao Khanong and Port (10.3 km), was opened to traffic in 1989. It links the expressway with the western side of the Chao Phraya River and also with Highway No.35, which stretches to Pak Tho and joins with Highway No.4 (which leads to the south of Thailand and Malaysia). The Rama IX Bridge is located on this section and crosses the Chao Phraya River.

The expressway is comprised of three types of structures: viaducts, embankments, and river crossings. The standard viaduct is composed of a cantilever pier top and simple girders with span lengths of 20m, 22.5m, 25m, and 30m to fit the terrain and road crossings (see Fig. 2.1 and Fig. 2.2). At-grade sections comprise approximately 20% of the expressway and the embankments are less than 1m high, as shown in Fig. 2.3.

The Rama IX Bridge is a large-scale cable-stayed bridge with a steel deck and box girders. The bridge's length is 781m with a 450m center span, as shown in Fig. 2.4. The approach viaducts for the bridge have 40m prestressed concrete girders and with a 50m span length.

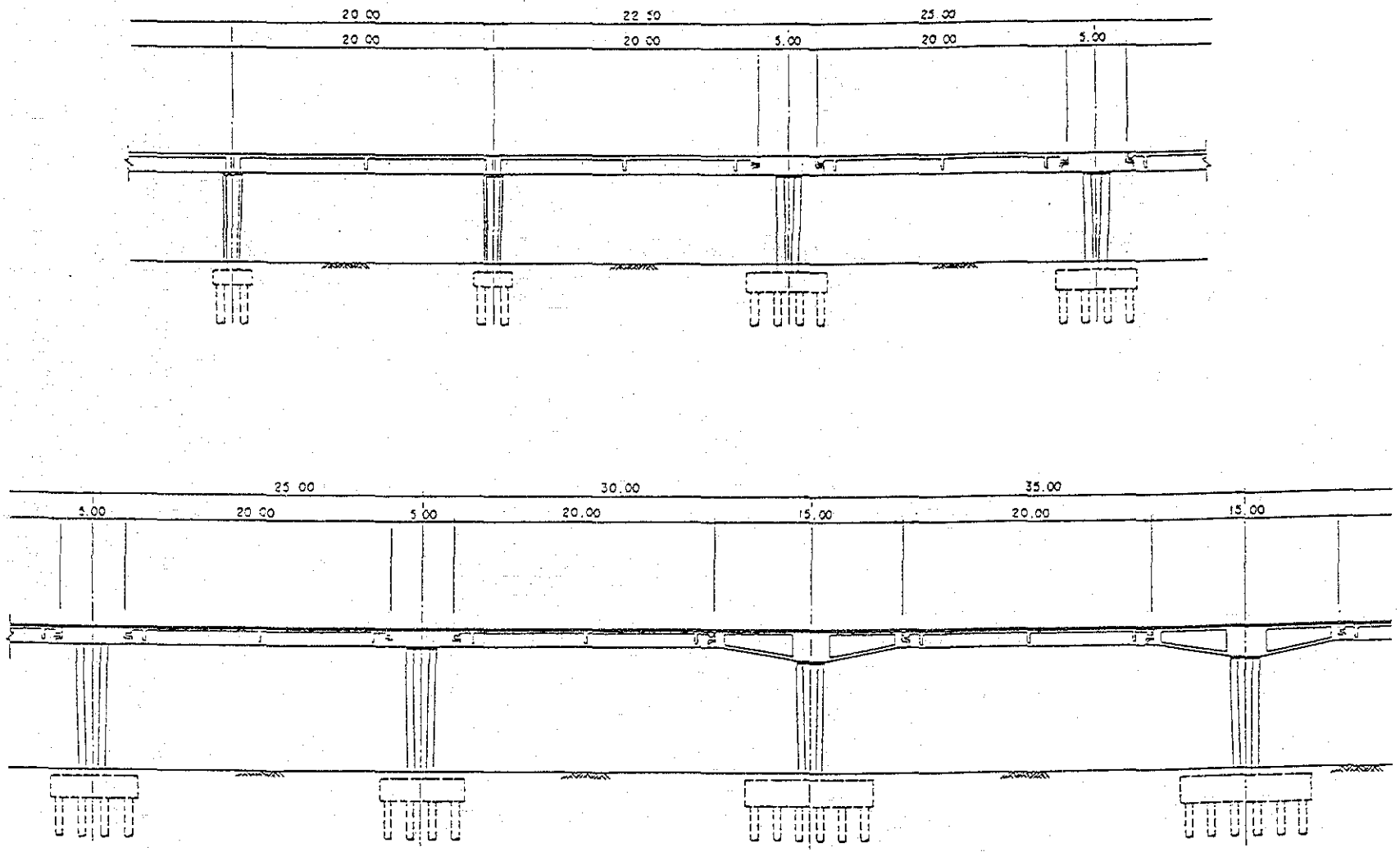
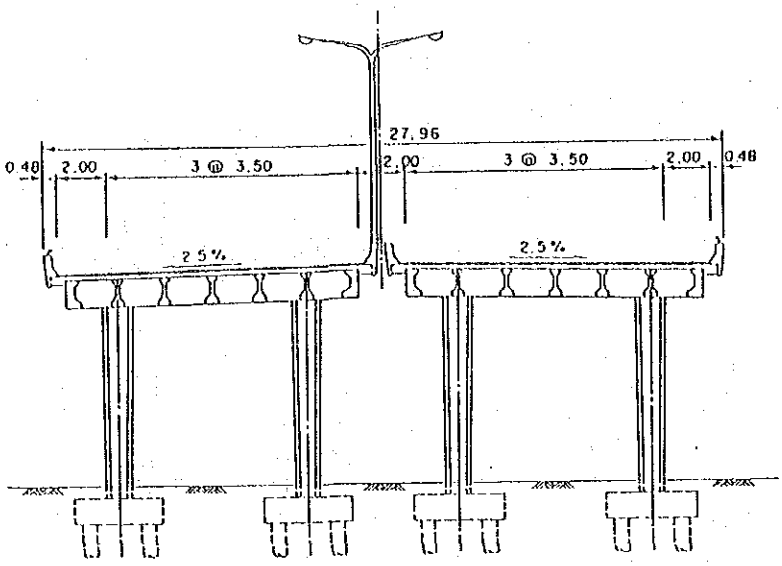
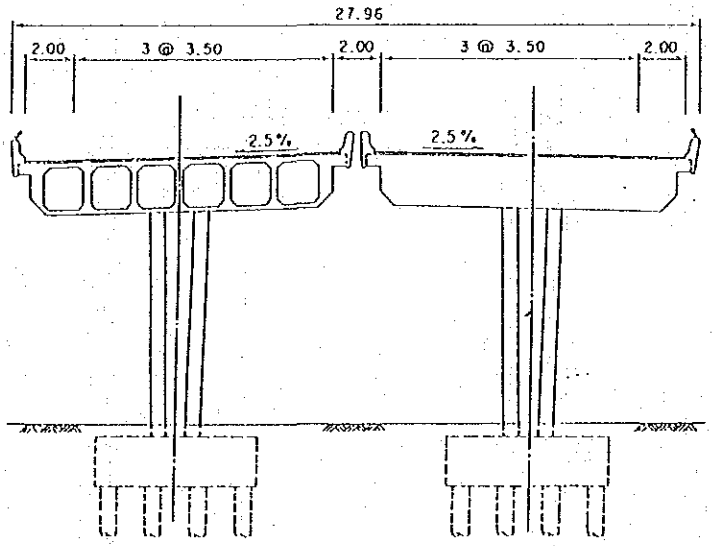


Fig. 2.1 Typical Viaduct Profile



CROSS SECTION (SPAN LENGTH 20 – 25 m.)



CROSS SECTION (SPAN LENGTH 30 – 35 m.)

Fig. 2.2 Typical Viaduct Cross-section

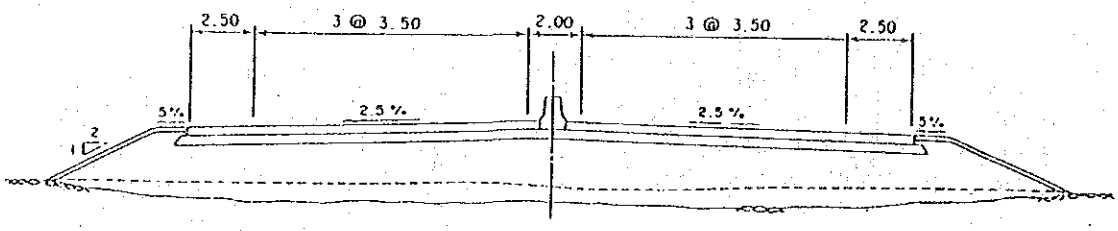
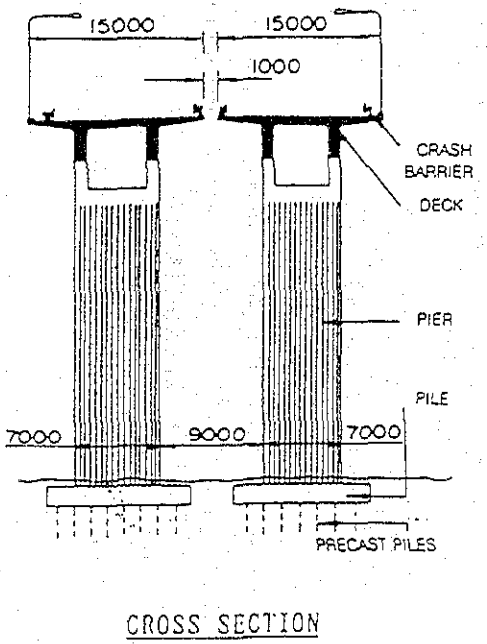


Fig. 2.3 Typical Embankment Cross-section



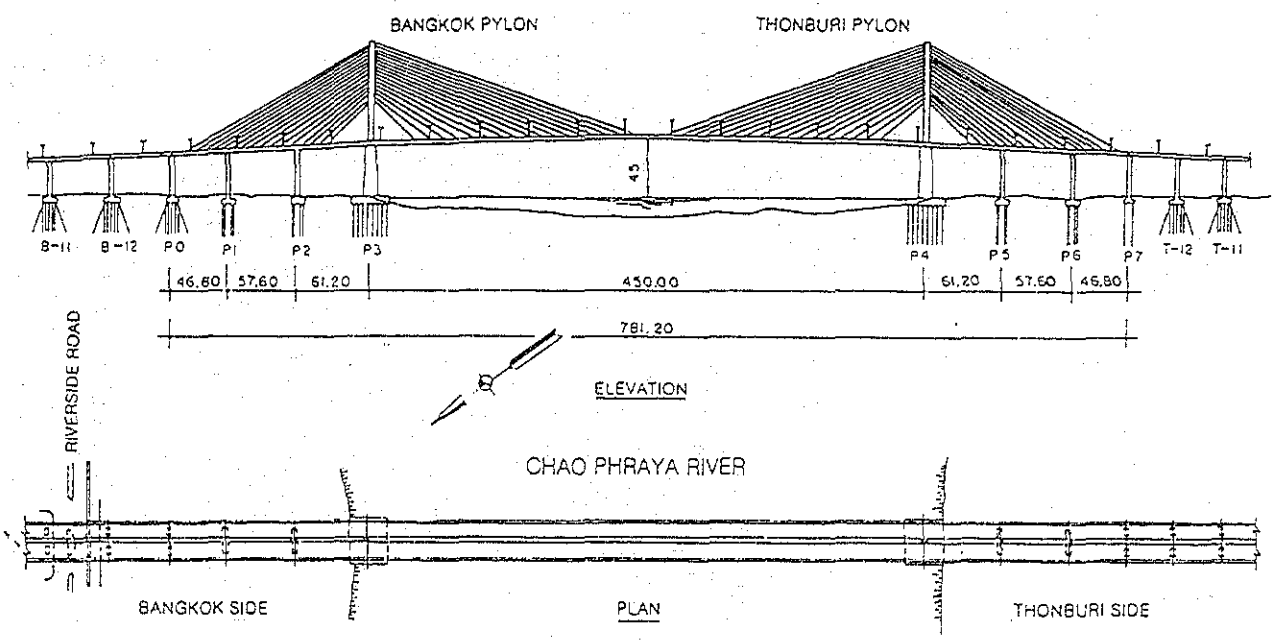


Fig. 2.4 Rama IX Bridge Profile

2.2 Maintenance Organization and Equipment

Maintenance for ETA's expressway is conducted by the Roadway Maintenance Section and Bridge Maintenance Section and both come under the Expressway Maintenance Division. The total number of staff working for these two sections is 111 persons, including drivers and workers.

ETA possesses about 20 pieces of equipment for light maintenance work; i.e., there are 4 inspection cars, 6 machines for concrete work, and 10 other machines and vehicles for pavement and welding work. However, since this equipment is unsuitable for heavy maintenance work, it is necessary to purchase appropriate equipment for such maintenance work in the future.

ETA is a self-supporting organization that covers it's expenditure with toll revenue from the expressway. The revenue for 1991 was 1.6 billion bahts, of which 80 % came from tolls. On the other hand, expenditures were 850 million bahts for administration and 180 million bahts for operation. The ratio of maintenance costs to operation costs was approximately 25% in 1991. However, this ratio was less than 10% in 1988 and has been increasing over time.

2.3 Types of Inspection and Damage

As shown below, here are currently three types of inspection.

- Routine Inspection
  A daily visual inspection from a running car of the expressway's condition.

- Periodic Inspection
  An inspection at regular intervals of major expressway structures using equipment.

- Special Inspection
  with any accidents.

The items considered in the above inspections are the expressway's general condition, road shoulders, drainage, pavement, road structures, steel works, and painting.

The existing expressway has been open to traffic for more than

ten years and damage and deterioration to structures and facilities is presently resulting in an increase in repairs. Most repairs conducted consist of light work on pavement and bridge joints and address problems such as following:

- Pavement Rutting and Cracking
  Embankment sections are prone to damage from roadbed settlement and are currently major repair work items.

- Cracking along Buried Joints
  Expansion joints, which are buried-type joints, are damaged by the direct loads of the wheel of vehicles. This type of damage is expected to increase.

- Retaining Wall Settlement
  Retaining walls subside in the Din Daeng-Port section. Since Bangkok's ground consists of soft clay, it is expected that this type of damage will increase in the future.

- Lateral Viaduct Movement
  The superstructure of the viaduct on the Bang Na-Port section has experienced lateral movement. It is assumed that the bridge pier is displaced by lateral ground movement caused by earthworks near the expressway.

- In addition to the above, some damage was reported on girders, slabs, drainage, etc.

2.4 Repairs

At present, repair work is mostly small in scale and is carried out under on of the following two systems:

- Force-account System
  Light repair work such as patching of pavement and painting, together with urgent repairs, is carried by ETA staff.

- Contract System
  Large-scale or routine repair work is farmed out to private contractors concerning pavement, bridge joints, pavement markings and guardrails.

3 Inspection and Maintenance System Concepts

3.1 Objectives of the System

The inspection and maintenance system focuses on improving and enhancing maintenance work by standardizing and systematizing information and work procedures for expressway maintenance. At present, maintenance work is carried out manually with the aid of inspection manuals that are insufficient for their intended application.

The system aims to achieve its stated objectives using inspection and repair manuals and computer databases to handle maintenance work from the construction to the inspection, repair and improvement stages. That is, an inventory database is established after construction while inspections and repairs are carried out efficiently with the aid of manuals and information stored in the database. This will lead to rationalization and improvement of maintenance work as shown in Fig. 3.1.

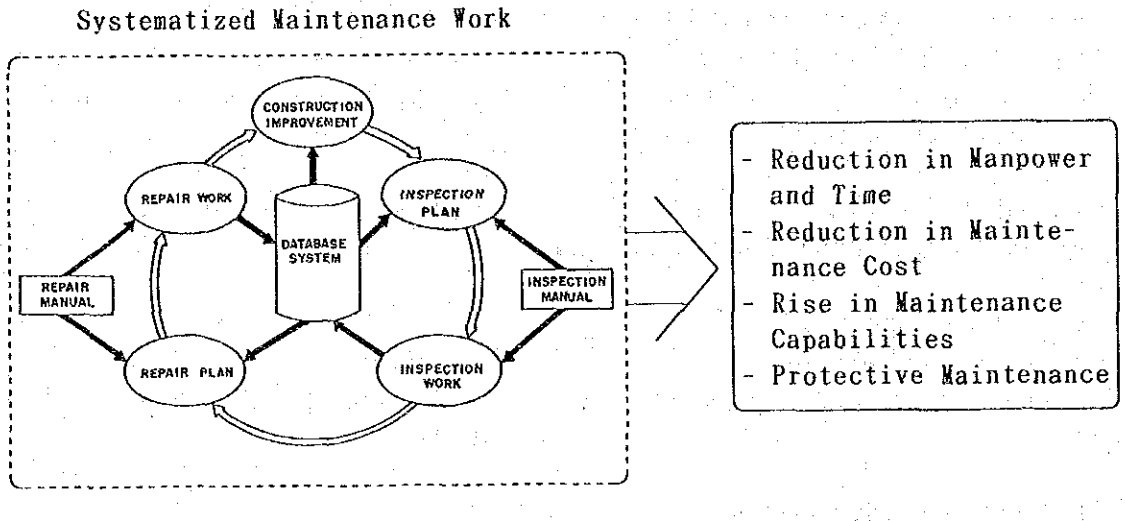


Fig. 3.1 Systematized Maintenance Work Flow

3.2 System Framework

The inspection and maintenance system is comprised of three major databases (inventory, inspection and repair), inspection manuals and a maintenance and repair manual, and a database system users manual as shown in Fig. 3.2.

The databases and inspection manuals are subdivided into the

Land Section and the Rama IX Bridge Section, since the Rama IX Bridge has peculiar technical factors that have to taken into account during inspection and maintenance.

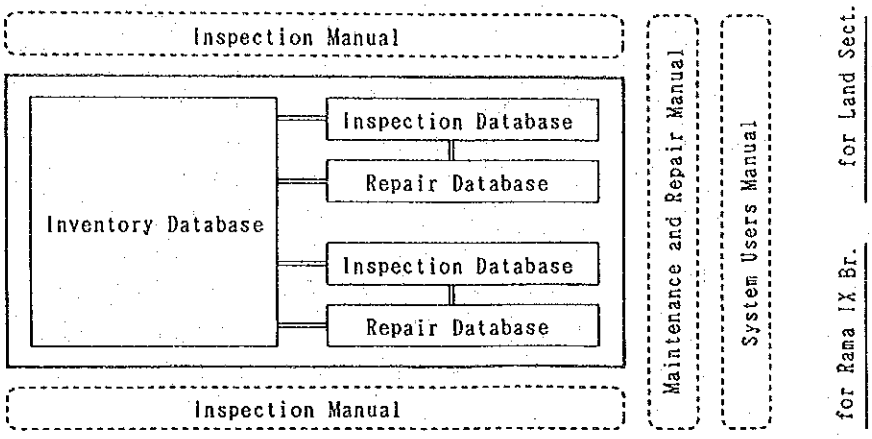


Fig. 3.2 System Framework

3.3 Inspection Categories

Inspection work is categorized into the following four types in terms of purpose, frequency, inspection items and methodology.

- Daily Inspection
  Daily visual inspection of traffic conditions and damage and deterioration to road structures and facilities, from a running car.

- Routine Inspection
  Routine inspection is classified into the following two types according to purpose and inspection items.

  Routine Inspection A:
  Periodic inspection on foot of the damage and deterioration to road structures using equipment at close range.

  Routine Inspection B:
  Periodic measurement on the comprehensive bridge behavior of the Rama IX Bridge to check for any irregularities.

- Special Inspection
  Investigation of road structures using more detailed methods to supplement the periodical inspection whenever necessary.

- Emergency Inspection
  Temporary inspection of road structures and facilities due to unexpected events, such as accidents or natural disasters.

3.4 Objective Structures and Damage Categorization

A roadway is composed of complicated structures and facilities made from various materials and structural types. Accordingly, in order to systematize information necessary for road maintenance, it is necessary to analyze and classify road characteristics in terms of structure, damage and repairs. Therefore, objective structures and facilities are classified and defined into 11 components for each the Land Section and the Rama IX Bridge, respectively, as shown in Table 3.1 and Table 3.2 below.

- Land Section
  Obstacles on road, concrete members, expansion joints, bearings, embankments, drainage, metal facilities, pavement, lighting, traffic signs, and noise barriers.

- Rama IX Bridge Section
  Obstacles on road, steel structures, cables, pavement, concrete piers, drainage, bearings, expansion joints, dampers, lighting and traffic signs.

Damage and deterioration to the above components are systematized by categorizing them into 4 to 7 items taken into consideration materials used, structure, function, and damage characteristics.

3.5 Damage Evaluation

In order to judge the necessity of repair work, observations of damage or deterioration are categorized into four ranks according to the following guidelines.

- Rating A
  Urgent repairs are necessary to secure the safety of vehicular traffic or to avoid the inconveniencing or injuring of third parties, due to outstanding damage or deterioration.

Table 3.1 Objective Members and Damage Items for Land Section

Objective Structure	Abbreviation	Damage Items
Obstacles to Road Traffic	FALLEN LOADS	: Obstacles to vehicular traffic by fallen loads
	DUST	: Obstacles to vehicular traffic by accumulating dusts
	OIL STAIN	: Slippery road surface by oil stain
	STANDING WATER	: Obstacles to traffic lanes by standing water
	CRASHED CAR	: Obstacles to traffic lanes by crashed car
	DISABLED CAR	: Obstacles to traffic lanes by disabled car
Concrete Members ・superstructure ・gaurd wall ・pier ・retaining wall	LEAKAGE	: Water leakage and leaching of free lime
	CRACKING	: Cracking
	SPALLING	: Spalling and corrosion of reinforcing bar
	CAVITIES	: Cavities
	DISPLACEMENT	: Displacement or settlement
Expansion Joints	DAMAGE-JOINT	: Damage to joint elements
	DAMAGE-PLUG	: Damage to plugging and faulting
	LEAKAGE	: Water leakage due to damage or deterioration
	NOISE	: Unusual noise due to damage or unevenness
Bearings	DAMAGE-BEARING	: Damage to rubber or steel bearing elements
	DAMAGE-BED	: Damage to bearing bed
	DAMAGE-BOLTS	: Damage to anchor bolts
	DEBRIS	: Accumulation of debris around bearings
Embankments	EROSION	: Erosion or heaving at bank shoulder
	SUBSIDENCE	: Subsidence of bank shoulder
	DAMAGE-MASONRY	: Damage to masonry wall
	DISPLACEMENT	: Displacement or settlement of masonry wall
Drainage	DAMAGE-INLET	: Damage to drain inlet
	DAMAGE-PIPE	: Damage to pipes, ditches or connections
	DEBRIS	: Accumulation or jamming up of debris
	DEFECT-DISCH.	: Defects of drain discharge
Metal Facilities ・guardrail ・handrail ・fence	CORROS-COLUMN	: Damage to paint and corrosion of support column
	DEFORM-COLUMN	: Deformation of support column
	DISP.-COLUMN	: Displacement or loosening/falling out of bolts of support column
	CORROS-PANEL	: Damage to paint and corrosion of panel/fence
	DEFORM-PANEL	: Deformation of panel
	DISP.-PANEL	: Displacement or loosening/falling out of bolts
Pavement	CRACKING	: Cracking to pavement
	DEFORMATION	: Deformation of pavement, rutting, corrugation, depression and faulting
	DISRUPTION	: Disruption of pavement, pot holes, exfoliation
	ABRASION	: Abrasion of pavement, scaling
	DAMAGE-MARK	: Deterioration of lane marking paints
Lighting	CORROS-POLE	: Damage to paint and corrosion of pole
	DEFORM-POLE	: Deformation of pole
	DISP-POLE	: Displacement or loosening/falling out of bolts of pole
	LAMP BREAK	: Burning out/decline in luminosity of lamp
	DAMAGE-REFLECT	: Damage to reflector
Traffic Signs	CORROS-POLE	: Damage to paint and corrosion of pole
	DEFORM-POLE	: Deformation of pole
	DISP-POLE	: Displacement or loosening/falling out of bolts
	VISUAL DEFECT	: Deterioration of visibility of signboards
	DAMAGE-PANEL	: Damage to panel/attachment of signboards
	LAMP BREAK	: Burning out/decline of luminosity of lamp
	DAMAGE-REFLECT	: Damage to reflector
Noise Barrier	CORROS-COLUMN	: Damage to paint and corrosion of support column
	DEFORM-COLUMN	: Deformation of support column
	DISP-COLUMN	: Displacement or loosening/falling out of bolts
	DAMAGE-PANEL	: Damage to barrier panel
	DAMAGE-BOLTS	: Loosening or falling out of bolts
	CORROS-PANEL	: Damage to paint and corrosion

Table 3.2 Objective Members and Damage Items of Rama IX Bridge

Objective Structure	Abbreviation	Damage Items
Obstacles to Road Traffic	FALLEN LOADS	: Obstacles to vehicular traffic by fallen loads
	DUST	: Obstacles to vehicular traffic by accumulating dusts
	OIL STAIN	: Slippery road surface by oil stain
	STANDING WATER	: Obstacles to traffic lanes by standing water
	CRASHED CAR	: Obstacles to traffic lanes by crashed car
	DISABLED CAR	: Obstacles to traffic lanes by disabled car
Steel Plates and Frame ・main girder ・pylon ・guard barrier ・handrail ・girder gantry ・pylon lift ・pylon ladder ・pylon gondola ・cable gondola	DEFORMATION	: Deformation of plates or frame
	CRACKING	: Cracking on plates or frame
	DAMAGE-BOLTS	: Loosening or falling out of bolts
	DAMAGE-CORROS.	: Damage to paint and corrosion
	DEBRIS/WATER	: Accumulation of debris or water
	DISPLACEMENT	: Displacement or settlement
Stay Cable	CRACK-CABLE	: Cracking or corrosion of cable
	SAG DISPLACE.	: Unusual displacement of sag
	VIBRATION	: Unusual vibration of cable
	CRACK-COVER	: Cracking of cable cover
	DAMAGE-BOLTS	: Loosening or falling out of bolts of cover
	PAINT-COVER	: Damage to paint of cable cover
	SOCKET SLIP.	: Socket slippage of cable anchorage
	OIL LEAKAGE	: *Oil leakage of cable anchorage*
	PAINT-ANCHOR	: Damage to paint of cable anchorage
Pavement	CRACKING	: Cracking to pavement
	DEFORMATION	: Deformation of pavement, rutting, corrugation, depression and faulting
	DISRUPTION	: Disruption of pavement, pot holes, exfoliation
	ABRASION	: Abrasion of pavement, scaling
	DAMAGE-MARK	: Deterioration of lane marking paints
Concrete Members ・pier	LEAKAGE	: Water leakage and leaching of free lime
	CRACKING	: Cracking
	SPALLING	: Spalling and corrosion of reinforcing bar
	CAVITIES	: Cavities
	DISPLACEMENT	: Displacement or settlement
Drainage	DAMAGE-INLET	: Damage to drain inlet
	DAMAGE-PIPE	: Damage to pipes, ditches or connections
	DEBRIS	: Accumulation or jamming up of debris
	DEFECT-DISCH.	: Defects of drain discharge
Bearings ・pendel ・neo-pot ・wind	DAMAGE-PAINT	: Damage to paint and corrosion
	CRACKING	: Cracking or deformation
	DAMAGE-BOLTS	: Damage to anchor bolts
	UNUSUAL MOVE.	: Unusual movement
	ABRASION	: Abrasion or deterioration of attach elements
	NOISE	: Unusual noise
Expansion Joints	DAMAGE-PAINT	: Damage to paint and corrosion
	ABRASION	: Abrasion or deformation
	DAMAGE-BOLTS	: Loosening or falling out of bolts
	UNUSUAL MOVE.	: Unusual movement
	NOISE	: Unusual noise due to damage or unevenness
	DAMAGE-DRAIN	: Damage to drainage
Damper ・pylon ・girder ・cable	*OIL LEAKAGE*	: *Oil leakage due to damage or deterioration*
	DAMAGE-BOLTS	: Loosening or falling out of bolts
	DAMAGE-PAINT	: Damage to paint and corrosion
	UNUSUAL MOVE.	: Unusual movement
Lighting	CORROS-POLE	: Damage to paint and corrosion of pole
	DEFORM-POLE	: Deformation of pole
	DISP-POLE	: Displacement or loosening/falling out of bolts of pole
	LAMP BREAK	: Burning out/decline in luminosity of lamp
	DAMAGE-REFLECT	: Damage to reflector
Traffic Signs	CORROS-POLE	: Damage to paint and corrosion of pole
	DEFORM-POLE	: Deformation of pole
	DISP-POLE	: Displacement or loosening/falling out of bolts
	VISUAL DEFECT	: Deterioration of visibility of signboards
	DAMAGE-PANEL	: Damage to panel/attachment of signboards
	LAMP BREAK	: Burning out/decline of luminosity of lamp
	DAMAGE-REFLECT	: Damage to reflector

- Rating B
  Repairs are required due to the existence of serious damage which effects the function or durability of the structure.

- Rating C
  Damage or deterioration is small and no repairs are necessary. However, further study may be necessary.

- Rating D
  Virtually no repairs and no further study are required due to the existence of slight damage or no damage.

3.6 Work Procedures of Inspection and Maintenance

A systematized inspection and maintenance work flow is shown in Fig. 3.3. Inspection is first carried out to grasp the condition of road structures and facilities, which influences further measures such as the repairs to be taken for damaged structures or facilities, and inspection results are compiled in the database. Repair data is also compiled in the database. Stored data can be outputted in a form of inspection or repair reports whenever necessary.

Stored information, which is in the form of road inventory, inspection and repair databases can also be utilized for inspection and repair planning, expressway operations, and expressway administration.

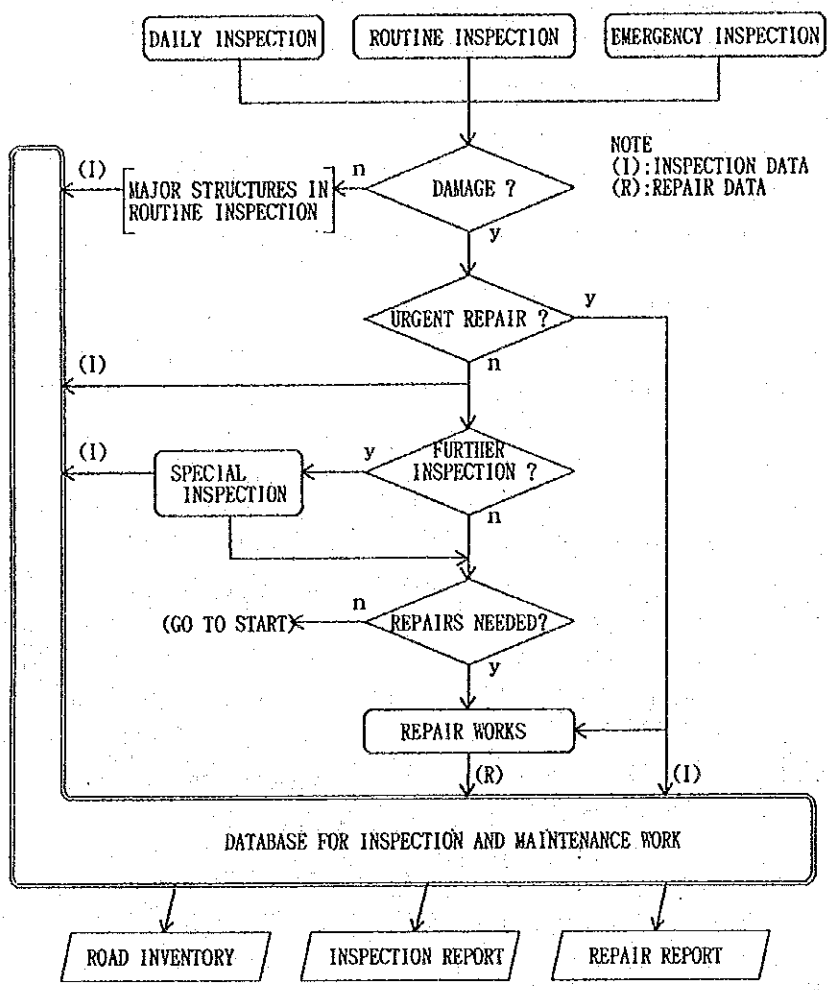


Fig. 3.3 Inspection and Maintenance Procedures

4 Inspection and Repair Manuals

4.1 Manual Framework

Since inspection is always conducted prior to repair, there are separate inspection and repair manuals. In addition, as the Rama IX Bridge is separately managed separately from the Land Section in ETA, inspection manuals are subdivided into those for the Land Section and the Rama IX Bridge Section. However, for reasons of convenience and efficiency, there is only one repair manual.

4.2 Inspection Manuals

The inspection manuals describe objectives, work plans, work methodologies, the rating of observations, coding, and databases. The contents of the inspection manuals are summarized below.

1) Inspection Manual for the Land Section

- Chapter 1 Introduction
  System framework, work procedures, key identifiers, and road structures and their design requirements.

- Chapter 2 Inspection General
  Objectives of inspection, inspection categories, objective structures, equipment and vehicles for inspection work, work safety, damage ratings and reporting.

- Chapter 3 Daily Inspection
  Objectives of daily inspection, objective structures and damage, inspection methods, and reporting.

- Chapter 4 Routine Inspection
  Objectives of routine inspection, objective structures and damage, work procedures, rating of possible damage to objective 10 components and work methods, and reporting.

- Chapter 5 Special Inspection
  Objectives of special inspection, work principles, inspection methods for concrete structures, rating of possible damage to pavement and expansion joints, and reporting.

- Chapter 6 Emergency Inspection
  Objectives of emergency inspection, work principles, work procedures, possible damages and their ratings, and reporting.

2) Inspection Manual for the Rama IX Bridge

- Chapter 1 Introduction
  System framework, work procedures and key identifiers.

- Chapter 2 General Description of the Bridge
  Bridge structures and design conditions.

- Chapter 3 Inspection General
  Objectives of inspection, inspection categories, objective bridge components, equipment and vehicles for inspection work, work safety, damage ratings and reporting.

- Chapter 4 Daily Inspection
  Objectives of daily inspection, objective structures and damage, inspection method, and reporting.

- Chapter 5 Routine Inspection (A)
  Objectives of Routine Inspection A, objective structures and damage, work procedures, rating of possible damage to 9 bridge components and work methods, and reporting.

- Chapter 6 Routine Inspection (B)
  Objectives of Routine Inspection B, work principles, inspection items, detailed work methods on 5 items such as pylon inclination and cable tension force, and reporting.

- Chapter 7 Special Inspection
  Objectives of special inspection, work principles, rating of possible damage to concrete structures, pavement, and reporting.

- Chapter 8 Emergency Inspection
  Objectives of emergency inspection, work principles, work procedures, possible damages and their ratings, and reporting.

4.3 Repair Manual

The Maintenance and Repair Manual describes not only repairs but daily routine maintenance work as well (see below).

- Chapter 1 Introduction
  System framework, inspection and maintenance work procedures, numbering system of bridge components, the roadway and its structures and their design requirements.

- Chapter 2 Repair and Maintenance General
  Objectives of maintenance, work components, objective structures, maintenance and repair planning, work safety, and reporting.

- Chapter 3 Ordinary Maintenance Operations
  Objectives and organization of work, work frequency, cleaning work methods for pavement, drainage and road appurtenances, and bridge painting.

- Chapter 4 Specialized Maintenance Operations
  Repair principles, selection of repair methods, repair methods for concrete structures, steel structures, pavement and bridge joints, and strengthening methods for concrete structures.

5 Database System Design

5.1 Database Framework

In the database system, detailed information on inventory and inspection/repair, which can not be stored in a single database, are compiled in separate databases for effective computer usage and to avoid the duplication of information. Therefore, 9 databases and 19 database files are formulated as shown in Fig. 5.1.

There are separate inspection and repair databases for the Land Section and the Rama IX Bridge Section, since component identification and the responsible maintenance crews are different. The member database file is formulated to manage bridge component information for the Rama IX Bridge, which has its bridge members subdivided into smaller components for reason of manageability. The code database manages code and its corresponding characters.

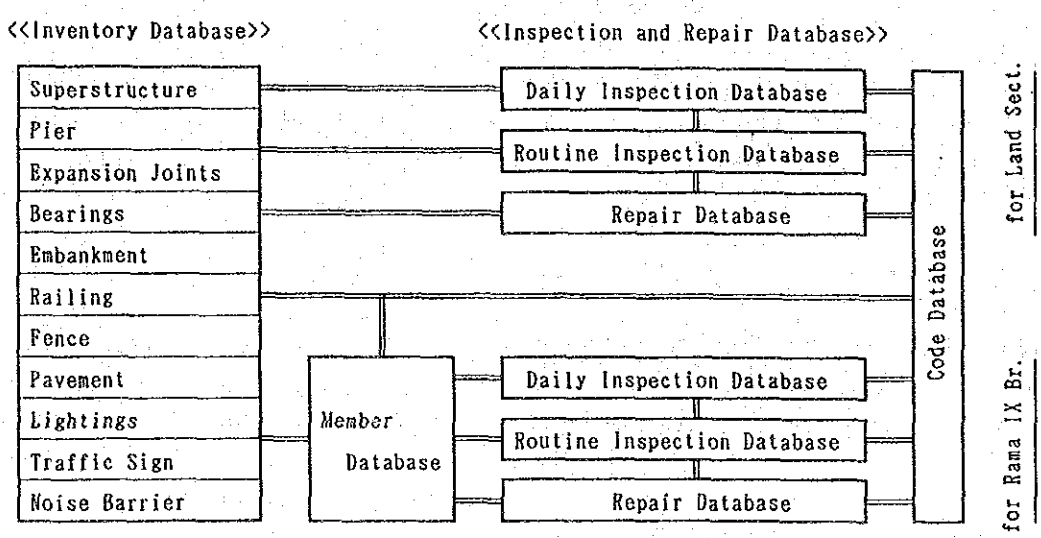


Fig. 5.1 Database Framework

5.2 Interrelationships among Databases

The road inventory database compiles information on roadway components and describes such things as their length and functions to achieve effective information management for the objective road structures and facilities. When inspection or repair is carried out, the inspection or repair information is stored in the relevant database of the system.

Accordingly, road inventory data shall be compiled first to bring about expressway maintenance. When inspection data is inputted into the database system, the system checks for the existence of the inputted component in the inventory database; in addition , the system checks for the existence of damage data in the inspection database when repair data is inputted (see Fig. 5.2).

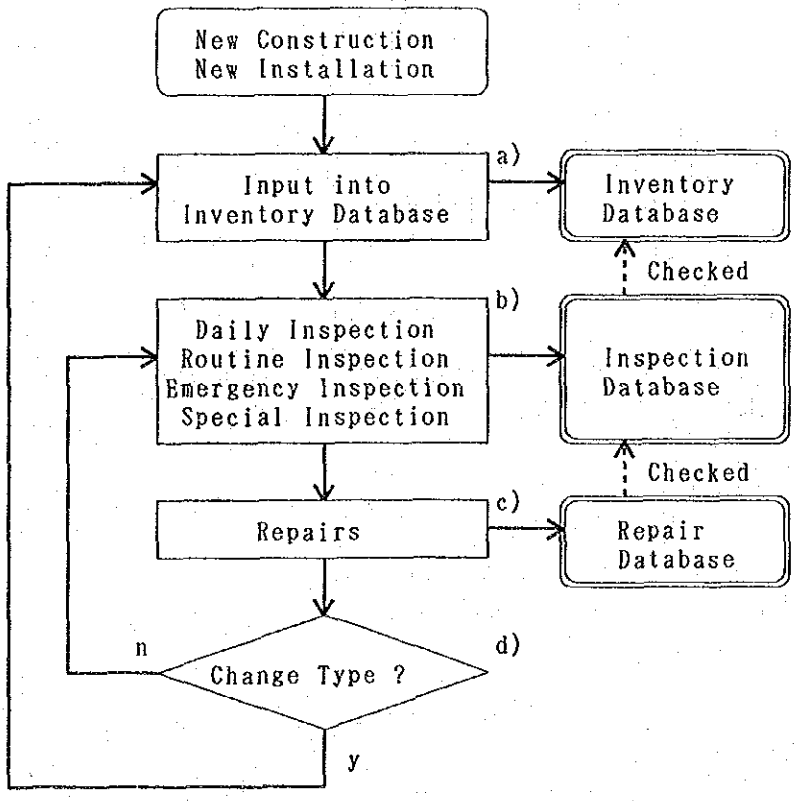


Fig. 5.2 Procedures to Create Database System

5.3 Data Items

The items in each database are composed of key identifiers, attributive data and control data. Key identifiers are items to identify such information as member type, location and date. Attributive data is necessary to identify such things as materials used, structural characteristics, and types of damage. Control data is necessary for information processing.

The number of data items for the above 19 database files is shown in Table 5.1. There are 442 items in total and of these 253 are attributive data items.

Table 5.1 Number of Data Items of Database Files

Database Files	Key Identif'r	Attributive Data	Control Data	Total Items	Length (bytes)
<Inventory>					
Superstructures	7	16	3	26	137
Piers	6	8	3	17	96
Expansion Joints	4	7	3	14	79
Bearings	6	6	3	15	71
Embankments	5	19	3	27	129
Railing	6	6	3	15	90
Fence	6	7	3	16	91
Pavement	5	40	3	48	218
Lighting	6	10	3	19	118
Traffic Signs	6	19	3	28	172
Noise Barrier	6	7	3	16	91
<Daily Inspection>					
Land Section	5	18	5	28	165
Rama IX Bridge	4	16	5	25	155
<Routine Inspection>					
Land Section	13	17	4	34	175
Rama IX Bridge	5	21	4	30	136
<Repair>					
Land Section	17	16	7	40	311
Rama IX Bridge	7	16	7	30	246
<Member>	3	1	4	8	24
<Code>	1	3	2	6	70

5.4 Input and Output

There are 43 types of coding sheets to facilitate the collection and entry of information into the database system (see below).

	Land Section	Rama IX Bridge	Total
Road Inventory	--	--	11 forms
Daily Inspection	1 forms	1 forms	2 do.
Routine Inspection	11 do.	9 do.	20 do.
Repairs	8n do.	2 do.	10 do.

The system allows for frequently used information to be shown on the computer screen and provides 50 different output forms to retrieve this information as hardcopy (see below).

	Land Section	Rama IX Bridge	Total
Road Inventory	--	--	11
Daily Inspection Report	1	1	2
Routine Inspection Report	11	9	20
Member List to be Inspected	1	1	2
Repair Report	8	2	10
Member List to be Repaired	1	1	2
Cost Estimation List	2	1	3

5.5 Database System Design Concepts

To make the system user-friendly, it interacts with users by displaying easy-to-understand messages on the screen. Major functions of the system are comprised of inputting, altering, deleting, retrieving and outputting information. The basic design concepts in updating a database are to protect the database from erroneous inputting by means of a password, code matching, checking of key identifiers, and prevention of record duplication.

In addition to the above, the system is designed to be capable of displaying code in Thai, as well as allowing the inputting and outputting of information in Thai. Fig. 5.3 and Fig. 5.4 show a sample screen layout of the system.

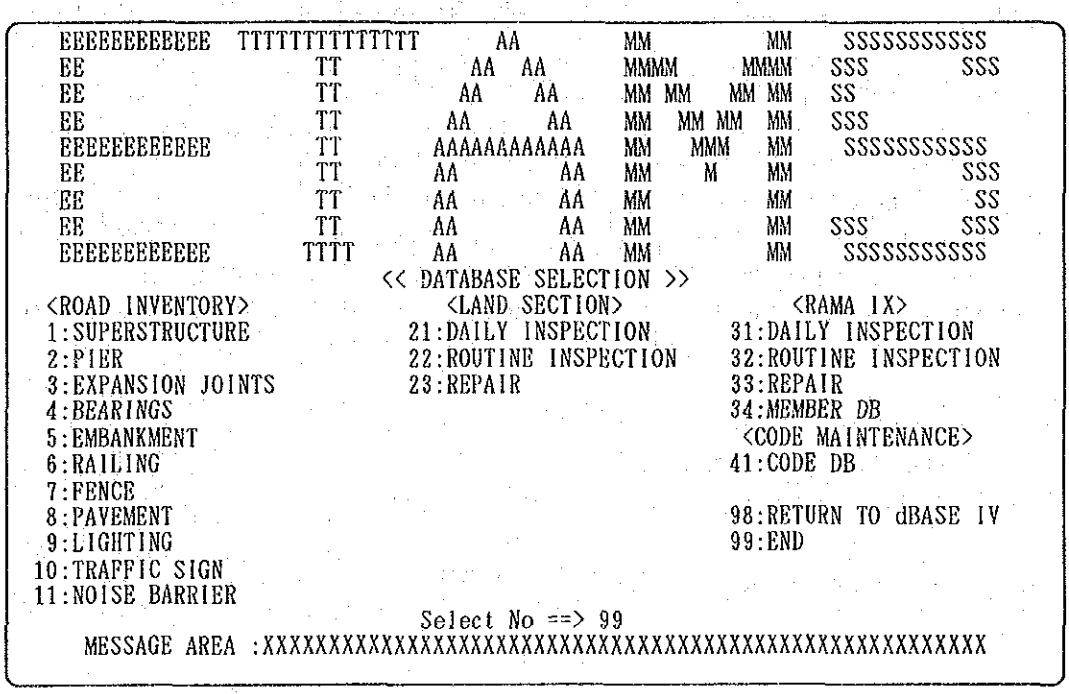


Fig. 5.3 Opening Screen of Database System

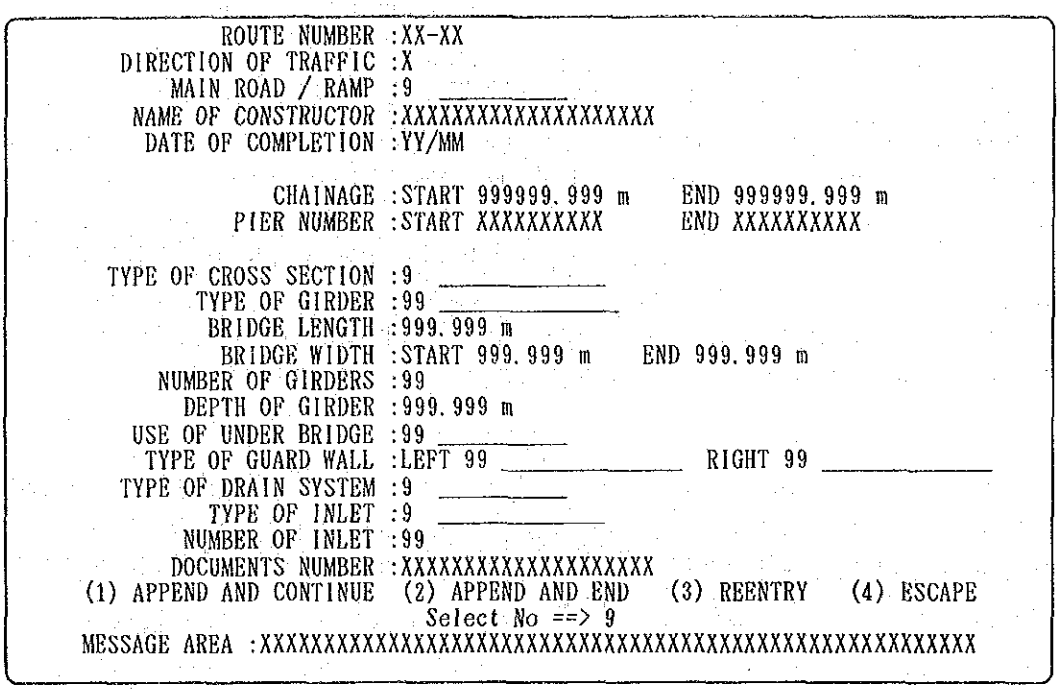


Fig. 5.4 Screen for Appending Superstructure Inventory

5.6 Programs

The database system, which is in dBASE4(Ver. 1), is operating on a NEC PowerMate 466i microcomputer in a MS-DOS environment. This machine has ample hard disk capacity (200MB) to accommodate the developed system's maintenance information.
The size of the developed programs totals 2,100KB as shown below.

Road Inventory System	:	379 KB
Daily Inspection System	:	195 KB
Routine Inspection System	:	850 KB
Repair System	:	588 KB
Code and Member System	:	88 KB

6 Road Inventory

6.1 Survey Method

Road inventory data was collected to create an inventory database for ETA's existing 27.1-kilometer long expressway in the same manner of the developed system, by means of documents survey and field survey. Collected data were coded and inputted into road inventory database. Data collection was ordered to the local consultant company, the study team and counterparts team assisted in case of being insufficient source information as well as field survey.

6.2 Survey Results

The collected data, as shown in Table 6.1, covers the total expressway's length of 27,262m, which has a pavement area of 858,547 square meters.

Table 6.1 Number of Data Records Collected

Database Files	Number of Records	Volume(KB)
Superstructure	1,637	227
Piers	1,601	154
Expansion Joints	2,715	218
Bearings	3,264	265
Embankments	431	61
Railing	197	16
Fence	822	75
Pavement	2,197	456
Lighting	1,267	150
Traffic Signs	335	58
Noise Barrier	7	1
Total		1,681

7 System Application and Evaluation

7.1 Tentative Application

In order to have the developed system applied by ETA staff to the ETA expressway after completing the study, as well as to transfer technology, a tentative application was carried out on a pilot road section between Petchburi Road and Rama IV Road, which includes viaducts and embankments for a total length of 3,075 m, and the Rama IX Bridge Section. The study team provided a code table, route maps, and a key list to facilitate the work.

Prior to application the framework of the inspection and maintenance system, including manuals, regulations, coding methods, and databases, was explained. Inspection work and other system operation works were carried out by ETA counterparts together with the study team on site for about three months. Collected data was inputted into the computer by operators, and the system's operation was successfully confirmed.

7.2 System Evaluation

The developed system can be expected to be effective for ETA's expressway maintenance in the following terms.

- Rise in Work Efficiency: reduction in costs and time and higher maintenance information accuracy.

- Dispersion of Information: better information accessibility, user-friendly system and real-time processing.

- Rise in Creativity: analyses in maintenance engineering, long-range planning and technical studies.

It is expected that the developed system would be able to reduce manpower in approximately 80% for maintenance information management, on the assumption of performing works in the same level between pre-and-post systematization. If all other site and office work, such as inspection and design, is considered together with maintenance information management, there would be a decrease in manpower of approximately 30 to 50%.

According to an evaluation of the system using a scoring model,

the system will produce both qualitative and quantitative benefits in costs and time. And this will be effective in raising work efficiency, dispersing information, and reinforcing work capabilities for expressway maintenance.

Here, the developed system was also evaluated using scoring model shown in Fig. 7.1 below. Zero represents no change the present, while the numerals 1, 2, 3, 4, and 5 represent an improvement over the present of 10, 30, 50, 70, and 90%, respectively. The system was evaluated using this model by study team members and counterpart team members and the results averaged to obtain a more objective assessment.

Evaluated results shows that indirect (qualitative) effects on reduction in cost and time will be larger than direct (quantitative) effects on improvement in information utilization and rise in work quality, as shown in Fig. 7.1.

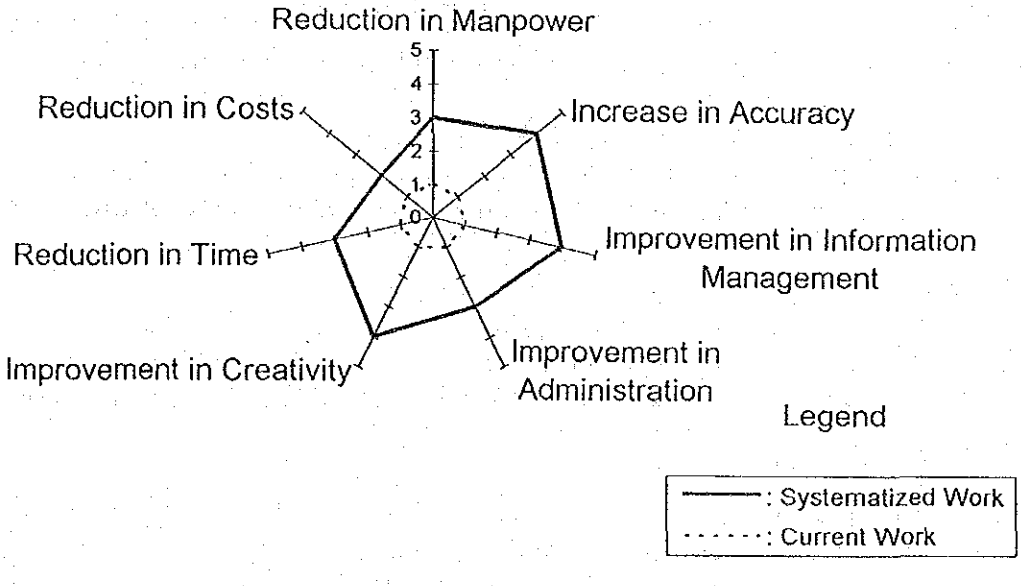


Fig. 7.1 Diagram of System Evaluation

8 Recommendations on ETA Expressway Maintenance

8.1 References and Equipment for Maintenance

In order to raise ETA's maintenance capabilities, the following are proposed.

- Route Maps
  Route maps along the expressway to conduct maintenance work efficiently to grasp roadside conditions and locations quickly.

- Numbering System
  Numbering system to assist with the identification of locations or designated inspection members using chainage, pier numbers, and kiloposts.

- Preservation of Drawings and Documents
  Establishment of rules and introduction of a microfilm system to preserve drawings and engineering documents.

- Vehicles for Maintenance Work
  Traffic-sign cars, patrol cars, and command cars for maintenance work in order to carry out work efficiently and safety.

8.2 Organization for Maintenance

A maintenance organization plan is recommended to raise the level of maintenance work via use of the developed system (see below).

- Organization for System Management
  Allocation of a manager and operators are recommended to utilize the developed system effectively, since new tasks will be generated with the introduction of the system as shown in Fig. 8.1. However, it is also proposed to be desirable that maintenance engineers operate the database system themselves.

- Strengthening Maintenance Staffing
  It is necessary to increase the number of engineers to improve maintenance work, since there is at present shortage. Also, it is recommended that engineering capabilities in material testing and traffic operations be strengthened.

- Sub-governmental Organization
  It is proposed that a sub-governmental organization be established under the jurisdiction of ETA to cope with increasing maintenance work, in term of using maintenance technology of retired engineers. It will carry out inspection, roadway cleaning, sales of tickets, user information service, and management of space under viaducts.

- Maintenance Branch Office
  For effective maintenance work, it is recommended that a new branch office be established when the Ramindra-Atnarong Expressway is completed.

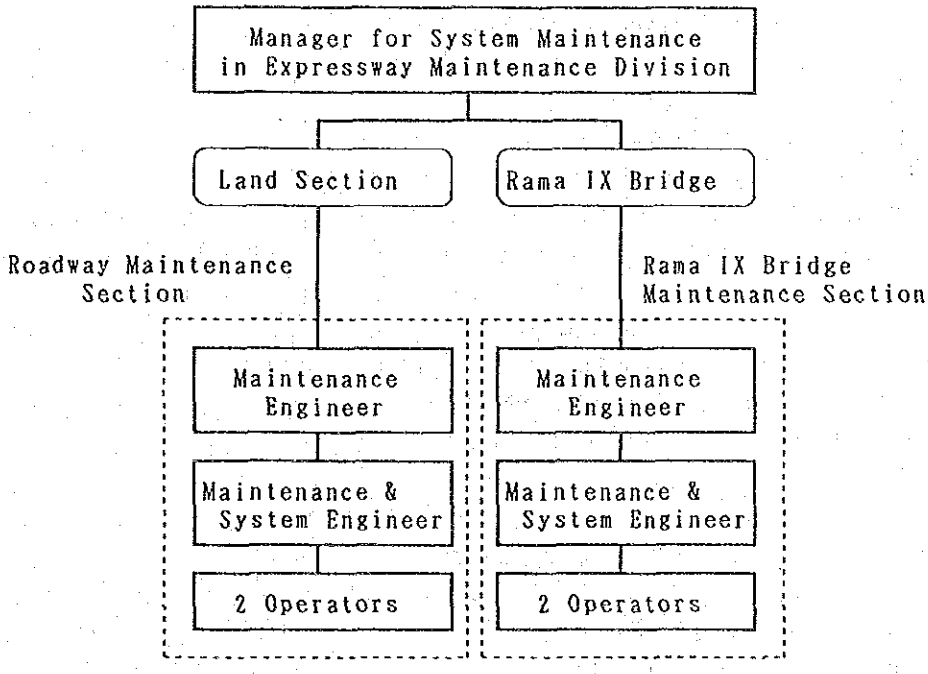


Fig. 8.1 Organization and Allocation of Personnel

8.3 Work System for Maintenance

To conduct maintenance work safely and efficiently, the following is recommended.

- Regulations for Maintenance Work Safety
  To secure worker safety on the expressway during maintenance work, it is proposed that information be provided to drivers, that sign-cars be stationed and relevant traffic regulations be established.

- Unit-Price Contract System
  In order to have contractors carry out promptly small and medium-scale repairs, the unit-price contract system is recommended.

- Initial Data Collection by Contractors
  In order not to increase ETA's work, it is recommended that initial data collection and coding for road inventory be performed by contractors for the future expressway network.

8.4 System Expansion

It is recommended for the possible expansion of the inspection and maintenance system, due to the extension of the expressway, that the following improvement be made.

- Extension of Expressway
  There will be no problems to accommodate maintenance data for the new Ramindra-Atnarong Expressway since the capacity of the microcomputer is sufficient.

- On-line Utilization of Database
  In order to have on-line use of the developed database system within ETA, conversion methods and work procedures are proposed using the existing network and the RISC/6000 workstation.

- Improvement of System Functions
  Possible expansion of system functions is proposed for the next generation of maintenance work in the future. There should be a full presentation in Thai, graphic displays, any improvement in output forms, automation of inventory updating, and introduction of analytical software.

9 Afterword

In order to manage expressway systems adequately and carry out timely remedial measures, the availability of information on road conditions is of great importance to road administrators. The inspection and maintenance system for ETA's expressway is formulated to cope with maintenance and other related problems and to improve maintenance methods as well.

The present maintenance organization of ETA is considered to be functioning without much problem in executing its current maintenance work. However, ETA still has to expand its functions and maintain an expressway network in Bangkok and the rural regions, to cope with the ever-increasing economic growth and social demands. This suggests that the role of ETA will become more important in operating and maintaining the expressway system in this country.

In addition to the above, it is expected that damage to road structures and facilities will escalate with the increases in traffic volume, the ratio of heavy vehicles and the number of age-worn structures and facilities. To cope with these problems, ETA's maintenance organization may have to improve its maintenance engineering capabilities and effectiveness in performing maintenance work.

The developed inspection and maintenance system aims to reduce total maintenance costs and manpower, and upgrade the quality of comprehensive maintenance work. However, an introduction of new system requires, in general, that ETA must raise its maintenance work capabilities in terms of personnel and organization concerned.

An important task for making full use of the new computerized database system is system maintenance to ensure effective utilization for practical rather than technical purposes. Therefore, updating of data on road inventory and inspection/repair should be both systematically and periodically implemented. This will lead to a better circulation of information and improve the effectiveness of maintenance work.

APPENDIX

Collected data/information for the study are listed below.

<National Development Plan and Statistics>	-The Seventh National and Social Develop-memt Plan (NESDB, 1992) -Statistical Year Book (Statics Bureau of Thailand, 1992) -Seventh Plan Urban and Regional Transport (NESDB, 1991)
<Road Development Plan>	-Feasibility Study on the Second Stage Expressway System in the Greater Bangkok (JICA, 1983) -The Study on Maintenance System for the Expressway in the Kingdom of Thailand (IECA, 1992) -Construction Plan of Bangkok Expressway System (JICA, 1983)
<Road Maintenance>	-Bridge Inspection and Maintenance Manual (AASHTO, 1978) -Inspection of Road and Bridge (DIN 1076, 1983) -Inspection of Road Structures (BS) -Bridge Inspection (OECD, 1976) -Bridge Maintenance (OECD,1981) -Road and Bridge Maintenance Standards for National Roads in Japan (Japan Road Association) -Road and Bridge Maintenance Standards (Tokyo Metropolitan Expressway Public Corporation) -Road and Bridge Maintenance Standards (Japan Highway Public Corporation) -Road and Bridge Maintenance Standards (Hanshin Expressway Public Corporation)
<ETA Expressway>	-Annual Report (ETA, 1983 - 1992) -Route Map of ETA Expressway (ETA, 1993) -Database of Maintenance for Urban Expressway (H. Kosaka, 1992) -Inspection and Maintenance System of the Expressway (H. Kosaka, 1991) -Inspection and Maintenance System of the Expressway (1) (JICA, 1989) -Inspection and Maintenance System of the Expressway (2) (JICA, 1991) -ETA's Organization and Roles (ETA)
<Drawings>	-Contract Drawings of the First Stage Expressway (ETA) -Inspection and Repair Records for the Land Section (ETA) -Contract Drawings of the Rama IX Bridge (ETA) -Inspection and Repair Records for the Rama IX Bridge Section (ETA)