PART II MASTER PLAN

6. BRIDGE CONDITION SURVEY AND ASSESSMENT

SURVEY LEVEL AND ITEMS

The existing conditions of the bridges indicated different levels of deterioration and damages that require appropriate level of field survey and analysis. Three (3) levels of survey were carried out.

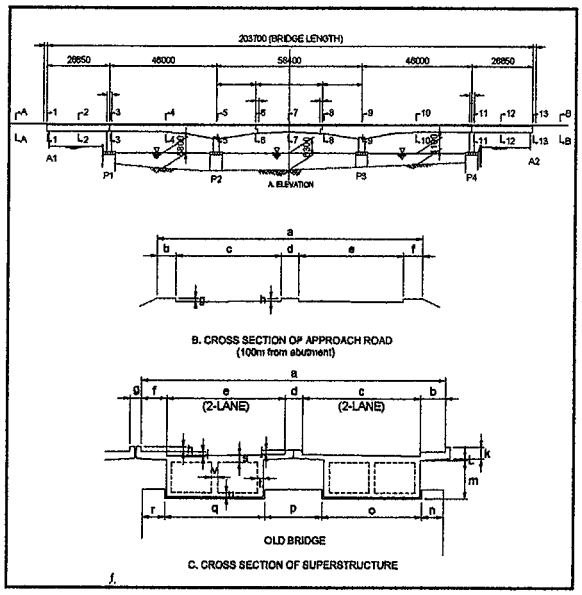
- Survey Level I : 3 bridges (Pandacan, C-5, Makati-Mandaluyong bridges)
- Survey Level II : 16 bridges
- Survey Level III : 1 bridge (Ayala Bridge)

VISUAL INSPECTION

Visual Inspection was conducted for the primary and secondary members of bridges. The types, scales and degree of damage were observed and reported in the Visual Inspection Sheets for assessment and diagnosis of damages.

SHAPE AND DIMENSION MEASUREMENTS

The shape and dimension of structural members were measured, and structural drawings of bridges were prepared. Non-measured structures such as foundation are assumed based on the presumption of original structural design.



Shape and Dimension Measurement

Survey Level and Items

Survey Level		I	II	III
Main Objectives		Data Collection Level	Master Plan Level	Feasibility Study Level
Superstructure	Concrete Bridge	a) Visual Inspection. b) Inspection on Structural Shapes. c) Inspection on Damage Type, Scale and Severity.	a) Visual Inspection. b) Measurement of Structural Shapes. c) Evaluation on Damage Type, Scale and Severity. d) Non-destructive Test (Schmidt Hammer Test).	a) Close-up Visual Investigation. b) Measurement of Structural Shapes/Dimension. c) Non-destructive Test (Schmidt Hammer Test). d) Material Test (Core, Neutralization, Alkali Aggregate). e) Electromagnetic Wave Radar (Location of Reinforcing Bar).
	Steel Bridge	a) Visual Inspection. b) Inspection on Structural Shapes. c) Inspection on Damage Type, Scale and Severity.	a) Visual Inspection. b) Measurement of Structural Shapes. c) Evaluation on Damage Type, Scale and Severity. d) Damage Survey (Damage Detection by Penetrant Test).	a) Close-up Visual Investigation. b) Measurement of Structural Shapes/Dimensions. c) Structural Survey d) Material Test (Chemical Analysis, Vickers Hardness Test). e) Damage Survey (Damage Detection by Penetrant Test).
Substructure		a) Visual Inspection. b) Inspection on Structural Shapes. c) Inspection on Damage Type, Scale and Severity.	a) Visual Inspection. b) Measurement of Structural Shapes. c) Evaluation on Damage Type, Scale and Severity. d) Non-destructive Test (Schmidt Hammer Test).	a) Close-up Visual Investigation. b) Measurement of Structural Shapes/Dimensions. c) Displacement Survey (Vertical, Horizontal). d) Non-destructive Test (Schmidt Hammer Test).
Foundation		-	Depending on bridge condition, stability test and scour survey are required.	a) Stability Test (Impact Vibration Test). b) Scour Survey (Echo Sounder). c) Topographic and Geotechnical Survey.
Loading Capacity of Superstructure		-	Depending on bridge condition, load test is required.	a) Static Load Test.

NON-DESTRUCTIVE TESTS OF MATERIALS

The tests aimed to measure the physical characteristics and damage that may be present in the material.

- Schmidt Hammer Test

Test Method for determining compressive strength of hardened concrete.

- Dye Penetrant Test

Test to find and measure the crack on the steel components.

- Brinell Hardness Test

Test to measure the hardness of the steel members.

- Ultrasonic Pulse Velocity Test

Test to estimate surface crack depth.

- Ultrasonic Flaw Detection Test

Test to determine the presence of any internal defects in the steel sections.

Schmidt Hammer Test

Dye Penetrant Test

Brinell Hardness Test

Ultrasonic Flaw Detection Test

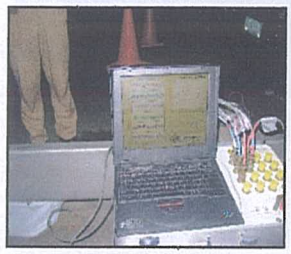
SPECIAL TESTS

- **Impact Vibration Test**

- To evaluate the substructure soundness by focusing on the natural frequency of the pier.
- Bridges conducted under this test: the Ayala Bridge, Jones Bridge and Vargas Bridge.

- **Microtremor Measurement Survey**

- To identify and confirm the modes relevant to the deformations due to the dead load, governing live load cases (MS 18 lane loadings) and seismic load considered in Modeling of Structure.
- Bridges conducted under this test: the Ayala Bridge, Jones Bridge and Vargas Bridge.



Data Acquisition System for Microtremor Survey

Pendulum in Swing for Impact Test

- **Static Load Test**

- This activity aims to obtain the data for use in modeling of structures and load rating.
- Bridges conducted under this test: the Ayala Bridge and Lambingan Bridge.

Step Load Pattern of Trucks

- **Scour Survey**

- The riverbed configurations were determined using a Digital Echo Sounder combined with Total Station. Data Points were taken at 1-meter interval. Using sound waves, the time it takes the sound to travel from the source to the riverbed and back to the source was electronically determined.
- Bridges conducted under this test: the Ayala Bridge, Jones Bridge and Vargas Bridge.

Scour Survey using Echo Sounder

Total Station

PRESUMPTION OF ORIGINAL DESIGN

Procedure for Presumption

Complete set of as-built drawings on design drawings are usually not available, especially for old bridges. While shapes and dimensions of visible or exposed parts can be determined from measurement survey, invisible parts such as substructures and foundations under water or ground, and arrangement or volume of reinforcing bars have to be presumed with analytical method with reference to the old code requirements at the time of design/construction or relevant data and materials.

Step 1: Prepare the general plan, elevation and section of the existing bridge.
Step 2: Identify missing structural data and information.
Step 3: Perform structural analysis to determine member requirements.
Step 4: Determine the basic structural section requirements.
Step 5: Prepare existing bridge structure drawings.

DAMAGE RATING AND DIAGNOSIS

XYZ Damage Rating Method

This method has been developed by Public Works Research Institute, Ministry of Construction, Japan in 1985. The method is mainly used as the close-up inspection method to evaluate the severity of damages. It presents a systematic guideline and overview to a structure under study.

By this method, the location or pattern (X) is to be known through observation. The depth of damage (Y) is identified by the type of damage to the member. Scale (Z) will provide an idea to the degree of damage. Such damage degree includes the following: Large/Many, Medium, Small, Few, Entire and others. The scale varies depending on the type of structure and member under study.

HMS Damage Rating Method

This method was developed by the Study Team to be used easily and conveniently in evaluating the severity of damages of each member, based on the XYZ method.

The principal concept of damage rating of this method is the same as the XYZ method. However, in this method, only one primary or two secondary factors are considered.

The damages are then evaluated in three (3) basic damage ratings, namely H (heavy), M (medium) and S (small). However, an additional rating "HH" equivalent to XYZ Method rating "I" is used in the diagnosis. The damages with rating "H" are candidate for "HH" diagnosis rating but the decision to increase the rating rank shall not be made automatically from the inspection results but by the Engineer (Responsible Person-in-Charge) after consultation with the Road Administrator or Official. An "HH" or "I" rating is a sensitive and crucial decision that should be made by a responsible person.

Damage Rating and Diagnosis

Damage Rating			Diagnosis	
X, Y, Z Method	H,M,S Method	Condition	Category	Action to be taken
I	HH	• Damage is serious • Traffic safety is in danger	A	•Emergency measures shall be taken immediately •Detailed study shall be conducted to decide remedial measures
II	H	• Damage is big • Detailed survey is necessary to ensure traffic safety	B	•Detailed survey or follow-up inspection shall be done to evaluate the severity of damage and to decide necessity of remedial measures
III	M	• Damage is found • Follow-up inspection is required		•Remedial measures shall be undertaken after evaluation of damages, if necessary
IV	S	• Small damage is observed • Damage is recorded	C	•No immediate action is necessary •Ordinary inspection shall be continued
OK		• No damage is observed		
Note: A higher diagnosis rank shall be given to bridges with high possibility of falling damaged parts or elements and with possibility of people entering the bridge from under.				

7. OVERALL EVALUATION OF BRIDGE CONDITION

EVALUATION ITEMS

Structural Soundness

The results of damage inspection on bridge members and components were categorized into superstructure, substructure, foundation and accessories. Damages observed on different bridge components are assessed using HMS or XYZ Methods with reason of assessment indicated. The diagnosis evaluation was indicated using Diagnosis Category A, B or C with recommendations on the next action to be done.

Vulnerability to Disaster

The bridge existing physical condition and its environment were assessed to determine its vulnerability to earthquake, wind and typhoon, and flood. Assessment can either be high, moderate or low vulnerability. Comments are included in the evaluation item.

Traffic Functionality

The condition of the bridge to perform its intended function to allow traffic to pass is assessed considering its load capacity, average daily traffic, number of lanes, volume/capacity (V/C) ratio and level of service (LOS) and the bridge geometry to allow ideal driving condition. An overall evaluation of the traffic functionality should be given which will be used later for the priority ranking of bridges. The distance and length of the nearest detour route should also be noted.

Special Issues

Other special issues included in the overall evaluation are river navigation clearances (both horizontal and vertical) for bridges crossing bodies of water, public/private utilities being supported by the bridge and the presence of informal dwellers.

OVERALL EVALUATION

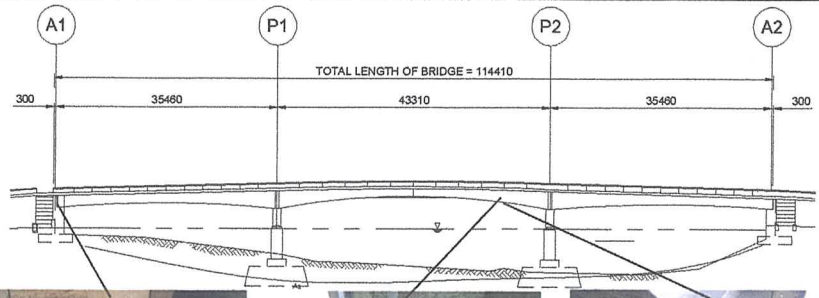
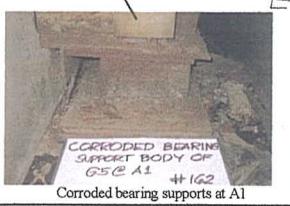
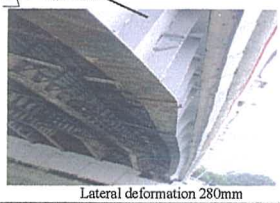
Observation

- Most of the bridge superstructures under the Study had local damages such as concrete cracks, steel corrosion, reinforcing bar exposure, etc. However, due to lack of bridge inventory data particularly on old bridges, a more in-depth study/survey should be conducted to determine the seismic resistance and stability of the substructures and foundations.
- Old bridges, especially steel bridges are assessed relatively more sound compared to newer concrete bridges. Defects on concrete bridges could be traced to construction quality and workmanship on site.
- With steel members/girders being fabricated in the fabrication yard, the quality of workmanship seems to be properly controlled resulting to a more durable structure.
- Lack of daily and periodic maintenance, including cleaning and painting, leads to the deterioration of steel structures.
- Damages on piers and superstructure soffits are usually caused by vessel collision. Proper vessel collision protection and measures should be placed on the bridge to prevent further collisions.

The following five (5) bridges were evaluated to show very serious damages other than the Ayala Bridge:

- Jones Bridge
  - Rupture and horizontal deformation of exterior girders.
- Quezon Bridge
  - Heavily corroded joint connections of floor system.
- Lambingan Bridge
  - Cracks on gerber hinge parts and girders on pier top, vertical deformation of superstructure.
- Guadalupe Bridge (Both Sides)
  - Cracks on gerber hinge.
- Vargas Bridge
  - Cracks on gerber hinge parts and girders on pier top, and
  - Vertical deformation of superstructure.

An Example of Overall Evaluation

Reference / Bridge Name		JONES BRIDGE				
Location / Name of Road		City of Manila / Q. Paredes St.			Year Constructed	1948
Elevation		  Corroded bearing supports at A1  Ruptured bottom flange and 1/3 height of web  Lateral deformation 280mm				
Length of bridge		114.43m (35.46m + 43.31m + 35.46m)			No. of Lanes	4
					Lane Width	2 – 7.66 m
Superstructure Type		Steel I-Girder (3-span continuous)			Substructure Type	Abutment: Wall (footing), Pier: Wall (existing caisson)
		Member	Location of Damage Members	Damage Assessment (XYZ) *1	Damage Assessment (HMS) *2	Reason for Assessment
Structural Soundness	Superstructure	Steel I-Girder	Span 1: Weld portion of steel plates	II	H	Remarkable deterioration due to corrosion.
			Span 1: Lower plate of main girders (near A1)	II	H	Extensive corrosion of **8 girders**.
			Span 2: Bottom flange and web of exterior girder at upstream side	I	HH	Ruptured bottom flange and 1/3 height of web due to vessel collision.
			Span 2: Main girder, G8, Near P2	II	H	Lateral deformation is 280mm due to vessel collision.
			Span 2: Sway bracings	II	H	Ruptured sway braces on **2 locations**.
			Span 1,2,3: Sway bracings	II	H	Missing top members in **10 locations**.
			Span 3: Sway bracing (A2)	II	H	Corrosion spreads over entire member.
			Span 3: Downstream exterior girder	III	M	Lateral deformation is 50mm.
			Span 3: Interior girder G4, Near A2	II	H	Extensive corrosion.
		Deck Slab	Span 3: Bottom of Deck Slab	III	M	Cracks at bottom deck with width of 0.3 – 0.8 mm
			Span 3: Bottom of Deck Slab	III	M	Wide area of deterioration to poor construction
	Substructure	Abutment	Abutment A2 Wall	IV	S	Horizontal cracks on wall.
		Pier	Pier 1 Body	IV	S	Vertical cracks of pier body
		Foundation	Existing Caisson	II	H	Does not meet latest code requirement
	Accessory	Bearing Shoe	Abutment A1 Bearing Shoes	II	H	Extensive corrosion of bearing shoes at Abutment A1
			Pier 2 Bearing Shoes	II	H	Extensive corrosion of bearing shoes at Pier 1.
	Diagnosis Evaluation *3	Category "A"	• **Urgent measure for Ruptured Exterior Girder at upstream side is necessary.** • **In-depth study necessary to determine permanent repair/rehabilitation of ruptured girder.** • **Repair / maintenance work necessary to prevent further corrosion and loss of members.**			
Vulnerability to Disaster	Seismic Resistance	• Pier and Foundation (Existing Caisson) are insufficient under latest code seismic requirements, In-depth study is needed to determine required strengthening . • High vulnerability.				
	Wind Resistance	Not critical to wind action.				
	Flood Resistance	Not critical to flood.				
	Evaluation	• **Bridge is highly vulnerable to seismic forces. In-depth study is needed to determine required strengthening of substructure.** • **Bridge is sufficient to wind and flood action.**				
Traffic Capacity and Function	Traffic Limit	20 Tons				
	Volume / Capacity	57,216 (2002) 4 Lanes Level of Service: D (0.74) Load Rating: 0.00 Inventory Level, 0.76 Operating Level (Exterior Girder, Upstream Side)				
	Smooth Driving Condition	Fair				
	Evaluation	**Traffic functionality reduced by decrease in live load capacity and steep slope at approach.**				
Special Issues	River Navigation	Vertical Clearance < Regulated (Near Piers); Horizontal Clearance: Preferable				
	Utilities	46 – ϕ100 mm PVC Telecommunication Pipe, 2 – ϕ100 mm GI Telephone Line, 1 – ϕ100 mm PVC Electrical Line, 1 – ϕ340 mm Water Line				
	Informal Dwellers	No informal dwellers under Jones Bridge				
	Evaluation	**Minimal social and environmental impact**				
Overall Evaluation		**Major rehabilitation of ruptured girder and sway braces are needed, minor measures necessary to improve traffic functionality. Provide vessel collision protection**				

Notes:

1. Damage Assessment (XYZ Method)
   - I : Damage is serious, Traffic safety is in danger
   - II : Damage is big, detailed survey is necessary
   - III : Damage is found, follow-up inspection is required
   - IV : Small damage is observed, damage is recorded
   - OK : No damage is observed
2. Damage Assessment (HMS Method)
   - HH : Extremely Heavy
   - H : Heavy
   - M : Medium
   - S : Small
3. Diagnosis Evaluation
   - "A" : Urgent measures shall be applied: Conduct In-depth Survey
   - "B" : Urgent measures not required; Conduct In-depth Survey
   - "C" : In-depth Survey not required

Summary of Overall Evaluation

The overall evaluation of existing bridges are summarized with description of major damages and causes.

Summary of Overall Evaluation of Existing Bridges

No.	Bridge Name (Year Const.)	Major Damages (Diagnosis Category)	Causes of Damages	Overall Evaluation
1	Delpan Bridge – Upstream (1965)	• Small cracks on concrete girders • Water leaking B	• Insufficient vertical clearance for road traffic crossing under the bridge • Aging and insufficient maintenance activities • Poor treatment of expansion joint	• Bridge is totally sound but repair works are necessary.
	Delpan Bridge – Downstream (1988)	• Minor cracks at the superstructure • Spalling out of the pier wall C	• Aging of concrete • Vessel collision with the pier	• Bridge is totally sound but small repair works are necessary.
2	Jones Bridge (1948)	• Two (2) ruptured and deformed exterior girders A	• Vessel collision with girders	• Major rehabilitation of ruptured girder and sway braces is urgently necessary. • Vessel collision protection is necessary.
3	McArthur Bridge (1948)	• Pier Inclination, minor cracks of concrete structures B	• Aging and insufficient maintenance activities • Insufficient resistance of foundation	• Bridge is totally sound but repair works are necessary.
4	Quezon Bridge (1946)	• Heavily corroded joint connections under the floor deck • Poor treatment of expansion joint A	• Insufficient maintenance and repair activities	• Replacement of corroded joint connections at floor system is necessary.
5	Ayala Bridge (1935/1950)	• Heavily corroded floor system • Ruptured stringers and section loss of lower chords A	• Aging and insufficient maintenance activities • Vessel collision with sway braces	• Major rehabilitation of superstructure and retrofitting of substructure are necessary. • Traffic load limit shall be adopted.
6	Nagtahan Bridge (1966)	• Corrosion on steel members • Cracks of substructures B	• Aging and insufficient maintenance activities	• Bridge is totally sound but repair works are necessary.
7	Pandacan Bridge (1997)	• Small cracks on deck slab C	• Related to bridge design and/or construction quality	• Bridge is totally sound but repair works are necessary.
8	Lambingan Bridge (1979)	• Cracks on girders at Gerber hinge parts and on pier tops • Insufficient uplift devices A	• Related to bridge design and/or construction quality	• Traffic functionality shall be reduced due to the decrease of live load capacity.
9	Makati-Mandaluyong Bridge (1986)	• Cracks on PC box girders and substructures B	• Aging and insufficient maintenance activities	• Bridge is totally sound but repair works are necessary.
10	Guadalupe Bridge (Central) (1962)	• Small corrosion on steel members • Water leaking at the south abutment C	• Damaged water pipes	• Bridge is totally sound but repainting is necessary.
	Guadalupe Bridge (Both Sides) (1979)	• Cracks of girders at gerber hinge parts A	• Related to bridge design and/or construction quality	• Urgent measures are needed at gerber hinge support
11	C-5 Bridge (1998)	• Small cracks of slab and substructures and honey comb B	• Increased traffic load • Honeycomb is due to water leaking	• Bridge is totally sound but repair works are necessary.
12	Bambang Bridge (1991)	• Cracks at the approach spans of superstructure C	• Related to bridge design and/or construction quality	• Bridge is totally sound but small repair works are necessary.
13	Vargas Bridge – Upstream (1992)	• Large vertical deformation and cracks on girders at gerber hinge parts and on pier tops A	• Related to bridge design and/or construction quality	• Urgent measures are for major crack portion.
	Vargas Bridge – Downstream (1973)	• Corrosion of steel members • Cracks on deck slab C	• Aging and insufficient maintenance activities	• Bridge is totally sound but repair works are necessary.
14	Rosario Bridge (1952)	• Cracks on deck slab B	• Aging and increased traffic load	• Bridge is totally sound but repair works are necessary.
15	Marcos Bridge (1978)	• Many cracks of pier copings of widening portions C	• Related to bridge design and/or construction quality	• Bridge is totally sound but small repair works are necessary.
16	Marikina Bridge (1980)	• Small cracks on deck slab C	• Increased traffic load	• Bridge is totally sound but small repair works are necessary.
17	San Jose Bridge (1980)	• Few cracks on the superstructure and water leaking • Exposed foundation C	• Open expansion joints • Scouring	• Bridge is totally sound but small repair works are necessary.

NOTE : ☐ Diagnosis Category

8. RECOMMENDED IMPROVEMENT MEASURES

COMPARATVE STUDY ON IMPROVEMENT MEASURES

Basic Policy

- To propose improvement measures which shall ensure at least the minimum structural safety and stability.
- To assess the structural soundness with the Load Rating Analysis (LRA).
- To employ Life Cycle Cost (LCC) Analysis in selecting the most economical improvement measures.
- To consider countermeasures against a vessel collision.
- To exclude the retrofit works against earthquakes from the measures.

Improvement Schemes

The three (3) possible schemes were prepared for each bridge in order to arrive at the best solution. These include the following with the different purposes.

- Repair : to remedy deteriorated members/parts to the original condition
- Rehabilitation : to restore deteriorated members/parts to the service level it once had and extends the service life of a bridge.
- Strengthening : to prolong the bridge life by strengthening major bridge components in order to meet the latest design code requirements including traffic function improvement by widening.

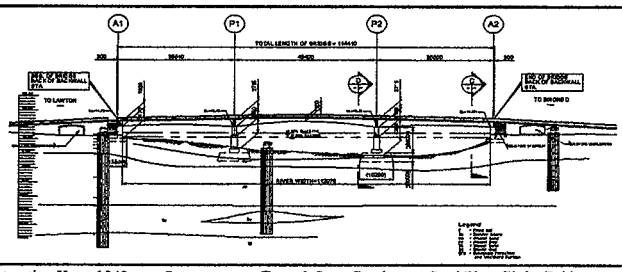
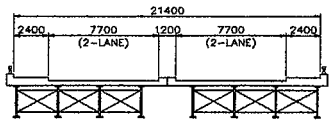
Evaluation Criteria

The three (3) schemes prepared for each bridge were evaluated from the following evaluation factors.

- Reliability of the Structural Safety,
- Construction Period and Difficulty,
- Traffic Management during Construction
- Bridge Life-Cycle Cost

Among evaluation items above, the reliability of the structural safety was given the highest weight.

Pa2 JONES BRIDGE **Exchange Rate: 2.269 (As of May 5, 2003)**

Elevation and Cross Section				
Construction Year and Bridge Type		Construction Year: 1948 Superstructure Type: 3-Span Continuous Steel Plate Girder Bridge Substructure Type: Abutment:Wall, Pier: Wall, Foundation Type: Abutment: Spread, Pier: (Caisson)		
Alternatives		Repair	Rehabilitation	Strengthening
Major Works	Superstructure	* Cleaning/Painting of corroded steel members * Repair of ruptured sway bracings * Repair of ruptured exterior girder by plate patching * Repair of sole plate and girder section at bearing	* Cleaning/Painting of steel structure for whole bridge * Replacement of ruptured sway bracings * Provide additional girder w/ new bearing shoes * Repair & retain existing exterior girder to function as vessel collision protection * Remove and reconstruct deck slab, sidewalk, railing and expansion joint.	* Cleaning/Painting of steel structure for whole bridge * Replacement of ruptured sway bracings * Provide additional girder w/ new bearing shoes * Repair & retain existing exterior girder to function as vessel collision protection * Remove and reconstruct deck slab, sidewalk, railing and expansion joint.
	Substructure	-	* Sealing of concrete crack, spalling & exposed rebars	(Retrofitting of pier wall by full concrete jacket)
	Foundation	-	-	* Enlargement of footing / pile cap and addition of bored piles
①Reliability for the structural safety		* RF = 0.00 (Load Rating 0 tons for ruptured girder) * C/Dpl=0.37 (Body of Pier 1) * C/Dpl=0.86 (Foundation of Pier 1) (Less resistance to latest seismic code)	* RF = 1.00 (Load Rating 32.7 tons) * C/Dpl=0.37 (Body of Pier 1) * C/Dpl=0.86 (Foundation of Pier 1) (Less resistance to latest seismic code)	* RF = 1.00 (Load Rating 32.7 tons) * C/Dpl=1.00 (Body of Pier 1) * C/Dpl=1.00 (Foundation of Pier 1)
②Construction Period and Difficulty		* 4 Month (easy)	* 18 Months (moderate)	* 24 Months (Hard)
③Traffic Management during Construction		No disturbance of existing traffic	No disturbance of existing traffic	Provision of temporary detour bridge
Navigation Clearance	Vertical	Less by 15cm than a regulatory clearance of 3.75cm	Less by 15cm than a regulatory clearance of 3.75cm	Sufficient
	Horizontal	Less than preferable space of 43m	Less than peferable space of 43m	Less than preferable space of 43m
Construction Cost (MP)		32	161.8	227.2
Evaluation		3	1	2

Note: ( ) Reference

An Example of Comparative Study on Improvement Measures

STRUCTURAL SOUNDNESS BY LOAD RATING

- Bridge load rating provides a basis for determining the safe load capacity and evaluating the structural soundness of a bridge. In general, the resistance of a structural member (R) should be greater than demand (Q).

$$R \leq Q_d + Q_l + \Sigma Q_i$$

Where, Q_d is the effect of dead load, Q_l is the effect of live load and Q_i is the effect of load i.

- In the bridge evaluation process, the maximum allowable live load Q_l can be determined. It then becomes a question of whether a fully loaded or what portion of vehicle (rating vehicle) can be allowed on the bridge. The portion of the rating vehicle is given by the ratio between the available capacity for live load effect and the effect of the rating vehicle. This ratio is called the rating factor (RF) as defined by:

$$RF = \frac{\text{Available capacity for live load effect}}{\text{Rating vehicle load demand}}$$

- When the rating factor equals or exceeds unity, the bridge is capable of carrying the rating vehicle. On the other hand, when the rating factor is less than unity, the bridge may be overstressed while carrying the rating vehicle. Refer to page 27 for detailed discussion.

LIFE-CYCLE COST ANALYSIS

The alternative improvement schemes are analyzed with the life-cycle cost (LCC) considerations of the following basic models.

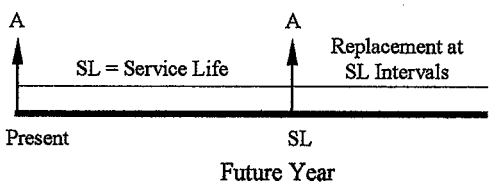
- Replacements

$$LCC_p\,(repl.) = A*(pwf'_{SL})$$

where:

LCC_p = Life-cycle (perceptual service)

A = Present worth of the cost of replacement



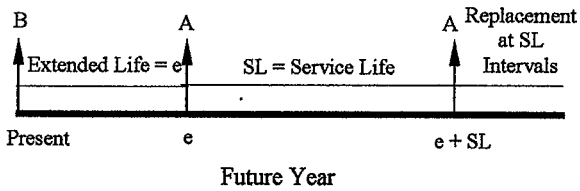
- Rehabilitation

$$LCC_p\,(rehab.) = B + A*(pwf'_{SL})*(pwf'_e)$$

where:

B = Present worth of the cost of rehabilitation and maintenance

e = extended life



Load Rating and Lifecycle Cost for Each Bridge

Bridge Name			Load Rating		Lifecycle Cost (M.pesos)			Level of Measures
			Inventory	Operating	Repair	Rehab.	Strength.	
1	Delpan Bridge	Upstream	1.27	1.69	45.2	**41.6**	129.4	Rehabilitation
		Downstream	1.26	1.67	**20**	-	-	Repair
2	Jones Bridge		**Negative**	**0.76**	232.2	**183.1**	248.5	Rehabilitation
3	McArthur Bridge		1.33	2.20	87.9	**79.1**	124.7	Rehabilitation
4	Quezon Bridge		**0.92**	1.59	353.8	**170.7**	206.6	Rehabilitation
5	Nagtahan Bridge		1.03	2.10	166.3	**159.2**	317.4	Rehabilitation
6	Pandacan Bridge		1.22	2.39	**13.6**	-	-	Repair
7	Lambingan Bridge		**0.63**	1.06	86.5	**56.5**	130.6	Rehabilitation
8	Makati Mandaluyong Bridge		1.67	2.91	**12.6**	-	28.4	Repair
9	Guadalupe Bridge	Central	1.01	2.07	98.0	**97.6**	100.6	Rehabilitation
		Both Sides	**0.44**	**0.74**	32.0	**28.0**	33.8	Rehabilitation
10	C-5 Bridge		1.02	2.67	**41.1**	-	-	Repair
11	Bambang Bridge		1.07	2.22	**8.6**	-	-	Repair
12	Vargas Bridge	Upstream	**0.83**	1.39	83.3	**25.9**	31.1	Rehabilitation
		Downstream	1.00	1.65	**11.7**	-	-	Repair
13	Rosario Bridge		1.03	1.95	44.48	**42.85**	56.45	Rehabilitation
14	Marcos Bridge		1.78	2.98	**36.0**	-	-	Repair
15	Marikina Bridge		1.01	2.20	**15.1**	-	-	Repair
16	San Jose Bridge		1.22	2.17	**17.5**	-	-	Repair

9. PREVENTION MEASURES AGAINST VESSEL COLLISION

PRESENT CONDITION OF VESSEL COLLISION

The present conditions of vessel collision are summarized as follows;

Damages of Superstructure due to Vessel Collision

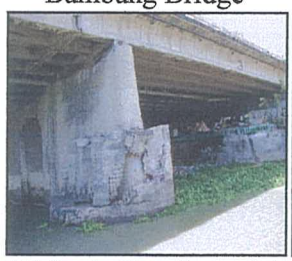
- Jones Bridge
- Ruptured exterior girder at the center span
- No countermeasures
- The Ayala Bridge
- Ruptured/Broken Bracings
- No countermeasures
- Lambingan Bridge
- Cracks at the center span's exterior girder of upstream side
- No countermeasures

Damages of Substructure/Protection due to Vessel Collision

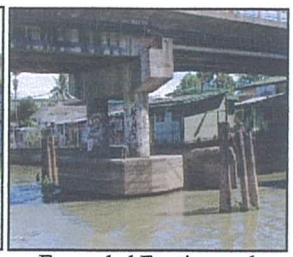
- Guadalupe Bridge
- Broken existing pier protection
- C-5 Bridge
- Broken existing pier protection
- Vargas Bridge
- Exposed rebars at Pier (Downstream Side)

Pier Protection Type Adopted

- Expanded Footing
- Nagtahan Bridge, Lambingan Bridge, Bambang Bridge, Vargas Bridge (downstream side), Rosario Bridge
- RC Fender Type Connected with Expanded Footing
- Guadalupe Bridge, C-5 Bridge
- Wooden Fender Type Separated from Footing
- Bambang Bridge



RC Fender Type Connected with Expanded Footing (Guadalupe Bridge)



Expanded Footing and Wooden Fender Type (Bambang Bridge)

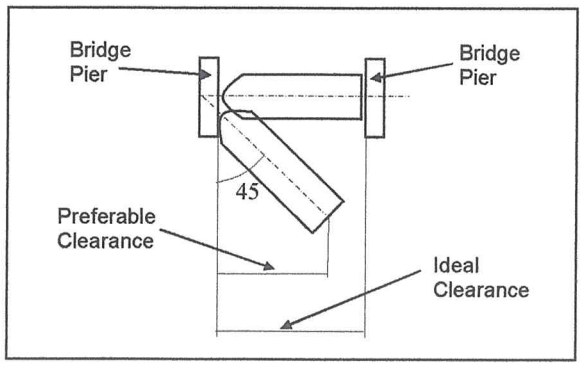
NAVIGATION CLEARANCES

The recommended horizontal and vertical clearances based on the interview survey with the Philippine Coast Guard (PCG), regulations and present condition on navigation are as follows;

Horizontal Clearance

Ideal and Preferable Spaces of Bridge Piers for One Vessel

Stretch	Ideal Space	Preferable Space (Min. Req't)
Pasig River (Manila Bay to Laguna Lake) and Lower Marikina River (Napindan Weir to Rosario Weir)	L=60 m	Lx sin(45) = 42.4 m = around 43 m
Marikina River (Rosario Weir to Marikina River)	L=15.1 m	L x sin(45) = 10.7 m = around 11 m
Marikina River (Marikina Bridge to San Jose Bridge)	L=6 m	L x sin(45) = 4.2 m = around 5 m



Vertical Clearance

Ideal and Minimum Vertical Clearances between Girder Bottom and the Highest Water Surface *

Stretch	Ideal Clearance	Preferable Clearance (Min. Req't)
Pasig River (Manila Bay to Laguna Lake) and Lower Marikina River (Napindan Weir to Rosario Weir)	5.0 m	3.75 (Regulatory Clearance)
Marikina River (Rosario Weir to Marikina Bridge)	3.0 m	3.0 m **
Marikina River (Marikina Bridge to San Jose Bridge)	1.5 m	1.5 m **

*:Recorded highest tide level or the water level at a run off discharge of 500 m^3, the water level of which is the highest water level for safe navigation

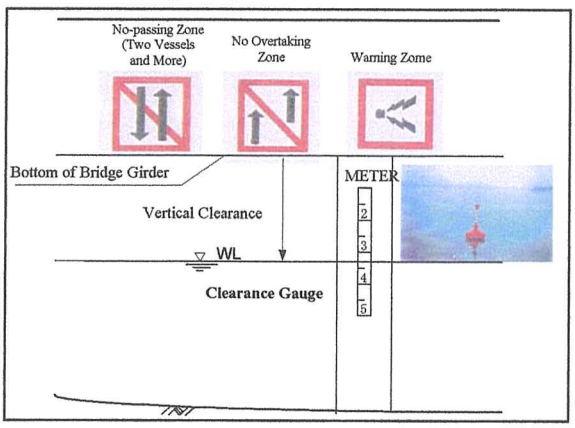
**:Actual required vertical clearance considering the possible scale of boats passing the river.

PREVENTION SYSTEM

Administrative Measures

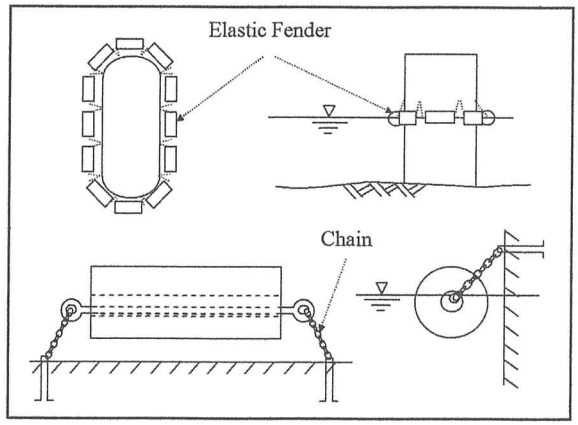
To prevent vessel collision with bridges, the enforcement of administrative measures is indispensable, practical and economical, as specified below:

- No passing zone
- No ovetaking zone
- Warning zone:
- Clearance gauge
- Warning buoy



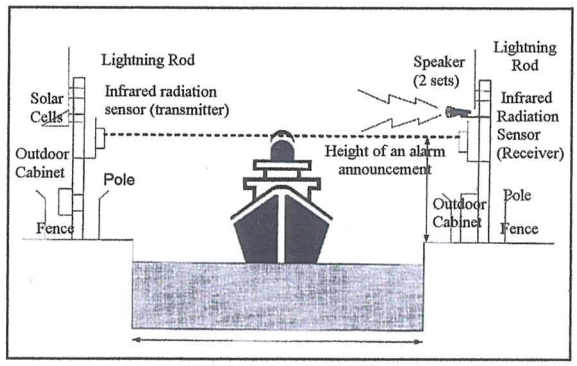
Signs and Marks for Safety Navigation

Protection to Pier and Abutment



Floating Fender

Protection for Bridge Girder



Bridge Collision Avoidance System with Infrared Radiation

Recommendation on Countermeasures against Vessel Collision

No.	Bridge Name	Countermeasures		Estimated Cost (million ₱)	Remarks
		For Girders	For Piers		
1	Delpan Bridge	-	-	-	•Sufficient clearances.
2	Jones Bridge	•Warning/Guide Buoy •Clearance Gauge •Detector Type	•Floating Fender	13.6	•Sections of exterior girders near piers have insufficient vertical clearance.
3	McArthur Bridge	-	•Floating Fender	4.5	•Insufficient vertical clearance.
4	Quezon Bridge	-	-	-	•Sufficient clearances.
5	Ayala Bridge	•Clearance Gauge •Detector Type	-	8.5	•Countermeasures for girders are recommended for bridges having a clearance less than 4.0m.
6	Nagtahan Bridge	-	•Warning/Guide Buoy •Floating Fender	1.7	•This bridge is located in the meandering river section. •Floating fender type may avoid causing damage to vessels.
7	Pandacan Bridge	-	-	-	•Sufficient clearances.
8	Lambingan Bridge	•Warning/Guide Buoy •Clearance Gauge •Detector Type	•Warning/Guide Buoy •Floating Fender	12.2	•This bridge is located in the meandering river section. •Countermeasures for girders are recommended for bridges having a clearance less than 4.0m.
9	Makati-Mandaluyong Bridge	-	-	-	•Sufficient clearances.
10	Guadalupe Bridge	-	•Floating Fender	4.5	•Existing RC fender is broken. •Insufficient horizontal clearance.
11	C-5 Bridge	-	•Warning/Guide Buoy •Floating Fender	5.7	•Existing RC fender is broken. •This bridge is located in the meandering river section.
12	Bambang Bridge	-	•Floating Fender	4.5	•Existing pier protection may not be enough.
13	Vargas Bridge	-	•Floating Fender	4.5	•There is evidence of vessel collision with bridge on downstream side.
14	Rosario Bridge	-	-	-	•Existing Pier Protection.
15	Marcos Bridge	-	-	-	•Insufficient clearances.
16	Marikina Bridge	-	-	-	•Insufficient clearances.
17	San Jose Bridge	-	-	-	•Insufficient clearances.

10. PROTECTION MEASURES AGAINST EARTHQUAKES

PRESENT PRACTICE

The DPWH has pursued the "Bridge Retrofit Program (BRP)" which aimed at minimizing the structural risk under the seismic actions. Therefore, protection work against earthquake are not included in the Study.

STABILITY ANALYSIS

Assumptions

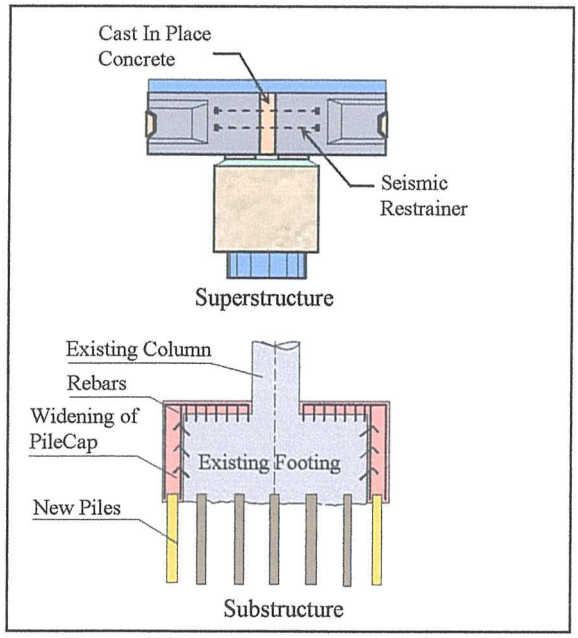
Assumptions in calculating the Capacity-Demand (C/D) Ratio for Substructures and Foundations are as follows:

- A multi-mode 3-D analysis model was established
- Seismic load was based on the AASHTO Seismic Response Spectra using a Peak Ground Acceleration of 0.4 (A = 0.4)
- The Elastic and Plastic C/D Ratios calculated are the basic capacity-demand ratio based on the original condition of the bridge.

Main Points

The following factors involve major effects on the bridge performance during an earthquake:

- Bridge Site
- Construction Details
- Structural Configurations
- Date of Construction



Retrofitting measures for bridge structural members

C/D Ratio of Substructure and Retrofitting Cost

BRIDGE NAME (Construction Year)		SUBSTRUCTURE C/D RATIO Structural Capacity / Demand Ratio		REQUIRED MEASURE AGAINST EARTHQUAKES	RETROFITTING COST (MP)
		COLUMN/WALL	FOUNDATION		
Delpan Bridge	Upstream (1965)	1.00 (Pier 3)	1.25 (Pier 2)	• No retrofitting works required.	-
	Downstream (1988)	1.03 (Pier 3)	2.01 (Pier 2 & 3)	• No retrofitting works required.	-
Jones Bridge (1948)		0.37 (Pier 1) 0.64 (Pier 2)	0.86 (Pier 1) 0.89 (Pier 2)	• Install full height concrete jackets at piers to increase capacity of wall piers.	77.10
Mac Arthur Bridge (1948)		0.26 (Pier 1)	0.85 (Pier 1)	• Install full height concrete jackets at piers to increase capacity of wall piers and to provide bored piles.	48.10
Quezon Bridge (1946)		0.70 (Abut)	0.70 (Abut)	• Install full height concrete jackets at abutments to the increase capacity of mainwall and provide additional piles.	35.90
Ayala Bridge (1935, 1950)		0.60 (Abut.) 0.32 (Pier)	0.57 (Abut) 0.41(Pier)	• Reconstruct abutment backwall and provide additional piles.	430.16
Nagtahan Bridge (1966)		0.56 (Pier 9 & 10)	0.64 (Pier 9 & 10)	• Install full height concrete jackets at piers to increase capacity of pier wall and provide additional piles.	132.50
Pandacan Bridge (1997)		1.58 (Pier 4)	1.58 (Pier 4)	• No retrofitting works required.	-
Lambingan Bridge (1979)		0.64 (Pier 1)	1.11 (Pier 1)	• Install full height concrete jackets at piers to increase capacity of pier wall.	4.80
Makati-Mandaluyong Bridge (1986)		0.81 (Pier 6)	0.81 (Pier 6)	• Install longitudinal restrainer cables at discontinuous spans. • Increase full height concrete jackets at piers to increase capacity of pier wall and provide additional piles.	25.20
Guadalupe Bridge	Central (1962)	1.27 (Pier 2)	1.05 (Pier 2)	•No retrofitting works required.	-
	Both Sides (1979)	0.85 (Pier 1& 2)	0.22 (Pier 1& 2)	•Install full height concrete jackets at piers to increase capacity of pier wall and provide additional piles.	6.40
C-5 Bridge (1998)		0.74 (Pier 8)	0.74 (Pier 8)	•Install longitudinal cable restrainers at discontinuous spans. •Increase full height concrete jackets at columns to increase capacity of piers and provide additional piles.	81.90
Bambang Bridge (1991)		2.05 (Pier 1)	4.89 (Pier 1)	•No retrofitting works required.	-
Vargas Bridge	Upstream (1992)	1.78 (Pier 1& 2)	6.18 (Pier 1& 2)	•No retrofitting works required.	-
	Downstream (1973)	1.19 (Pier 1)	3.59 (Pier 1)	•No retrofitting works required.	-
Rosario Bridge (1952)		0.69 (Pier 4)	0.97 (Pier 4)	•No retrofitting works required.	19.70
Marcos Bridge (1978)		1.47 (Pier 4)	3.14 (PSC Piles)	•Install full height concrete jackets at piers to increase capacity of wall piers and provide additional piles.	-
Marikina Bridge (1980)		1.49 (Pier 2 & 3)	9.65 (Pier 2 & 3)	•No retrofitting works required.	-
San Jose Bridge(1980)		0.68 (Pier 3,4,5)	0.33 (PSC Piles)	•Provide longitudinal restrainer cables at discontinuous spans. •Install full height concrete jackets at piers to increase capacity of wall piers and provide additional piles.	75.40

11. OVERALL IMPLEMENTATION PLAN

IMPLEMENTATION STRATEGY

The bridge condition survey and structural analysis on the nineteen (19) bridge structures except the Ayala Bridge revealed the fact that five (5) bridges were evaluated to require urgent improvement measures, based on the technical judgment.

The following strategy was adopted in proposing the overall implementation schedule of the project.

Time Frame

- Short Term; 10 years (2004~2013)
- Medium Term; 10 years (2014~2023)
- Long Term; 10 years (2024~2033)

Technical Urgency

20 Bridge structures were classified into three (3) priority group in accordance with the technical urgency of each bridges, among others.

- First Priority (Very Urgent or Urgent); Implementation (2004~2007)
  5 Bridges (Jones, Quezon, Lambingan, Guadalupe (both sides), Vargas)
- Second Priority (Minor Damage Condition); Implementation (2008~2013)
  10 Bridges (Delpan (upstream), Mc Arthur, Nagtahan, Makati-Mandaluyong, Guadalupe (central), Vargas (downstream), Rosario, Marcos, Marikina, San Jose)
- Third Priority (Normal Condition); Implementation (Medium Term)
  4 Bridges (Delpan (downstream), Pandacan, C-5, Bambang)

Measures against Vessel Collision (Fender)

- The implementation timing of the protection for piers may be separated from improvement works because no serious damages on piers were found.

Retrofitting to Earthquakes

- The implementation timing of retrofit against earthquakes is decided to be separated from improvement works of bridge because of their nature of necessity.

Balanced Annual Expenditure

- The annual expenditure for the project is to be maintained equal as much as possible.

Special Consideration of the Ayala Bridge and Second Ayala Bridge

- The Ayala Bridge shall be improved at the soonest possible time because of the existing deteriorated condition.
- The Second Ayala Bridge shall be constructed at the most economical timing.

PROPOSED IMPROVEMENT WORKS

The proposed improved works are shown in the table classifying the works under short, medium and long terms. In the table, the expected repair works are also included aside from the proposed improvement works.

The expected repair works are determined based on the engineering judgment that rehabilitated or repaired bridges may require further repair works for other structural members remained unrepaired, about every ten (10) years.

TOTAL COST

Project Cost

Improvement Works	₱ 869.44 M
Protection of Piers to Vessel Collision	₱ 51.20 M
Ayala Bridge Improvement Works	₱ 1,256.90 M
Second Ayala Bridge Construction	₱ 941.00 M

The biggest annual fund is required at the second 2-Year amounting ₱ 1,525.49 M for the Year 2006 and 2007.

Improvement Works not included in the Project

Succeeding Repair and Rehabilitation in the future.	₱ 330.77 M
Retrofitting to Earthquakes	₱ 507.00 M

Summary of Recommended Improvement Measures

Bridge No.	Bridge Name	Superstructure Type	Construction Year	MAJOR WORKS		
				Short Term (2004 – 2013)	Medium Term (2014 – 2023)	Long Term (2020 – 2033)
1	Delpan Br. (Upstream)	PC Gerber Box Girder (5span)	1965	• Repair/sealing of concrete cracks • Countermeasure for truck collision	*Repair	*Repair
	Delpan Br. (Downstream)	PC Gerber Box Girder (5span)	1988	-	*Repair	*Repair
2	Jones Br.	3 Span Continuous Steel Plate Girder	1948	• Cleaning/painting of corroded steel members • Additional steel girders adjacent to existing exterior girders	*Cleaning/painting of corroded steel members	*Cleaning/painting of corroded steel members
3	Mc Arthur Br.	3 Span Continuous Steel Plate Girder	1948	• Cleaning/painting of corroded steel members • Adding rivets to missing portion • Sealing of concrete cracks honeycomb & spalling	*Cleaning/painting of corroded steel members	*Cleaning/painting of corroded steel members
4	Quezon Br.	Single Steel Arch	1946	• Cleaning/painting of corroded steel member • Replacement of corroded joint connections at floor system	*Cleaning/painting of corroded steel members	*Cleaning/painting of corroded steel members
6	Nagtahan Br.	3-Span Continuous Steel Truss Br.	1966	• Cleaning/painting of corroded steel member & deformation • Sealing of Concrete cracks honeycomb & spalling	*Cleaning/painting of steel members * Repair	*Cleaning/painting of steel members * Repair
7	Pandacan Br.	PC I Girder (5span)	1997	*Repair/sealing of concrete cracks	*Repair	*Repair
8	Lambingan Br.	PC I Girder (3span)	1975	• Rehabilitation of Gerber Hinge parts • Replacement of uplift/hold-down devices • Repair/sealing of concrete cracks	*Repair	*Repair
9	Makati-Mandaluyong Br.	PC Box Girder with Gerber I Girder (3span)	1986	• Repair of expansion joints * Repair/sealing of concrete cracks	*Repair	*Repair/sealing of concrete cracks
10	Guadalupe Br. (Central)	3-Span Continuous Steel Truss Br.	1962	• Cleaning/painting of corroded steel member • Repair/sealing of concrete cracks	*Cleaning/painting of corroded steel members	*Cleaning/painting of corroded steel members
	Guadalupe Br. (Both Sides)	PC Gerber Girder (3span)	1979	• Rehabilitation of Gerber Hinge parts • Sealing of concrete cracks	*Repair	*Repair
11	C-5 Br.	PC I Girder (9span)	1998	-	*Repair	*Repair
12	Bambang Br.	PCI Girder (9span)	1991	-	*Repair	*Repair
13	Vargas Br. (Upstream)	PC Gerber Girder (4span)	1992	• Rehabilitation of Gerber Hinge parts • Installation of External Tendons • Sealing of Concrete cracks	*Repair	*Repair
	Vargas Br. (Downstream)	Steel Plate Girder (4span)	1973	• Cleaning/painting of corroded steel member • Rehabilitation of corroded steel member	-	*Cleaning/painting of corroded steel members
14	Rosario Br.	PC I Girder (6span)	1952	• Rehabilitation of concrete deck slab • Repair/sealing of concrete cracks	*Repair	*Repair/sealing of concrete cracks
15	Marcos Br.	PC I Girder (11span)	1978	*Repair/sealing of concrete cracks	*Repair	*Rehabilitation of expansion joints bearing shoes
16	Marikina Br.	PC I Girder (5span)	1980	*Repair/sealing of concrete cracks	*Repair	*Rehabilitation of expansion joints bearing shoes
17	San Jose Br.	PC I Girder (8span)	1980	• Rehabilitation of expansion joints, bearing shoes • Repair/sealing of concrete cracks	*Repair	*Repair
TOTAL (MILLION PESOS)				805.45	175.78	219.0
5	Ayala Br.	Single Steel Arch (2span)	1935 1950	• Strengthening of superstructure • Strengthening of substructure	-	-
	Second Ayala Bridge			*New Construction	-	-
TOTAL (MILLION PESOS)				2,197.90	-	-

Note: • Proposed Improvement Measures
* Expected Repair Works

Overall Implementation Schedule

Bridge No.	REF.	Bridge Name (Construcion Year)	Short Term (Year 2004 - 2013)										Medium Term (Year 2014 - 2023)										Long Term (Year 2024 - 2033)										Protection of Piers	Retrofitting to Earthquake
			04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33		
1	Pa1-1	Delpan Bridge (Upstream) (1965)							(23.70)										(9.0)										(9.0)				-	-
	Pa1-2	Delpan Bridge (Downstream) (1988)											(11.40)										(8.0)										-	-
2	Pa2	Jones Bridge (1948)		(97.1)	(64.7)									(12.0)										(12.0)									13.60	77.1
3	Pa3	McArthur Bridge (1948)					(50.70)												(7.0)										(7.10)				4.50	48.1
4	Pa4	Quezon Bridge (1946)		(23.92)		(95.68)										(17.0)										(17.0)							-	35.9
6	Pa6	Nagtahan Bridge (1966)					(124.75)															(21.0)										(21.0)	1.70	132.50
7	Pa7	Pandacan Bridge (1997)											(12.20)										(2.0)										-	-
8	Pa8	Lambingan Bridge (1975)			(48.90)												(5.0)										(5.0)						12.20	4.8
9	Pa9	Makati-Mandaluyong Bridge (1986)									(9.4)										(3.0)								(17.70)				-	25.2
10	Pa10-1	Guadalupe Bridge (Central) (1962)								(47.4)	(47.4)									(15.0)										(15.0)			-	-
	Pa10-2	Guadalupe Bridge (Both Sides) (1979)		(15.3)	(5.1)										(2.50)										(2.50)								4.50	6.4
11	Pa11	C-5 Bridge (1997)											(32.9)										(10.50)								(10.50)		5.70	81.9
12	Pa12	Bambang Bridge (1991)											(7.50)										(1.50)										4.50	-
13	Ma1-1	Vargas Bridge (Upstream) (1992)			(24.31)												(7.50)										(7.50)						4.50	-
	Ma1-2	Vargas Bridge (Downstream) (1973)									(18.64)													(1.50)									-	-
14	Ma2	Rosario Bridge (1952)					(36.35)													(3.0)										(3.10)			-	19.7
15	Ma3	Marcos Bridge (1980)										(25.70)										(3.50)									(53.10)		-	-
16	Ma4	Marikina Bridge (1980)										(12.40)										(3.70)									(22.90)		-	-
17	Ma5	San Jose Bridge (1980)								(17.0)	(17.0)										(2.58)										(2.58)		-	75.4
SUB TOTAL (MILLION PESOS)			136.32		238.69		211.8		88.1		130.54		76.00		19.50		12.50		34.00		33.78		35.50		19.50		12.50		51.90		110.08		51.20	507.0
5	Pa5-1	Ayala Bridge (1950)	(103.9)		(1,153)																												-	-
	Pa5-2	Second Ayala Bridge			(133.8)		(451.2)		(356.0)																								-	-
SUB TOTAL (MILLION PESOS)			103.9		1,286.8		451.20		356.0		-		-		-		-		-		-		-		-		-		-		-		-	-
GRAND TOTAL (MILLION PESOS)			240.22		1,525.49		663.00		444.10		130.54		76.00		19.50		12.50		34.00		33.78		35.50		19.50		12.50		51.90		110.08		51.20	507.00

: New Construction : Strengthening : Rehabilitation : Repair expected in the future With color: First Phase