CHAPTER 9

COMPARATIVE STUDY ON IMPROVEMENT MEASURES

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9.1 BASIC POLICY AND EVALUATION CRITERIA

9.1.1 Basic Policy

The comparison on improvement measures for 16 bridges except for Ayala Bridge was studied in compliance with the following basic policies:

- To propose improvement measures which ensure the structural safety and stability by rehabilitation of structural damages and defects and increasing traffic load carrying capacities if necessary,
- To apply the Load Rating Analysis (LRA) for evaluation of structural capacity of superstructures,
- To employ Life Cycle Cost Analysis (LCCA) in selecting the scale of the improvement measures,
- To consider countermeasures against vessel collision for bridge superstructures and substructures, and
- To consider the retrofit works against earthquakes separately from the improvement project studied in this chapter because of its nature of necessity and magnitude of works.

9.1.2 Evaluation Criteria

In conducting the comparative study on improvement measures, three (3) possible schemes are prepared for each bridge in order to arrive at the best solution. The schemes are classified according to its purpose as follows:

- Repair : to restore or remedy deteriorated members/parts to the original condition and secure the minimum safety of a bridge.
- Rehabilitation : to restore deteriorated members/parts to the service level it once had and has now lost and extend the service life of the bridge. (Include repair cost).
- Strengthening : to prolong the bridge life by strengthening major bridge components such as floor system, superstructure members and substructures in order to meet the latest design code requirements including traffic function improvement by widening. (Include rehabilitation cost).

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

- Reliability of the Structural Safety,
  - The structural safety of bridges are evaluated based on the findings of field inspection and the following analysis.
    - RF (Load Rating Factor of Superstructure)
    - C/D (Capacity-Demand Ratio of Substructure)
- Construction Period and Difficulty,
- Traffic Management during Construction, and
- Bridge Life-Cycle Cost

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

9.2 PROPOSED MEASURES AND ENGINEERING EVALUATION

9.2.1 Proposed Measures

As previously discussed, three (3) schemes, namely (1) Repair, (2) Rehabilitation and (3) Strengthening were prepared for each bridge and those schemes were evaluated from the engineering viewpoint, refer to **Appendix 9.2.1-1.**

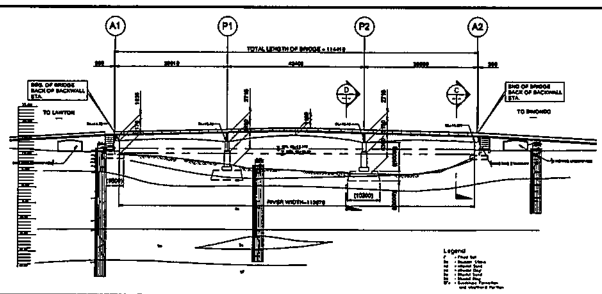
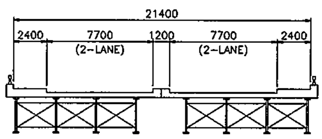
Examples of proposed schemes and evaluation for the following five (5) bridges are shown in **Table 9.2.1-1.** In this table retrofitting options were included.

- Jones Bridge
- Quezon Bridge
- Lambingang Bridge
- Guadalupe Bridge (Both Sides)
- Vargas Bridge (Upstream Side)

Table 9.2.1-1 (a) Comparative Study on Improvements Measures Jones Bridge

Pa2 JONES BRIDGE

Exchange Rate: 2.269 (As of May 5, 2003)

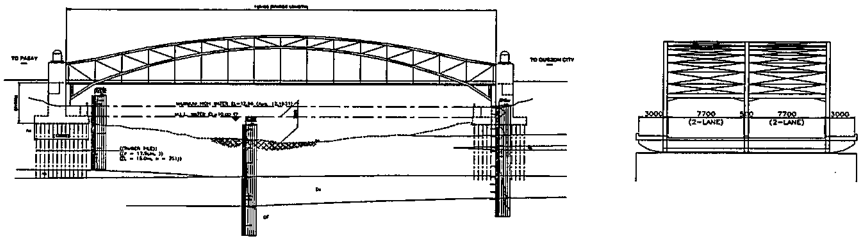
Elevation and Cross Section				
Construction Year and Bridge Type		Construction Year: 1948 Superstructure Type: 3-Span Continuous Steel Plate Girder Bridge Substructure Type: Abutment:Wall, Pier: Wall, Foundation Type: Abutment: Spread, Pier: (Caisson)		
Alternatives		Repair	Rehabilitation	Strengthening
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: RF: Rating Factor (ratio to 32.7 tons) C/Dpl=Capacity/Demand ratio based on Plastic Forces with column hinging

Table 9.2.1-1 (b) Comparative Study on Improvement Measures Quezon Bridge

Pa4 QUEZON BRIDGE

Exchange Rate: 2.269 (As of May 5, 2003)

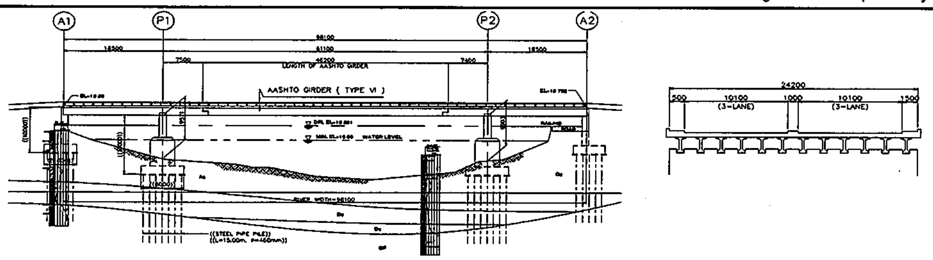
Elevation and Cross Section				
Construction Year and Bridge Type		Construction Year: 1946 Superstructure Type: Single Steel Type Arch Bridge, Substructure Type: Abutment:Wall, Foundation Type: Abutment: ((Timber Pile))		
Alternatives		Repair	Rehabilitation	Strengthening
Major Works	Superstructure	• Cleaning/Painting of corroded sections of floor • Repair of expansion joint to seal water leakage • Cleaning and painting of corroded gusset plates and replacement of corroded gusset plate	• Cleaning/Painting of corroded steel members • Replacement of expansion joint to seal water leakage • Replacement of gusset plates • Replacement of corroded sections of floor beam longitudinal tie beam & vertical members • Sealing gap between vertical hanger and sidewalk • Remove and reconstruct deck slab near abutment • Replace corroded stringers	• Cleaning/painting of corroded steel members • Replacement of expansion joint to seal water leakage • Replacement of gusset plates • Replacement of corroded sections of floor beam longitudinal tie beam & vertical members • Sealing gap between vertical hanger and sidewalk • Remove and reconstruct deck slab near abutment • Replace corroded stringers
	Substructure	• No damage	• No damage	•No damage
	Foundation	• No inspection data	• No inspection data	• No inspection data
①Reliability for the structural safety		• RF = 0.92 (Load Rating 30.10 tons; for stringer)	• RF = 1.00 (Load Rating 32.7 tons; for stringer)	• RF = 1.00 (Load Rating 32.7 tons; for stringer)
②Construction Period and Difficulty		• 1.5 Months (easy)	• 2 Months (moderate)	• 4 Months (hard)
③Traffic Management during Construction		• Temporary disturbance of existing traffic	• Temporary disturbance of existing traffic	• Provision of temporary detour bridge
Navigation Clearance	Vertical	Sufficient	Sufficient	Sufficient
	Horizontal	Sufficient	Sufficient	Sufficient
Construction Cost (MP)		29	119	154.9
Evaluation		3	1	2

Note: RF: Rating Factor (ratio to 32.7 tons) C/Dpl=Capacity/Demand ratio based on Plastic Forces with column hinging

Table 9.2.1-1 (c) Comparative Study on Improvement Measures Lambingan Bridge

Pa8 LAMBINGAN BRIDGE

Exchange Rate: 2.269 (As of May 5, 2003)

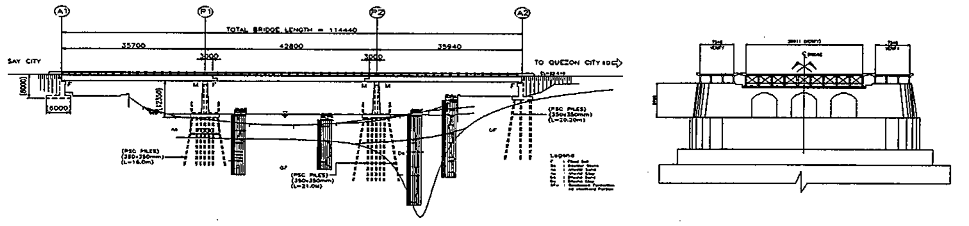
Elevation and Cross Section				
Construction Year and Bridge Type		Construction Year: 1975 Superstructure Type: PC Gerber I Girder Bridge, Substructure Type: Abutment:Wall, Pier: Wall, Foundation Type: Abutment: ((Steel Pipe Pile)), Pier ((Steel Pipe Pile))		
Alternatives		Repair	Rehabilitation	Strengthening
Major Works	Superstructure	• Repair and sealing of concrete cracks, honey comb, and spalling. • Additional concrete block dowelled to abut. & girder as uplift countermeasures. • Installation of CFRP (Carbon Fiber Reinforced Polymer) vertically and horizontally • Additional bars at top of girder / pier support	• Additional concrete block dowelled to abut. & girder as uplift countermeasure • Installation of CFRP (Carbon Fiber Reinforced Polymer) • Repair/sealing of concrete cracks, honeycomb and spalling. • Additional bars at top of girder / pier support • Rehabilitation of gerber hinge portion with slanted P/S cables • Reconstruction of diaphragm at gerber hinge	•Additional concrete block doweled to abutment and girder as uplift countermeasure • Repair/sealing of concrete cracks, honeycomb and spalling • Rehabilitation of gerber hinge portion with slanted P/S cables • Reconstruction of diaphragm at gerber hinge • Installation of external cables on each side of the girder
	Substructure	-	-	• Retrofit of pier wall by full height concrete jacket
	Foundation	• No inspection data	• No inspection data	• No need
①Reliability for the structural safety		• RF = 1.00 (Load Rating 32.7 tons) • C/Dpl=0.64 (Wall of Pier 1) • C/Dpl=1.11 (Foundation of Pier)	• RF = 1.00 (Load Rating 32.7 tons) • C/Dpl=0.64 (Wall of Pier 1) • C/Dpl=1.11 (Foundation of Pier)	• RF = 1.00 (Load Rating 32.7 tons) • C/Dpl=0.64 (Wall of Pier 1) • C/Dpl=1.11 (Foundation of Pier)
②Construction Period and Difficulty		3 Months	6 months	8 months
③Traffic Management during Construction		No disturbance of existing traffic volume	No disturbance of existing traffic volume	No disturbance of existing traffic volume
Navigation Clearance	Vertical	Sufficient	Sufficient	Sufficient
	Horizontal	Sufficient	Sufficient	Sufficient
Construction Cost (MP)		25	48.9	125.3
Evaluation		2	1	3

Note: RF: Rating Factor (ratio to 32.7 tons) C/Dpl=Capacity/Demand ratio based on Plastic Forces with column hinging

Table 9.2.1-1 (d) Comparative Study on Improvement Measures Guadalupe Bridge

Pa10.2 GUADALUPE BRIDGE (BOTH SIDES)

Exchange Rate: 2.269 (As of May 5, 2003)

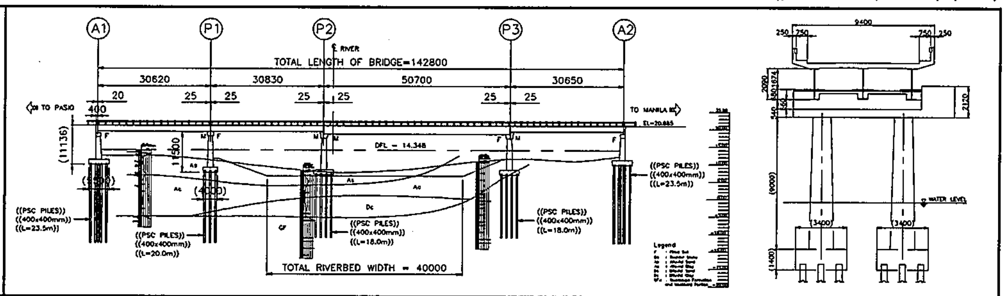
Elevation and Cross Section				
Construction Year and Bridge Type		Construction Year: 1979 Superstructure Type: PC Gerber Girder Bridge, Substructure Type: Abutment:Wall, Pier: Wall, Foundation Type: Abutment: (PSC Pile), (Pier: (PSC Pile)		
Alternatives		Repair	Rehabilitation	Strengthening
Major Works	Superstructure	* Repair/sealing of concrete cracks, honeycomb, exposed rebars	* Repair/sealing of concrete cracks, honeycomb, exposed rebars * Rehabilitation of gerber hinge portion with slanted P/S cables * Replacement of diaphragm and partial replacement of deck slab * Additional elastomeric bearing pads at diaphragm of gerber hinge portion.	* Repair/sealing of concrete cracks, honeycomb, exposed rebars * Rehabilitation of gerber hinge portion with slanted P/S cables * Replacement of diaphragm and partial replacement of deck slab * Additional elastomeric bearing pads at diaphragm of gerber hinge portion.
	Substructure	-	-	* Retrofitting of pier wall by full height concrete jacket
	Foundation	* No countermeasures	* No countermeasures	* Enlargement of pile cap and additional piles.
①Reliability for the structural safety		* RF = 0.44(Load Rating 14.40 tons,at Gerber Hinge) * C/Dpl=0.85 (Column of Pier) * C/Dpl=0.22 (Foundations of Pier) (Less resistance to latest seismic code)	* RF = 1.00(Load Rating 32.7 tons) * C/Dpl=0.85 (Column of Pier) * C/Dpl=0.22 (Foundations of Pier)	* RF = 1.00 (Load Rating 32.7 tons) * C/Dpl=1.00 (Column of Pier) * C/Dpl=1.00 (Foundations of Pier)
②Construction Period and Difficulty		* 2 Months	* 4 Months	* 8 Months
③Traffic Management during Construction		No disturbance of existing traffic	No disturbance of existing traffic	No disturbance of existing traffic
Navigation Clearance	Vertical	Sufficient	Sufficient	Sufficient
	Horizontal	Less than a preferable space of 43m	Less than a preferable space of 43m	Less than a preferable space of 43m
Construction Cost (MP)		8.3	23.1	29.5
Evaluation		3	1	2

Note: RF: Rating Factor (ratio to 32.7 tons) C/Dpl=Capacity/Demand ratio based on Plastic Forces with column hinging

Table 9.2.1-1 (e) Comparative Study on Improvement Measures Vargas Bridge

Ma1.2 VARGAS BRIDGE (DOWNSTREAM)

Exchange Rate: 2.269 (As of May 5, 2003)

Elevation and Cross Section				
Construction Year and Bridge Type		Construction Year: 1965 Superstructure Type: PC Gerber Box Girder Bridge, Substructure Type: Abutment:Wall, Foundation Type: Abutment: ((Timber Pile)), Pier: ((Timber Pile))		
Alternatives		Repair	Rehabilitation	Strengthening
Major Works	Superstructure	* Cleaning, Painting/maintenance work of corroded steel member * Repairs/sealing of concrete cracks, honeycomb, exposed rebars	* Cleaning, Painting/maintenance work of corroded steel member * Repairs/sealing of concrete cracks, honeycomb, exposed rebars * Rehabilitation of corroded steel members	* No need
	Substructure	* Repair/sealing of concrete cracks	* Repair/sealing of concrete cracks	* No need
	Foundation	* No inspection data	* No inspection data	* No need
①Reliability for the structural safety		* RF = 1.00 (Load Rating 32.73 tons) * C/Dpl=1.19 (Column of Pier) (minimum) * C/Dpl=3.59 (Foundation) (Minimum)	* RF = 1.00 (Load Rating 32.73 tons) * C/Dpl=1.19 (Column of Pier) (minimum) * C/Dpl=3.59 (Foundation) (Minimum)	-
②Construction Period and Difficulty		* 1 Month (easy)	* 2 Months (Easy)	-
③Traffic Management during Construction		No disturbance of existing traffic	Preservation of existing traffic volume	-
Navigation Clearance	Vertical	Sufficient	Sufficient	-
	Horizontal	-	-	-
Construction Cost (MP)		9.69	18.64	-
Evaluation		2	1	-

Note: RF: Rating Factor (ratio to 32.7 tons) C/Dpl=Capacity/Demand ratio based on Plastic Forces with column hinging

9.2.2 Engineering Evaluation

The engineering evaluation on the proposed schemes are summarized in **Tables 9.2.2-1.**

Table 9.2.2-1 Proposed Measures and Engineering Evaluation

BRIDGE NAME (Construction Year)		REPAIR	RANKING	REHABILITATION	RANKING	STRENGTHENING	RANKING
DELPAN BRIDGE	Upstream Side (1965)	• Repair/sealing of concrete crack, spalling, exposed rebars and honeycomb	3	• Depressing of crossing road by excavation due to insufficient vertical clearance for trucks	1	• Jack up of approach span by 60 cm due to insufficient vertical clearance for trucks	2
DELPAN BRIDGE	Downstream Side (1965)	• Repair/sealing of concrete crack, spalling and exposed rebars	1	-	-	-	-
JONES BRIDGE (1948)		• Repair of ruptured exterior girder	3	• Replacement of ruptured exterior girder	1	• Improvement of navigation clearance (• Strengthening of pier body against earthquake)	2
MC ARTHUR BRIDGE (1948)		• Cleaning/Painting of corroded steel members	3	• Adding of rivets on missing rivet portions • Replacement of corroded members	1	(• Retrofitting of piers P1 column and foundation) (• Countermeasure for inclination at Pier P1)	2
QUEZON BRIDGE (1946)		• Cleaning/Painting of corroded steel members	3	• Rehabilitation of corroded steel stringers, cross beams, tie beams and gusset plates	1	• Replacement of corroded floor system	2
NAGTAHAN BRIDGE (1966)		• Cleaning/Painting of corroded steel members	3	• Rehabilitation of corroded steel members and deformation	1	(• Retrofitting of piers P1 column and foundation of P9 and P10) (• Countermeasure for inclination at Pier P10)	2
PANDACAN BRIDGE (1977)		• Repair/sealing of concrete cracks	1	-	-	-	-
LAMBINGAN BRIDGE (1975)		• Repair/sealing of concrete cracks, spalling and exposed rebars • Cleaning/Painting of corroded steel wires (Uplift/hold-down devices)	2	• Strengthening of uplift/hold-down devices • Rehabilitation of gerber hinge • Rehabilitation of girder on pier top	1	• Strengthening of uplift/hold-down devices • Rehabilitation of gerber hinge • Rehabilitation of gerber on pier top (• Retrofitting of pier wall and foundation)	3
MAKATI-MANDALUYONG BRIDGE (1986)		• Repair/sealing of concrete cracks, honeycomb and exposed rebars	2	-	-	(• Retrofitting of pier/column bent)	1
GUADALUPE BRIDGE	Central (1962)	• Cleaning/Painting of corroded steel members	2	• Replacement of damaged members	1	-	-
GUADALUPE BRIDGE	Both Sides (1979)	• Repair/sealing of concrete cracks, honeycomb and exposed rebars	3	• Rehabilitation of gerber hinge	1	(• Retrofitting of superstructure and foundation)	2
C-5 BRIDGE (1998)		• Repair of concrete cracks, honeycomb, spalling and exposed rebars	1	-	-	(• Retrofitting of superstructure (Restrainer bars)) (• Strengthening of pier body against earthquake)	2
BAMBANG BRIDGE (1991)		• Repair/sealing of concrete cracks, and exposed rebars	1	-	-	-	-
VARGAS BRIDGE	Upstream Side (1992)	• Repair/sealing of concrete cracks, honeycomb and spalling	2	• Rehabilitation of gerber hinge • Rehabilitation of girder on pier top	1	-	-
VARGAS BRIDGE	Downstream Side (1973)	• Repair/sealing of concrete cracks, honeycomb and exposed rebars	2	• Rehabilitation of corroded steel members	1		-
ROSARIO BRIDGE (1952)		• Repair/sealing of concrete cracks, honeycomb, spalling and exposed rebars	2	• Rehabilitation of concrete deck slab	1	(• Retrofitting of pier body and foundation)	3
MARCOS BRIDGE (1978)		• Repair/sealing of concrete cracks, honeycomb, spalling and exposed rebars	1	-	-	-	-
MARIKINA BRIDGE (1980)		• Repair/sealing of concrete cracks, honeycomb, spalling and exposed rebars	1	-	-	-	-
SAN JOSE BRIDGE (1980)		• Repair/sealing of concrete cracks, honeycomb, spalling and exposed rebars	2	-	-	• Replacement of water tight expansion joint (• Retrofitting of superstructure and Substructure)	1

[shaded box] : Proposed Improvement Work ( ) : Measures against earthquakes only for reference as explained in **Section 9.1.1**

9.3 ECONOMIC EVALUATION WITH LIFE-CYCLE COST ANALYSIS

9.3.1 Basic Principle

The analysis of bridges with a distinct deficiency – for example, a deficient load rating – involves a decision from available improvement alternatives such as repair, rehabilitation, strengthening, and the do-nothing option. At the project level, the usual and probably most effective method in selecting an alternative is by means of an economic analysis. The ability to quantify candidate solutions in terms of the associated-economic values provides engineers with a rational method in comparing alternatives.

A commonly used definition of the term cost-effectiveness analysis is as "a system analysis whereby information of the effectiveness and cost of alternative systems are used in conjunction with specified decision – making rules to choose among alternatives."

Lifecycle cost analysis is one of cost-effectiveness analysis methods, which includes future costs. One problem associated with this approach is, therefore, the difficulty in accurately assessing future costs as they may apply to most bridge projects. However, progress has been made in determining bridge lifecycle costs and other economic aspects associated with bridges through better bridge management systems.

Typically, future costs include maintenance, future rehabilitation expenditures, salvage value at the end of the useful life, and probable replacement costs. In lifecycle cost analysis, future cost must be discounted to a present worth before they are combined with present costs. Basic formulas for converting future sums into present worth by discounting are presented in **Figure 9.3.1-1.**

- Single Payment: $F\left(\frac{1}{(1+i)^{n}}\right)$
- Uniform Series: $A\left(\frac{1-(1+i)^{-n}}{i}\right)$
- Uniform Gradient: $\frac{G}{i}\left(\frac{1-(1+i)^{-n}}{i} \quad \frac{n}{(1+i)^{-n}}\right)$
- Perpetual Series: $A\left(\frac{(1+i)^{-n}}{(1+i)^{-n}-1}\right)$

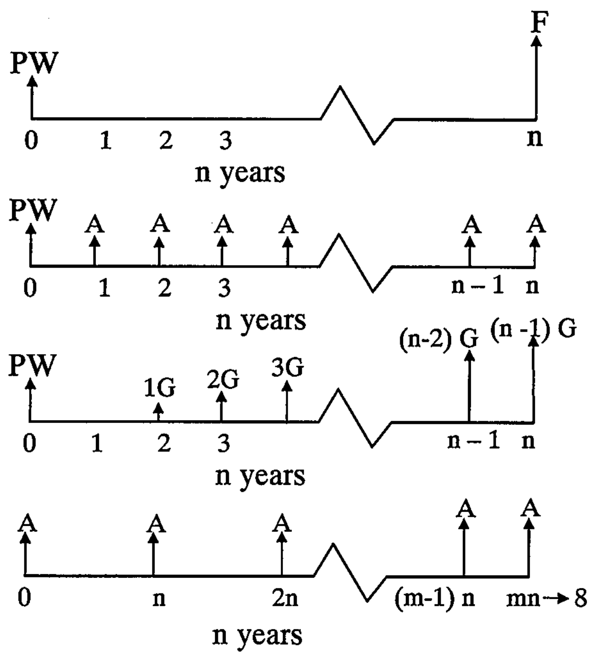


Figure 9.3.1-1 Present worth calculated by discounting (i = effective interest rate)

For the usual cases, lifecycle cost profiles are developed on the basis of bridge history and the expected rate of deterioration. Profiles thus obtained are good estimates of expected future costs, although it is unlikely that the amount and timing of future expenditures will match exactly the initial projections. Lifecycle analysis is indicated when the comparison involves alternatives of equal performance. If they are not, the procedure may still be applied but the results will not be complete.

For the simple case of lifecycle cost comparison of two or more alternatives, bridge improvement scenarios, cost profiles conforming to the probable sequence, timing, and values of all costs are generated. These costs are then discounted to a single point in time. If the performance or level of service of each alternative is the same or comparable, the best option is the one with the least total discounted cost over time.

The higher an alternative cost is, the less attractive an improvement option becomes, meaning usually the small costs tend to favor the small scale option. However, an alternative with higher initial rehabilitation costs may have lower operation, maintenance and repair costs after rehabilitation works. Life-cycle cost analysis allows engineers to determine which alternative is cost effective over its intended service life.

9.3.2 Analytical Procedure

(1) Bridge Deterioration Model

The Transportation Systems Center (TSC) study has used linear regression analysis to develop equation describing the deck, superstructure and substructure conditions as a function of the following independent variables: age, Average Daily Traffic (ADT), state, main structure type, skew, number of spans, and custodian (ownership). Among those variables, age has the most critical effect, followed by the ADT.

Through the regression analysis, the TSC has presented the deterioration form for the deck, superstructure and substructure as follows:

$$\left.\begin{aligned}\text{Deck Condition Level} &= 9 - a_1 \times (AGE) - a_2 \times (ADT) \times (AGE/10)\\ \text{Superstructure Condition Level} &= 9 - b_1 \times (AGE) - b_2 \times (ADT)\\ \text{Substructure Condition Level} &= 9 - c_1 \times (AGE) - c_2 \times (ADT)\end{aligned}\right\} \quad \text{—(9.3.2-1)}$$

Where, $a_1=0.119$, $a_2 = 6$, $b_1 = 0.103$, $b_2 = 6$, $c_1 = 0.07$, $c_2 = 6$

In this Study, effects of ADT to the superstructure and substructure were not considered because effect due to traffic volume were relatively insensitive.

The deterioration model suggested by the Transportation Research Board (TRB) of the National Academies in U.S.A. backs up the TSC's model above. According to the TRB's suggestion, typical deterioration model is to be expressed as illustrated in **Figure 9.3.2-1.**

If a bridge is placed in service following its construction, the deterioration curve represents the bridges condition as it declines with wear and aging, from its initially high level (level 9) to a level considered unacceptable (Cf).

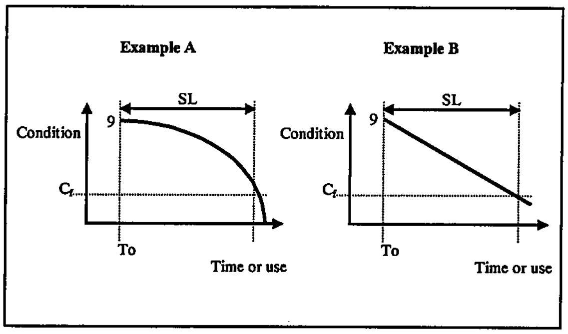


Figure 9.3.2-1 Models of Bridge Element and Bridge Deterioration

In **Figure 9.3.2-1** Example A represents a concrete deck where the damage of gradual cra-king accumulates and then begins to accelerate as water and chemicals penetrate more deeply beneath the surface; Example B represents a bridge as a whole where the overall condition progresses through a series of defined states.

Unacceptable level (C_f) was considered as follows.

Level 3 : Meets minimum tolerable limits to be left in place as is.

Level 2 : Basically intolerable limit requiring high priority of corrective action.

Level 1 : Basically intolerable limits requiring high priority of major rehabilitation/s or replacement.

In this Study, Level 2 was regarded as the unacceptable level (C_f) considering the present situation of this country.

(2) Estimation of Extended Service Life

In lifecycle cost analysis, the condition of bridges and their components must be adjusted or updated to include the effect of improvement projects. If this condition is only a function of age, this variable can be reset to 0 when a bridge component is replaced, and the analysis can then proceed from the top (Level 9) of the deterioration curve.

This procedure is illustrated in **Figure 9.3.2-2**, in which a graph is devised to represent the condition after the work is performed. Longitudinal axis is the ratio of improvement cost to replacement cost of the major bridge component, horizontal axis is the condition level after rehabilitation.

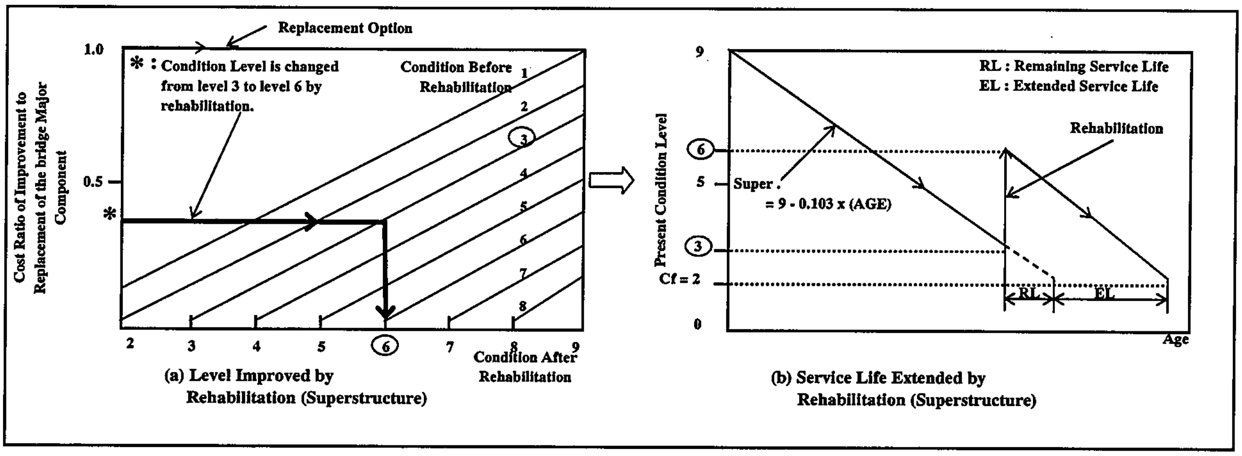


Figure 9.3.2-2 Improvement Effect

By inserting a condition of improved level into the Formula (9.3.2-1), extended service life of a particular component can be presumed.

(3) Analysis of Life-Cycle Cost

(a) Replacement Case

If the bridge is replaced immediately, as shown in **Figure 9.3.2-3**, its lifecycle cost for replacement case is calculated as follows.

$$LCCp\ (repl.) = A \bullet (pwf'_{SL}) \qquad (9.3.2\text{-}2)$$

Where LCCp (repl.) = lifecycle cost (perpetual service)

A = present worth of the cost of one replacement lifecyle with maintenance activities

pwf'_{SL} = perpetual series present worth factor

= $(1 + i/100)^m / [(1 + i/100)^m - 1]$

i = discount rate (%) (15%)

m = service life year

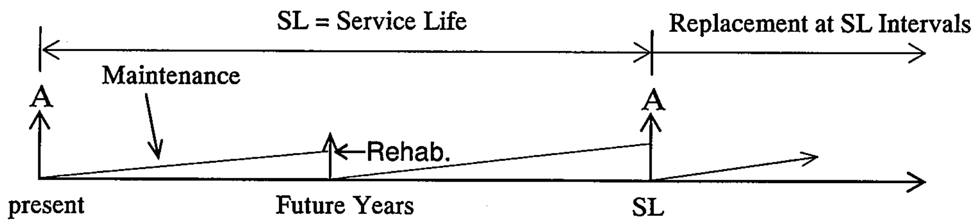


Figure 9.3.2-3 Life-Cycle Calculation Model for Replacement Case

(b) Rehabilitation Case

Rehabilitation moves replacement "e" years into the future, as shown in **Figure 9.3.2-4.** In this case, the lifecycle cost to the replacement case is expressed as follows:

$$LCCp\ (rehab.) = B + A \bullet (pwf''_{SL}) \bullet (pwf'e) \qquad (9.3.2-3)$$

where B = present worth of the cost of rehabilitation and maintenance over the remaining life of the existing bridge

pwf'e = single payment present worth factor

= $1/(1+i/100)^e$

e = extended service life of the existing bridge through maintenance and rehabilitation (years)

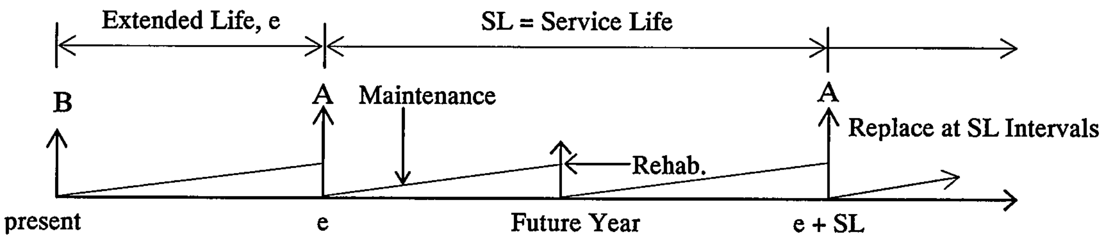


Figure 9.3.2-4 Life-Cycle Cost Calculation Model for Rehabilitation Case

Let formulas (9.3.2-2) and (9.3.2-3) equal in order to obtain the break even point as follows:

$$A\ .\ (pwf''_{SL}) = B + A \bullet (pwf''_{SL}) \bullet (pwf'e)$$

Which yields

$$C = \frac{B}{A} = (1 - pwf'e) \bullet (pwf''_{SL}) \qquad (9.3.2-4)$$

The parameter C with the discount rate is plotted in **Figure 9.3.2-5** versus the service life "e" extended through rehabilitation, assuming that SL (service life) of the superstructure equals to 67 which is calculated with formula (9.3.2-1).

If the point B/A plots below the lines which are the break-even line between replacement and rehabilitation options, the solution to rehabilitate is cost effective; if it falls above the lines, it is cost effective to replace.

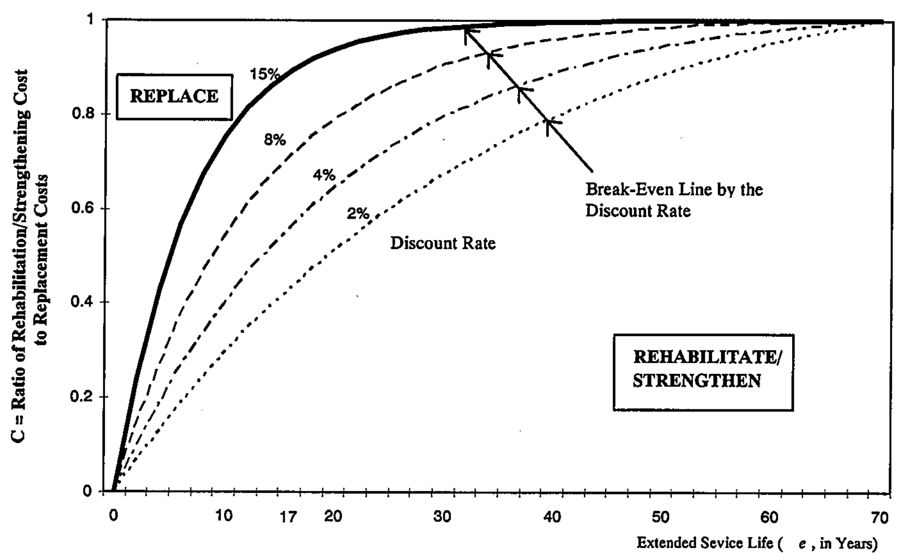


Figure 9.3.2-5 Evaluation on Alternative Improvement Strategies

9.3.3 Results of Lifecycle Cost Analysis

The lifecycle cost analysis was performed on proposed measure alternatives for each bridge, as summarized in **Table 9.3.3-1.**

Table 9.3.3-1 Comparison on Life-Cycle Cost of Measure Alternatives

			Lifecycle Cost (M.Pesos)			Remaining Life (RL) and Extended Life (EL) of Least Lifecycle Cost Option	
			Repair	Rehab.	Strength.		
1	Delpan Bridge	Downstream S.	20.0	-	-	RL = 48 Years	EL = 4 Years
		Upstream S.	45.2	41.6	129.4	RL = 25	EL = 9
2	Jones Bridge		232.2	183.1	248.5	RL = 5	EL = 31
3	McArthur Bridge		87.9	79.1	124.7	RL = 5	EL = 18
4	Quezon Bridge		353.8	170.7	206.6	RL = 5	EL = 22
5	Nagtahan Bridge		166.3	159.2	317.4	RL = 26	EL = 11
6	Pandacan Bridge		13.6	-	-	RL = 57	EL = 12
7	Lambingan Bridge		86.5	56.5	130.6	RL = 3	EL = 36
8	Makati Mandaluyong Bridge		12.6	-	28.4	RL = 46	EL = 3
9	Guadalupe Bridge	Central S.	98.0	97.6	100.6	RL = 22	EL = 17
		Both S.	32.0	28.0	33.8	RL = 6	EL = 23
10	C-5 Bridge		41.1	-	-	RL = 57	EL = 6
11	Bambang Bridge		8.6	-	-	RL = 51	EL = 9
12	Vargas Bridge	Upstream S.	83.3	25.9	31.1	RL = 4	EL = 47
		Downstream S.	11.70	-	-	RL = 33	EL = 10
13	Rosario Bridge		44.48	42.85	56.45	RL = 12	EL = 19
14	Marcos Bridge		36.0	-	-	RL = 38	EL = 6
15	Marikina Bridge		15.1	-	-	RL = 40	EL = 9
16	San Jose Bridge		17.5	-	-	RL = 40	EL = 1

9.4 RECOMMENDED IMPROVEMENT MEASURES

9.4.1 Recommended Improvement Measures

Based on the engineering evaluation and economic evaluation (life-cycle cost analysis, the improvement measure for each bridge is recommend as shown in **Table 9.4.1-1**.

Table 9.4.1-1 Recommended Measures for Each Bridge

	Bridge Name		Major Works	Level of Measures	Estimated Cost (MP)
1	Delpan Bridge	Upstream Side	• Depressing of Crossing road by excavation	Rehabilitation	20.6
		Downstream Side	• Repair / sealing of damaged parts	Repair	9.5
2	Jones Bridge		• Additional girders for ruptured girders • Existing exterior girders to function as fenders	Rehabilitation	161.8
3	Mc Arthur Bridge		• Improvement of missing rivet parts and corroded areas	Rehabilitation	68.9
4	Quezon Bridge		• Replacement of corroded joints	Rehabilitation	119.2
5	Nagtahan Bridge		• Rehabilitation of corroded members	Rehabilitation	124.7
6	Pandacan Bridge		• Repair / sealing of damaged parts	Repair	8.6
7	Lambingan Bridge		• Rehabilitation of Gerber hinge and girder on pier top • Strengthening of uplift/hold-down devices	Rehabilitation	49.0
8	Makati-Mandaluyong Bridge		• Repair / sealing of damaged members	Repair	9.3
9	Guadalupe Bridge	Central Side	• Replacement of damaged members	Rehabilitation	94.9
		Both Side	• Rehabilitation of Gerber hinge	Rehabilitation	20.4
10	C-5 Bridge		• Repair of damaged parts	Repair	26.4
11	Bambang Bridge		• Repair / sealing of damaged parts	Repair	5.9
12	Vargas Bridge	Upstream Side	• Rehabilitation of Gerber hinge and girder on pier top	Rehabilitation	24.3
		Downstream Side	• Rehabilitation of corroded members	Rehabilitation	16.8
13	Rosario Bridge		• Rehabilitation of concrete deck slab	Rehabilitation	30.3
14	Marcos Bridge		• Repair / sealing of damaged parts	Repair	21.3
15	Marikina Bridge		• Repair / sealing of damaged parts	Repair	9.4
16	San Jose Bridge		• Rehabilitation of water tight expansion joint	Rehabilitation	30.8

9.4.2 Bridges to be Urgently Improved

Through the comparative study, the following five (5) bridges were found to require urgent improvement with the recommended improvement measures as shown in **Table 9.4.2-1.**

Table 9.4.2-1 Bridges to be Urgently Improved

Bridge Name	Major Deficiencies	Probable Cause	Urgency	Recommended Measures
Jones Bridge	• Exterior girder in upstream side at near pier is heavily damaged. • Exterior girder in downstream side at near piers is laterally deformed.	• Vessel collision because of insufficient navigational vertical clearance. • Vessel collision because of insufficient navigational vertical clearance.	• RF_I = Negative (Exterior Girder is ruptured) • RF_O = 0.76 (Very Urgent)	• Additional girders adjacent to the existing exterior girders to take its structural functions. • Existing exterior girders to be repaired and serve as vessel collision protection.
Quezon Bridge	• Corroded joint connections of floor system, ends of braces and ends of additional stringers at abutments.	• Water seepage through vertical members	• RF_I = 0.92 • RF_O = 1.59 (Very Urgent)	• Cut and replace deteriorated joint connections, ends of braces and end of stringers at abutments. Provide water sealant at vertical hangers to prevent seepage. • Cleaning and painting of corroded truss members.
Lambingan Bridge	• Cracks at gerber hinge supports and over the piers. • Cracks at exterior girder at top of pier	• Insufficient hanger bars at gerber hinge • Insufficient longitudinal tendons	• RF_I = 0.63 • RF_O = 1.06 (Very Urgent)	• Provide P/S slanted cables and carbon fiber at Gerber Hinge • Provide carbon fiber to increase flexural capacity
Guadalupe Bridge	• Cracks at gerber hinge supports	• Insufficient hanger and shear bars.	• RF_I = 0.44 • RF_O = 0.74 (Very Urgent)	• Provide P/S slanted cables to close the cracks and carbon fiber at Gerber Hinge.
Vargas Bridge	• Cracks at gerber hinge supports • Cracks on exterior girders at top of piers. • Large deformation of girder at cantilever portion	• Insufficient hanger bars in gerber hinge supports. • Insufficient longitudinal tendons. • Ratio of side span to center span is lower than 0.65 which causes uplift at sidespan	• RF_I = 0.83 • RF_O = 1.37 (Very Urgent)	• Provide P/S slanted cables and carbon fiber at Gerber Hinge • Provide external longitudinal tendons • Provide external longitudinal tendons

RF_I = Rating Factor at Inventory Level
RF_O = Rating Factor at Operating Level

CHAPTER 10

PROTECTION MEASURES AGAINST
EARTHQUAKE

CHAPTER 10

PROTECTION MEASURES AGAINST EARTHQUAKE

10.1 PRESENT PRACTICE OF PROTECTION MEASURES

The eastern part of the metropolis is transversed by the Marikina Valley Fault System (MVFS), the East Valley Fault and West Valley Fault as shown in **Figure 10.1-1**. According to the recent research, four major events were inferred to have occurred in the past, approximately 400 years apart.

Whether a bridge has sufficient resistance and safety against a large scale earthquake largely depends on the design or construction year, since smaller seismic forces were adopted in older bridges.

From the above context, the DPWH has pursued the "Bridge Retrofit Program (BRP)" as described in **Section 2.3**, which aimed at minimizing the structural risk under seismic actions.

Bridges retrofitted under the BRP which are involved in the Study are summarized in **Table 10.1-1**.

The Study did not delve deeper into the scope of the BRP project but performed the basic seismic analysis to check the seismic vulnerability of the bridges.

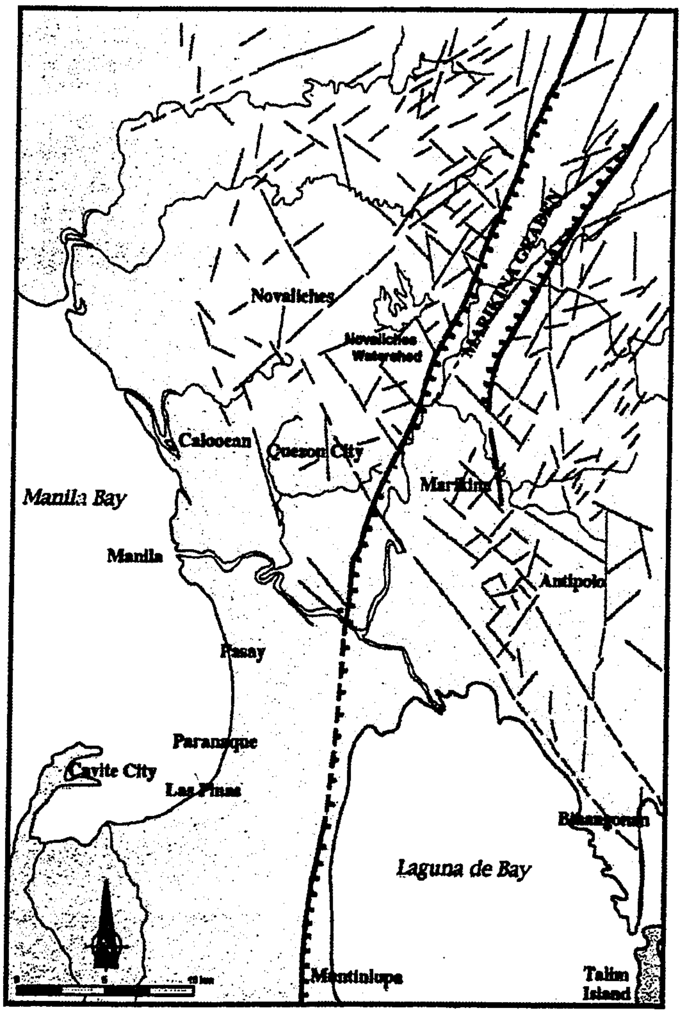


Figure 10.1-1 Marikina Valley Fault System (MVFS)

Table 10.1-1 Scope of Retrofit Works Performed by the BRP

Ref. No.	Bridge Name (Year Built)	Bridge Type (Bridge Length)	Retrofit Made	Completion
Pa1.1	Delpan Bridge - Upstream (1965)	5-Span PC Box Girder with Gerber Hinge (204 m)	• Widening of seat width at pier • Longitudinal cable restrainers are installed at Piers 1 & 4 and intermediate hinges of second span to prevent falling-off	June 1997
Pa1.2	Delpan Bridge - Downstream (1988)	5-Span PC Box Girder with Gerber Hinge (203 m)	• Widening of seat width at pier • Longitudinal cable restrainers are installed at Piers 1 & 4 • Longitudinal cable restrainers at intermediate hinges of second span	June 1997
Pa2	Jones Bridge (1948)	3-Span Continuous Steel Plate Girder (114 m)	• Longitudinal and transverse shear keys added at pier copings • Pier 2 bearing encased in concrete to make fixed condition	June 1997
Pa3	Mac Arthur Bridge (1948)	3-Span Continuous Steel Plate Girder (115 m)	• Longitudinal and transverse shear keys added at pier copings and abutments	June 1997
Pa4	Quezon Bridge (1946)	Single Span Steel Type Arch Bridge (102.4m)	None	-
Pa5	Ayala Bridge (1935)	Two-Span Steel Truss Bridge (142m)	None	-
Pa6	Nagtahan Bridge (1966)	3-Span Continuous Truss Bridge (432 m)	• Longitudinal and transverse shear keys added at pier copings. • Install full height steel jackets at multi-column bent piers (Approach Bridge). • Pier cap strengthening • Install longitudinal cable restrainers to all piers (except piers 8 to 11) to prevent falling off. • Replacement of girders at spans 12 to 15 (north-bound only). • Half width of south-bound deck at spans 16 to 25 made continuous.	November 2001
Pa7	Pandacan Bridge (1997)	3-Span PC I-Girder Bridge (145 m)	None	-
Pa8	Lambingan Bridge (1979)	3-Span PC I-Girder Gerber Bridge (98 m)	• Deck slab made continuous • Longitudinal and transverse shear keys added at pier copings. • Install vertical cable restrainers at abutments.	June 1997
Pa9	Makati-Mandaluyong Bridge (1986)	PC Box Girder Cantilever Type Bridge (207 m)	None	-
Pa10.1	Guadalupe Bridge (Central) (1962)	3-Span Continuous Truss Bridge (114 m)	None	-
Pa10.2	Guadalupe Bridge (Both Sides) (1979)	3-Span PC I-Girder Gerber Bridge (114 m)	• Longitudinal and transverse shear keys added at pier copings. • Install longitudinal cable restrainers on intermediate hinges • Install vertical cable restrainers at abutments	June 1997
Pa11	C-5 Bridge (1997)	10-Span PC I-Girder Bridge (272.96m)	None	-
Pa12	Bambang Bridge (1991)	3-Span PC I-Girder Bridge (163 m)	• Deck slab made continuous • Longitudinal and transverse shear keys added at copings of piers 3,4,5 & 6. • Install full height steel jackets at columns of piers. • Added four bored piles each at footing of piers 4 & 5.	June 1997
Pa13.1	Vargas Bridge (Upstream) (1992)	4-Span PC I-Girder Gerber Bridge (122 m)	• Deck slab made continuous • Longitudinal and transverse shear keys added at pier copings. • Added four steel H-piles at each footing • Provide footing overlay to accommodate new piles • Install vertical cable restrainers at abutments.	June 1997
Pa13.2	Vargas Bridge (Downstream) (1973)	4-Span Steel Plate Girder Bridge (143 m)	• Install longitudinal cable restrainers at expansion joints • Longitudinal and transverse shear keys added at pier copings.	June 1997
Ma14	Rosario Bridge (1952)	6-Span PC I-Girder Bridge (175 m)	• Longitudinal and transverse shear keys added at pier copings & abutments. • Install longitudinal cable restrainers at all piers. • Install cable restrainer block.	March 2001
Ma15	Marcos Bridge (1978)	11-Span PC I-Girder Bridge (312 m)	• Widening of seat width at pier • Install full height steel jackets at columns of piers. • Install longitudinal cable restrainers at expansion joints	Feb. 1997
Ma16	Marikina Bridge (1980)	5-Span PC I-Girder Bridge (138 m)	• Longitudinal and transverse shear keys added at pier copings. • Install full height concrete jackets at columns of piers. • Added piles on every piers • Provide footing overlay on all piers.	June 1997
Ma17	San Jose Bridge (1980)	8-Span PC I-Girder Bridge (200 m)	None	-

10.2 PRELIMINARY STABILITY ANALYSIS AGAINST EARTHQUAKES

10.2.1 Procedure and Assumptions

(1) Situation of the Bridges

In assessing the bridge resistance to disaster caused by seismic forces, considerations for potential ground motions that are large enough to cause failure to occur to a bridge site become as an important issue. The most probable source of large ground movement in the vicinity of the bridges under study would be the Marikina Valley Fault System (MVFS), illustrated in **Figure 10.1-1.** The following condition of the bridges can be observed from **Figure 10.2.1-1.**

- At least three bridges – Marcos, C-5 and San Jose are less than 1 kilometer (about 500m) from the MVFS,
- Seven bridges – Rosario, Guadalupe (2), Vargas (2), Marikina and Bambang are from 1 km to 1.5 km from the MVFS,
- One bridge – Makati-Mandaluyong is about 3 kms from the MVFS, and
- The rest of the bridges are more than 10 kms from the MVFS with Delpan bridge being the farthest at 15 kms.

The type of soil and its response characteristics have to be evaluated to determine the magnitude of potential movements as well as forces that the bridges under the study will have to resist.

The 1971 San Fernando earthquake was a major turning point in the development of seismic design criteria for bridges in the United States. Prior to 1971, the AASHTO specifications for seismic design of bridges were based in part on the lateral force requirements for building developed by the Structural Engineers Association of California. In 1973 the California Department of Transportation introduced the new seismic design criteria for bridges, which include the relationship of site to active faults, the seismic response of the soil at the site and the dynamic response characteristics of the bridge. In 1975, AASHTO adopted the Interim Specifications which were slightly modified version of the 1973 CalTrans provisions, and made them applicable to all regions of the United States. In addition to these code changes, the 1971 San Fernando Earthquake stimulated research activity on seismic activity and seismic problems related to bridges.

The seismic code evolution as presented in **Figure 10.2.1-1** clearly indicates that bridges designed in the early years are prone to seismic action. At least eight (8) bridges in the study built prior to 1970 did not consider the seismic design requirements considering the bridge proximity to active faults and its dynamic characteristics.

Although AASHTO revolutionize its seismic design requirements in the 1970's the Philippines did not readily adopt such provisions and not until the 1990's that the AASHTO seismic design requirements are implemented in the Philippines.

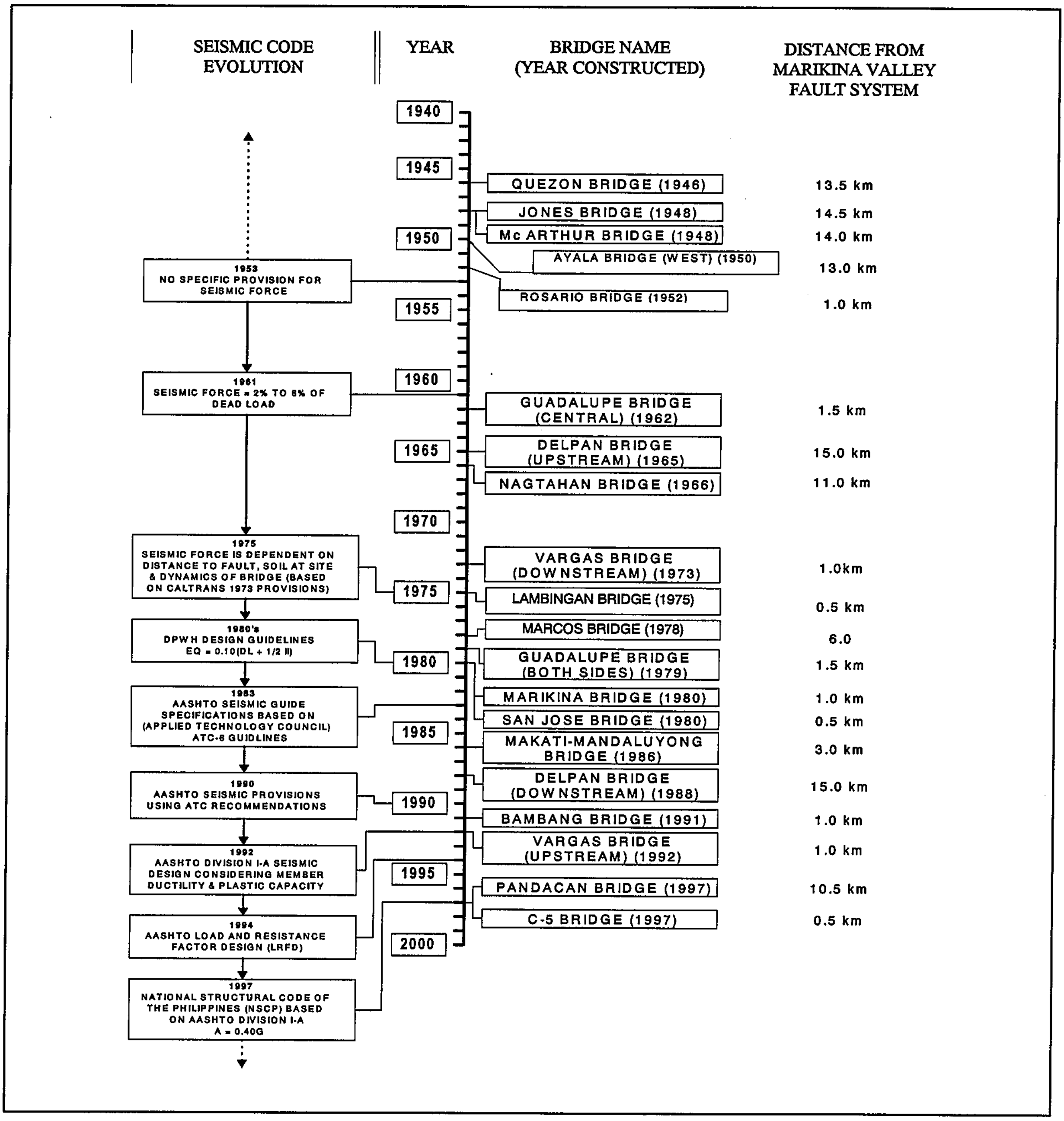


Figure 10.2.1-1 Relationship among Bridge Construction Year Chronology of Seismic Code and Distance from MVFS

(2) 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 based on the following data:
    - Results of dimension and shape measurements for the seventeen bridges along Pasig and Marikina rivers.
    - Available as-built plans of the existing bridges.
    - Assumptions on details of girder, pier/columns, and foundation (e.g. if no reinforcement data is available for piers/columns, the minimum required during the time of construction is assumed, or if foundation information is not available, the type and quantity (including size) is assumed based on the prevailing technology at the time of construction).
    - Unknown material properties and strengths are assumed based on the results of field tests (e.g. Schmidt Hammer Test and the available materials at the time of construction.
- The seismic load was based on the AASHTO Seismic Response Spectra using a Peak Ground Acceleration of 0.4 (A = 0.4)
- Structural number/element capacity was calculated based on the information given in the above condition. When cross-section data, including reinforcements are unknown, the section is assumed based on the demand forces at the time of design/construction or the minimum required by the code prevailing at the time of construction.
- Support conditions are taken from as-built drawings or those observed on site.
- The demand forces analysis was carried-out based on the bridge condition under the elastic range and the plastic range if the member section is capable of supporting plastic forces. The C/D Ratios are calculated for the columns and foundations by dividing the ultimate capacity of the sections by the elastic/plastic demand forces under seismic loading.

  In calculating the C/D Ratio for Piers/Columns, the shear and bending demand forces were taken only at the top and bottom of the columns.

  In calculating the C/D Ratios for foundations, the axial demand forces are taken at the top of the piles only.
- The Elastic and Plastic C/D Ratios calculated are the basic capacity-demand ratio based on the original condition of the bridge. At this stage, no detailed iterative calculation was done to investigate changes in force demand when structural conditions change, e.g. formation of plastic hinges on columns and foundations. It was thus taken that the bridge including superstructure and substructure was resisting the

seismic forces in the elastic range and reduced to plastic range if the section is capable of forming plastic hinges.

- Plastic C/D Ratios are used on bridges which have been retrofitted with concrete or steel jackets.

(3) Key Points in Analysis

The earthquake vulnerability of a bridge system is taken to be the measure of the potential failure mechanism of the system under seismic forces. Although all bridges under the study are vulnerable to some degree, judgment and reason should be applied to identify the practical vulnerabilities.

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

- Bridge Site: Local site conditions and proximity to sources of ground motion could amplify strong ground motions and subsequently increase the vulnerability of bridges on soft soil sites. Potential for site liquefaction will tend to influence the bridge stability.

- Construction Details: Single-column supported bridges are deemed more vulnerable due to lack of redundancy. Brittle elements with inadequate details always limit their ability to deform inelastically.

- Structural Configurations: Structural irregularity such as expansion joints and C bents can cause stress concentration and thus catastrophic consequences.

- Date of Construction: Bridges designed using AASHTO Recommendations are prone to seismic forces prior to 1971. However, the seismic design requirements of the AASHTO was not fully implemented in the Philippines until the 1990s and even some bridges are still designed using an equivalent static lateral force of 10% of the dead load plus ½ live load.

10.2.2 Results of Analysis

Table 10.2.2-1 shows the results of seismic analysis. According to the analysis, the following bridges are in lack of seismic capacity.

- Jones Bridge
- McArthur Bridge
- Quezon Bridge
- Ayala Bridge
- Nagtahan Bridge
- Lambingan Bridge

- Makati-Mandaluyong Bridge
- Guadalupe Bridge (Both Sides)
- C-5 Bridge
- Rosario Bridge
- San Jose Bridge

Table 10.2.2-1 Results of Seismic Analysis

BRIDGE NAME (Construction Year)		SUBSTRUCTURE C/D RATIO Structural Capacity / Demand (C/D) Ratio	
		COLUMN/WALL	FOUNDATION
Delpan Bridge	Upstream (1965)	C/D_{PL} = 1.00 (Pier 3) min. (Wall Pier)	C/D_{PL} = 1.25 (Pier 2) (Timber Piles)
Delpan Bridge	Downstream (1988)	C/D_{PL} = 1.03 (Pier 3) (Wall Pier)	C/D_{PL} = 2.01 (Pier 2 & 3) (Cast-In-Place Bored Piles)
Jones Bridge (1948)		**C/D_{PL} = 0.543** (Pier 1) **C/D_{PL} = 0.64** (Pier 2) (Wall Pier)	**C/D_{PL} = 0.90** (Pier 1) **C/D_{PL} = 0.89** (Pier 2) (Caisson)
Mac Arthur Bridge (1948)		**C/D_{PL} = 0.26** (Pier 1) (Wall Pier)	**C/D_{PL} = 0.85** (Pier 1) (Timber Piles)
Quezon Bridge (1946)		**C/D = 0.70** (Abut)	**C/D = 0.70** (Abut) (Timber Piles)
Ayala Bridge (1935, 1950)		**C/D = 0.60** (Mainwall Abut.) **C/D = 0.32** (Wall Pier)	**C/D = 0.57** (Abut found.) **C/D = 0.41** (Pier found.) (Timber Piles)
Nagtahan Bridge (1966)		**C/D_{PL} =0.56** (Pier 9 & 10) (Wall Pier)	**C/D_{PL} = 0.64** (Pier 9 & 10) (Timber Piles)
Pandacan Bridge (1997)		C/D_{PL} = 1.58 (Pier 4) (Column Bent)	C/D_{PL} = 1.58 (Pier 4) (Cast-In-Place Bored Piles)
Lambingan Bridge (1975)		**C/D_{PL} = 0.64** (Pier 1) (Wall Pier)	C/D_{PL} = 2.36 (Steel Pipe Piles)
Makati-Mandaluyong Bridge (1986)		**C/D_{PL} = 0.81** (Pier 6) (Column Bent)	**C/D_{PL} = 0.81** (Pier 6) (Cast-In-Place Bored Piles)

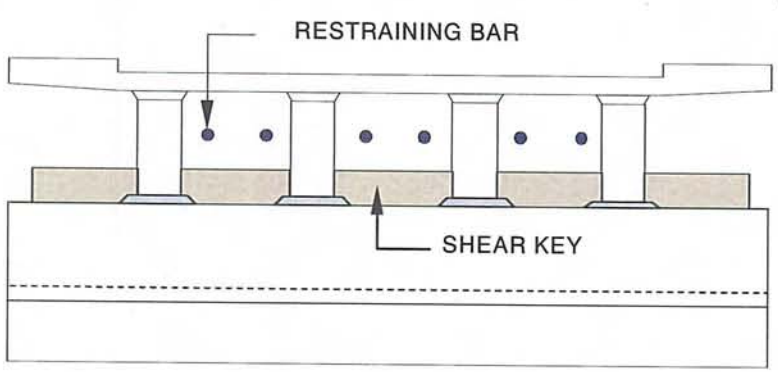
BRIDGE NAME (Construction Year)		SUBSTRUCTURE C/D RATIO Structural Capacity / Demand (C/D) Ratio	
		COLUMN/WALL	FOUNDATION
Guadalupe Bridge	Central (1962)	C/D_{PL} = 1.27 (Pier 2) (Wall Pier)	C/D_{PL} = 1.05 (Timber Piles)
Guadalupe Bridge	Both Sides (1979)	**C/D_{EL} = 0.85** (Pier 1& 2) (Wall Pier)	**C/D_{PL} = 0.61** (Pier 1& 2) (PSC Piles)
C-5 Bridge (1998)		**C/D_{PL} = 0.74** (Pier 8) (Column Bent)	**C/D_{PL} = 0.74** (Pier 8) (Cast-In-Place Bored Piles)
Bambang Bridge (1991)		C/D_{PL} = 2.05 (Pier 1) (2-Column Bent)	C/D_{PL} = 4.89 (PSC Piles)
Vargas Bridge	Upstream (1992)	C/D_{PL} = 2.87 (Pier 1& 2) (2-Column Bent)	C/D_{PL} = 6.18 (Pier 1& 2) (Steel H-Piles)
Vargas Bridge	Downstream	C/D_{PL} = 1.19 (Pier 1) (2-Column Bent)	C/D_{PL} = 3.59 (Pier 1) (PSC Piles)
Rosario Bridge (1952)		**C/D_{PL} = 0.69** (Pier 4) (Wall Pier)	**C/D_{PL} = 0.97** (Timber, PSC & Steel Pipe Piles)
Marcos Bridge (1978)		C/D_{PL} = 1.47 (Pier 4) (Column Bent)	C/D_{PL} = 3.14 (PSC Piles)
Marikina Bridge (1980)		C/D_{PL} = 1.49 (Pier 2 & 3) (4-Column Bent)	C/D_{PL} = 9.65 (Pier 2 & 3) (PSC Piles)
San Jose Bridge (1980)		**C/D_{PL} = 0.68** (Pier 3,4,5) (Wall Pier)	**C/D_{PL} = 0.33** (PSC Piles)

10.3 RECOMMENDED PROTECTION MEASURES

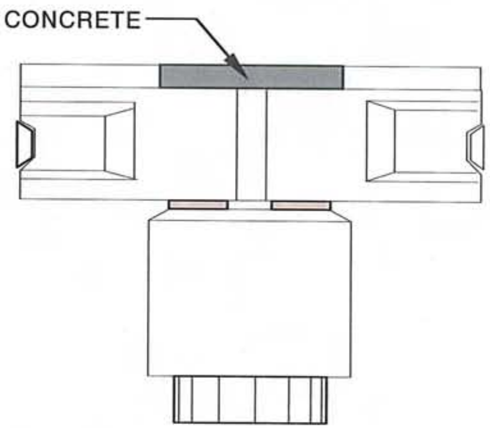
Table 10.3-1 shows bridges requiring retrofitting and measures with costs against earthquakes. **Figure 10.3-1** illustrates an example of retrofitting

Table 10.3-1 Measures and Cost Retrofitting

Bridge Name (Construction Year)		History of Retrofitting (Main Bridge)	Required Measure Against Earthquakes	Retrofitting Cost (MP)
Delpan Bridge	Upstream (1965)	• Widening of seat width at pier • Longitudinal cable restrainers are installed at Piers 1 & 4 and intermediate hinges of second span to prevent falling-off	• No retrofitting works required.	-
	Downstream (1988)	• Widening of seat width at pier • Longitudinal cable restrainers are installed at Piers 1 & 4 • Longitudinal cable restrainers at intermediate hinges of second span	• No retrofitting works required.	-
Jones Bridge (1948)		• Longitudinal and transverse shear keys added at pier copings • Pier 2 bearing encased in concrete to make fixed condition	• Install full height concrete jackets at piers to increase capacity of wall piers. • Enlarge footing and provide bored piles at each side	77.10
Mac Arthur Bridge (1948)		• Longitudinal and transverse shear keys added at pier copings and abutments	• Install full height concrete jackets at piers to increase capacity of wall piers. • Provide additional piles to increase capacity of footing.	48.10
Quezon Bridge (1946)		None	• Enlarge pile cap/footing and provide additional piles to increase capacity of footing.	35.90
Ayala Bridge (1935, 1950)		None	• Reconstruct abutment backwall • 100% reconstruction of pier • Provide additional piles on pier and abutments to increase capacity of footing.	430.16
Nagtahan Bridge (1966)		• Longitudinal and transverse shear keys added at pier copings.	• Install full height concrete jackets at piers to increase capacity of pier wall. • Provide additional piles to increase capacity of footing.	132.50
Pandacan Bridge (1997)		None	• No retrofitting works required.	-
Lambingan Bridge (1975)		• Deck slab made continuous • Longitudinal and transverse shear keys added at pier copings. • Install vertical cable restrainers at abutments.	• Install full height concrete jackets at piers to increase capacity of pier wall.	4.80
Makati-Mandaluyong Bridge (1986)		None	• Install longitudinal restrainer cables at discontinuous spans • Increase full height concrete jackets at piers to increase capacity of pier wall. • Provide additional piles to increase capacity of footing.	25.20
Guadalupe Bridge	Central (1962)	None	• No retrofitting works required.	-
	Both Sides (1979)	• Longitudinal and transverse shear keys added at pier copings. • Install longitudinal cable restrainers on intermediate hinges. • Install vertical cable restrainers at abutments.	• Install full height concrete jackets at piers to increase capacity of pier wall. • Provide additional piles to increase capacity of footing to meet demands.	6.40
C-5 Bridge (1998)		None	• Add longitudinal and transverse shear keys at pier copings and abutments. • Install longitudinal cable restrainers at discontinuous spans for prevention of falling-off. • Install full height concrete jackets at columns to increase capacity of piers. • Provide additional piles to increase capacity of footing.	81.90
Bambang Bridge (1991)		• Deck slab made continuous • Longitudinal and transverse shear keys added at copings of piers 4 & 5. • Install full height steel jackets at columns of piers. • Added four bored piles each at footing of piers 4 & 5.	• No retrofitting works required.	-
Vargas Bridge	Upstream (1992)	• Deck slab made continuous • Longitudinal and transverse shear keys added at pier copings. • Added four steel H-piles at each pier with footing overlay. • Install vertical cable restrainers at abutments.	• No retrofitting works required.	-
	Downstream (1973)	• Install longitudinal cable restrainers at expansion joints. • Longitudinal and transverse shear keys added at pier copings.	• No retrofitting works required.	-
Rosario Bridge (1952)		• Longitudinal and transverse shear keys added at pier copings & abutments. • Install longitudinal cable restrainers at all piers. • Install cable restrainer block	• Install full height concrete jackets at piers to increase capacity of wall piers. • Provide additional piles to increase capacity of footing.	19.70
Marcos Bridge (1978)		• Widening of seat width at pier. • Install full height steel jackets at columns of piers. • Install longitudinal cable restrainers at expansion joints.	• No retrofitting works required.	-
Marikina Bridge (1980)		• Longitudinal and transverse shear keys added at pier copings. • Install full height concrete jackets at columns of piers. • Added piles on every piers • Provide footing overlay on all piers	• No retrofitting works required.	-
San Jose Bridge (1980)		None	• Make the deck slab continuous. • Provide longitudinal restrainer cables at discontinuous spans. • Provide longitudinal and transverse shear keys at all copings of piers. • Widening of pier coping. • Install full height concrete jackets at piers to increase capacity of wall piers. • Provide additional piles to increase capacity of footing.	75.40



a. Installation of restraining bars for hold-down device and shear keys to transmit forces from superstructure to substructure



b. Deck slab made continuous at joints expansion joi

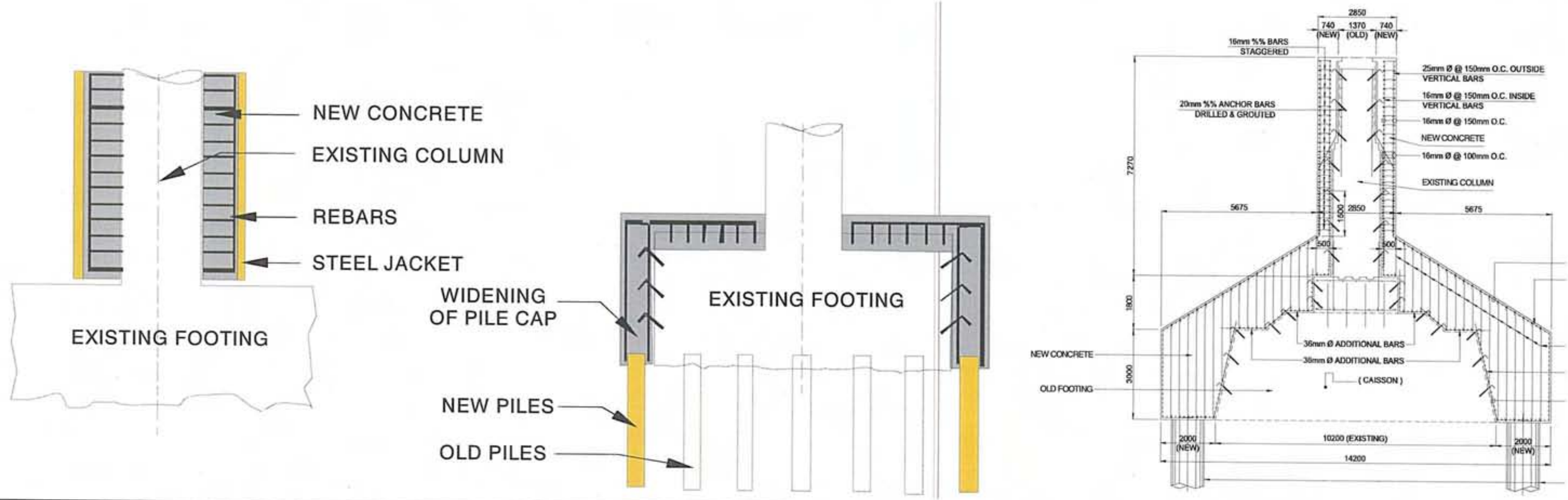


Figure 10.3-1 Example of Retroffiting

CHAPTER 11

PREVENTION MEASURES AGAINST
VESSEL COLLISION

CHAPTER 11

PREVENTION MEASURES AGAINST VESSEL COLLISION

11.1 REGULATIONS AND MANAGEMENT SYSTEM OF RIVER NAVIGATION

11.1.1 Regulations on River Navigation

(1) Presidential Decree No. 857

Presidential Decree No. 857 declares that the main responsibility of the Philippine Ports Authority (PPA) is to implement an integrated program for the planning, development, financing, operation and maintenance of all ports or port districts in the Philippines.

(2) Republic Act No. 5173

Republic Act No. 5173 mandates the Philippine Coast Guard (PCG) to enforce or assist in the enforcement of all applicable laws, maintain and operate, with due regard to the requirement of national defense, aid to maritime navigation and rescue facilities for the promotion of safety on and over the seas and waters within the Philippines.

In addition, the PCG has specific responsibilities on the Pasig-Marikina River under Republic Act No. 5173. The Coast Guard Station (CGS) in Pasig City is accountable within this territory. This includes the security of Pasig River to prevent and repel waterborne infiltration and attack against the Malacañang Palace Complex, protect the President and his family while transiting, inspect and control movement of transversing watercraft, and enforce rules and regulations along the river.

(3) Memorandum Circular No. 04-97 of PCG

Memorandum Circular No. 04-97 issued by the PCG on 18 August 1997 in connection with RA No. 5173 specifies the **Special Rules and Regulations Prescribing Navigation along Pasig River**. This Memorandum Circular applies to all navigational activities operating for the safety of life and property in the Pasig River including the territorial waters of the Philippines.

The Memorandum provides the following rules of navigation under or near bridges in the Pasig-Marikina River:

A. All tugboats, self-propelled barges, fish carriers, ferry boats and other watercrafts transversing the Pasig River shall have on board for ready use searchlights or strong 5 to 7 cell flashlights and a crew member to identify derelict markers for emergency use, such as man over-board or any rescue operation.

B. Vessel going-up-river (bound for Laguna Bay) shall give way to vessels going down-river (bound for Manila Bay).

C. Overtaking is prohibited in approaching a bend or in passing under the bridge.

D. In case of approaching a curve or passing under the bridge, both vessels shall sound three (3) long blasts on the whistle, to give advance caution to approaching vessels and observe the rules of the road.

E. When two (2) tugboats in towing operations are meeting, the tugboat which is navigating down-river (bound for Manila Bay) is deemed to be the privileged vessel and the other tugboat, the burdened vessel, which shall give way.

F. All vessels passing the vicinity of ferryboats shall slow down to avoid damage caused by waves to the ferryboats. Likewise, ferryboats shall slow down in the Pandacan area (from Nagtahan Bridge to Pandacan Bridge).

G. All vessels operating along the river shall have a marine VHF radio with exclusive frequency/channel on board to enable communication among them and make known the steps or actions they will undertake to promote safe navigation or conduct rescue operations (Calling Channel 6, Working Channel 79).

H. All vessels passing the vicinity of Malacañang Palace shall be subject to security inspection by the presidential security waterborne personnel. Thereafter, they shall speed up to the shortest transit time to clear the Malacañang restricted area.

I. In case of accident involving watercrafts, navigation in the vicinity of the accident shall cease until cleared/verified by the PCG.

This Memorandum Circular enforces penalty to a master or patron and ship-owner found violating any provision of the above regulations without prejudice to the penalties, as follows:

A. First Offense – Warning and a fine of ₱1,000.00.

B. Second Offense – A fine of ₱3,000.00 and a recommendation for suspension of license.

C. Third Offense – A fine of ₱5,000.00 and a recommendation for revocation of license.

(4) Memorandum Circular No. 05-97 of PCG

Memorandum Circular No. 05-97 issued by PCG on 13 October 1997 in connection with RA No. 5173 specifies the Navigational Clearance for Road Bridges as follows:

- The construction of all bridges over navigable waters has to be referred to the PCG for issuance of the appropriate clearance, particularly confirming that the structure would not be hazardous to navigation.

- As far as practicable, a road bridge for inland waters must have a minimum vertical clearance of **3.75 meters** from the highest water level that would allow safe passage of vessels or watercrafts.
- The navigational span of the bridge should be provided in a way that it does not obstruct the safe navigation of appropriate vessels or watercrafts passing through the area.
- The installation and placement of all applicable navigational lights and markings in the navigable approaches of a road bridge, which is an inherent obligation of the constructor, have to be in conformity with the International Association of Lighthouse Authorities Buoyage System.

This Memorandum Circular applies to all road bridges over all bays, rivers, and lakes subject to the jurisdiction of the Philippines. Based on the interviews with PCG, there is no regulation on length, width (breadth), depth and draught of vessels on the Pasig River. The operators of vessels judge by themselves if the vessels are passable or not in the Pasig River.

11.1.2 Management on River Navigation

The System on River Navigation is in charge of planning the navigation route in the Pasig-Marikina River. The Department of Transportation and Communication (DOTC) has no plans to expand commercial navigation up to the Marcos Highway in the middle Marikina River, Marikina City. Instead, DOTC's plan is to extend the operation up to the Laguna Lake through the Pasig River.

The PCG, as a whole, is more involved in the security and safeguard of welfare of natural resources and vessels tranversing the Pasig-Marikina River in accordance with RA No. 5173. The PCG is the agency responsible for managing the safety of navigation by facilitating marks and signs.

The PPA has the responsibility of port management in the Pasig-Marikina River including the survey, study and implementation work for the development, construction and supervision of all port works, facilities and dredging. The PPA, in addition, conducts periodic inspection and audit of the operation and management of all ports and navigational waterways in the Pasig-Marikina River.

The DPWH-NCR has the responsibility of survey, planning, design, and operation and maintenance of bridges in the Pasig-Marikina River. Since these bridges have been affected by vessel collision, the installation of fenders and signboards to avoid or lessen the chance of vessel collision could be undertaken for the sustainable maintenance works with instructions from the PCG.

11.2 PRESENT CONDITIONS OF VESSEL COLLISION

11.2.1 Past Record of Vessel Collision

(1) Report of PCG and DOTC

The Philippine Coast Guard (PCG) of the Department of Transportation and Communication (DOTC) is the main agency responsible for safety in river navigation. The following three (3) cases were reported during the past twelve months from October 2001 to September 2002.

- One barge bumped the girder of the **Pandacan railway bridge** on 23 October 2001, and the railway track was misaligned by approximately two (2) meters.
- Misalignment of railway track by around 1 meter from original position was found at the **Pandacan railway bridge** on 02 May 2002 due to continuous accidental bumping of vessels.
- One barge accidentally hit the **south span of Ayala Bridge** on 03 July 2002, resulting in the damage of the steel girder.

(2) Interview with DPWH-NCR

The National Capital Region of the Department of Public Works and Highways (DPWH-NCR) is responsible for undertaking inspections and maintenance of the existing bridges in the Pasig-Marikina River.

According to the interview survey with the Maintenance Division of DPWH-NCR, the following cases of vessel collision with bridges were reported in the past few years:

- During a typhoon in 1995, a barge moored for the dredging works in Marikina River broke away and the uncontrolled barge bumped **the pier of Marcos Bridge**. The damaged pier has been retrofitted.
- During the works for the repair and rehabilitation of Nagtahan Bridge in 1997, a barge accidentally hit the **northern pier**. However, no serious damage was reported.
- For the past five (5) years, two cases of vessel collision with **the Ayala Bridge** were reported to the DPWH-NCR, including the damage on 03 July, 2002.

However, minor damages and scratch marks on bridge structures have not been reported, and the causes of damage have not also been surveyed and reported in writing.

11.2.2 Present Condition of Vessel Collision

Table 11.2.2-1 shows the present conditions of vessel collisions for each bridge including evidences, existing countermeasures, horizontal clearances between piers and vertical clearance with girders and the recorded highest tide.

Table 11.2.2-1 Present Condition of Vessel Collision

	No.	Bridge Name	Clearance (m)		Evidence of Collision	Existing Counter-measures
			Horizontal	Vertical		
Pasig River	1	Delpan Bridge	46.5	4.0-6.0	No	No
	2	Jones Bridge	**__40.8__**	**__3.6__**-4.8	Ruptured Exterior Girders at Center Span	Pier Protection (Expanded Footing)
	3	McArthur Bridge	**__36.6__**	4.0	No	No
	4	Quezon Bridge	81.9	6.1	No	No
	5	Ayala Bridge	60.2	**__3.50__**	Ruptured/Broken Bracing	No
	6	Nagtahan Bridge	54.1	4.4	No	Pier Protection (Expanded Footing)
	7	Pandacan Bridge	**__44.5__**	8.2	No	No
	8	Lambingan Bridge	58.9	3.8	Cracks at the center span exterior girder of upstream sidge.	Pier Protection (Expanded Footing)
	9	Makati-Mandaluyong Bridge	48.6	5.6	No	No
	10	Guadalupe Bridge	**__34.2__**	8.3	Broken Existing Pier Protection	Pier Protection (RC Fender Type Connected with Footing)
	11	C-5Bridge	**__42.5__**	8.2	Broken Existing Pier Protection	Pier Protection (Independent RC Fender Type)
	12	Bambang Bridge	**__38.7__**	4.6	No	Pier Protection (Expanded Footing and Wooden Fender Type)
Markina River	13	Vargas Bridge	**__40.4__**	5.7	Exposed Rebars at Pier & (Downstream Side)	Pier Protection for Downstream side (Expanded Footing) No Protection for Downstream side pier.
	14	Rosario Bridge	**__28.7__**	5.2	No	Pier Protection (Expanded Footing)
	15	Marcos Bridge	25.6	4.9	No	No
	16	Marikina Bridge	26.3	5.7	No	No
	17	San Jose Bridge	24.0	5.7	No	No

Note: Values in bold and underline are insufficient for regulatory clearances

As seen in **Table 11.2.2-1**, only vessel collision protection for piers were undertaken, there is no case of that for bridge girders due to difficult/costly construction and maintenance of countermeasures.

From the **Table 11.2.2-1**, the present condition of vessel collision are summarized as follows:

Damages of Superstructure due to Vessel Collision

- Jones Bridge : Ruptured Exterior Girders at the Center Span
  : No Countermeasures
- Ayala Bridge : Ruptured/Broken Bracings
  : No Countermeasures
- Lambingan Bridge : Cracks at the Center Span's Exterior Girder of Downstream Side
  : No Countermeasures

Damages of Substructure/ Protection due to Vessel Collision

- Jones Bridge : Exposed Rebars at Pier (Downstream Side)
  : Broken RC Shear Key (Upstream Side)
- Nagtahan Bridge : Exposed Rebar at Pier Upstream Side
- 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 : Jones Bridge, Nagtahan Bridge, Lambingan Bridge, Bambang Bridge, Vargas Bridge (Downstream Side), Rosario Bridge
- RC Fender Type Connected with Expanded Footing : Guadalupe Bridge
- RC Fender Type Independent from Footing : C-5 Bridge
- Wooden Fender Type Independent from Footing : Bambang Bridge

Pictures 11.1.2-1, 2 and 3 shows damages to typical pier protections.

Picture 11.2.1-1 RC Fender Type Connected with Expanded Footing (Guadalupe Bridge)

Picture 11.2.1-1 RC Fender Type (C-5 Bridge)

Picture 11.2.1-3 Expanded Footing and Wooden Fender Type

11.2.3 River Traffic

(1) Pasig River

The Pasig River is a major river for water navigation, and the vessels navigating the river are the motorized tugboats, barges, motor tankers, bankers and fishing boats. The PCG gives the destination of vessels and the daily average traffic volume in 2002 as follows:

Destination of Vessels and Daily Average Traffic

Vessels	Destination	Daily Traffic Volume
Motorized Tanker	Laguna Lake through Pasig River	44
Fishing Boat	Laguna Lake through Pasig River	5 (weekly)
Tugboat	Between Pandacan and C-5 bridge	77
Barge	Between Pandacan and C-5 bridge	28
Total		150 (daily)

The maximum dimensions of vessels that usually navigate Pasig River are shown in **Table 11.2.3-1.**

Table 11.2.3-1 Maximum Dimensions of Vessels

Length	Breadth	Depth	Gross Tonnage
60 meters	13 meters	3.78 meters	720 tons

According to the monthly records of navigation for the past 18 months at the Philippine Ports Authority (PPA), the annual total number of vessels using port in the Pasig River and the volume of cargoes are around 12,600 and 9.4 million tons, respectively, from July 2001 to June 2002.

(2) Marikina River

The estimated monthly volume of water navigation by barges in the Marikina River up to Rosario, Pasig City is less than 10 because of siltation, according to the interview survey with PCG.

At present, navigation is made only by small boats for fishing and farming. Speedboats are for rescue operations of the village administrators in the Lower Marikina River. Specifications of boats are as given in **Table 11.2.3-2.**

Table 11.2.3-2 Specifications of Boat

Item	Speedboat	Small Boat
Power	35 HP	12 HP
Weight	250 kg.	-
Passenger	4 persons	4-5 persons
Speed (Maximum)	50-60km/h (13.9-16.7 m/s)	20km/h (5.6 m/s)

In addition to the above, the specifications of the ferryboats which used to operate in the lower Marikina River are given in **Table 11.2.3-3**.

Table 11.2.3-3 Specifications of Ferry Boat

Item	Type-1	Type-2
Weight of the Boat	19.4 ton	16.4 ton
Length of the Boat	15.1 m	11.9 m
Width of the Boat	5.0 m	2.5 m
Required River Depth	1.9 m*	1.3 m*
Vertical Clearance above River Surface	3.0 m*	3.0 m*
Required Width	8.0 m*	5.5 m*

* Confirmed by the Philippine Ports Authority (PPA) during the meeting on 10 November 2000 for the Detailed Engineering Design of Pasig-Marikina River Channel Improvement Project.

Commercial transportation by ferry boat is not presently conducted upstream of the Mangahan Floodway until the Marikina Bridge. Only small emergency patrol boats operate within the Marikina City area. The Type-1 of ferry boat, which has a bigger size, was used to verify the adequacy of vertical and horizontal spaces under bridges for navigation in this river stretch.

In the river stretch **from Marikina to San Jose Bridge**, only fishing bankers are presently operating and no navigation by motorboat is planned. The dimensions of bankers are as given in **Table 11.2.3-4.**

Table 11.2.3-4 Dimensions of Banker

Length	Width	Required Vertical Clearance
6 m	1 m	1.5 m

11.3 RECOMMENDATION ON NAVIGATION CLEARANCES

As discussed in **Section 11.1.2**, only the vertical clearance of 3.75 m from the highest water level is regulated for the navigation. In this section adoption of horizontal and vertical clearances to the study bridges was discussed accordingly, based on interview survey with the PCG, existing regulations and the present condition on navigation.

11.3.1 Horizontal Clearance

The horizontal clearance for navigation may be determined in consideration of collision patterns with a bridge pier as shown in **Figure 11.3.1-1**, which is related to both vessel length and space between piers.

- Ideal Clearance is the same as the maximum length of vessels passing the rivers.
- Preferable clearance is the maximum length from pier surface to the near end of a vessel at a deflection angle of 45 degrees.

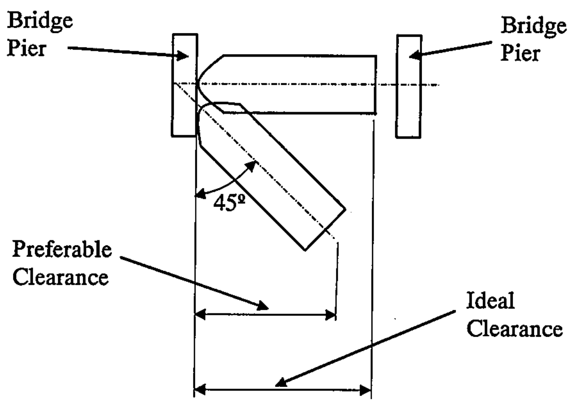


Figure 11.3.1-1 Assumed Vessel Collision Patterns

The ideal and preferable clearances are categorized as to the scale of vessels passing the river sections as shown in **Table 11.3.1-1**. The horizontal clearance was recommended to be wider than the preferable space.

Table 11.3.1-1 Ideal and Preferable Spaces of Bridge Piers for One Vessel

Stretch	Ideal Space	Preferable Space (Minimum Requirement)	Reference Tables
Pasig River (Manila Bay to Laguna Lake) and Lower Marikina River (Napindan Weir to Rosario Weir)	L=60 m	L x sin(45) = 42.4 m = around 43 m	Table 11.2.3-1
Marikina River (Rosario Weir to Marikina River)	L=15.1 m	L x sin(45) = 10.7 m = around 11 m	Table 11.2.3-3
Marikina River (Marikina Bridge to San Jose Bridge)	L=6 m	L x sin(45) = 4.2 m = around 5 m	Table 11.2.3-4

<u>During Construction</u>

Considering temporary application and traffic control which will be strictly undertaken during construction, the allowable horizontal clearance was recommended to be over than 1.8 times the maximum width of vessels, which is 24 m for the Pasig River.

11.3.2 Vertical Clearance

The regulated vertical clearance specified under PCG Memorandum Circular No. 05-97, **Navigational Clearance for Road Bridges**, is 3.75 meters (10 ft.), which should be applied on the Pasig River (Manila Bay to Laguna Lake) and the Lower Marikina River (Napindan Weir to Rosario Weir) for transportation by barge.

However, the scale of vessels recently has been becoming increasingly large. According to the interview survey with the PCG, the ideal vertical clearance between girder bottom and the highest water level is actually required to be 5.0 m for the Pasig River.

In due consideration of the present vertical clearance of each existing bridge and the above requirement, the vertical clearance was recommended to be higher than the preferable clearance as shown in **Table 11.3.2-1.**

Table 11.3.2-1 Ideal and Minimum Vertical Clearances between Girder Bottom and the Highest Water Surface *

Stretch	Ideal Clearance	Preferable Clearance (Minimum Requirement)
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 (Refer to **Table 11.3.2-2**).

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

Table 11.3.2-2 Estimation of the Highest Water Level for Navigation Clearance

	Bridge Name	Water Level at Runoff Discharge		Recorded Highest Tide (m)	Highest Water Level (m)
		V (m/s)	H (m)		
	Pasig River				
1	Delpan Bridge	1.0	11.5	12.1	12.1
2	Jones Bridge	1.4	11.6	12.1	12.1
3	Mac Arthur Bridge	1.1	11.6	12.1	12.1
4	Quezon Bridge	1.4	11.6	12.1	12.1
5	Ayala Bridge	0.9	11.7	12.1	12.1
6	Nagtahan Bridge	1.0	11.9	12.1	12.1
7	Pandacan Bridge	1.0	12.0	12.1	12.1
8	Lambingan Bridge	0.9	12.2	12.1	12.2
9	Makati-Mandaluyong Bridge	1.2	12.5	12.1	12.5
10	Guadalupe Bridge	1.2	12.6	12.1	12.5
11	C-5 Bridge	0.9	12.9	12.1	12.9
	Marikina River				
12	Vargas Bridge	1.1	13.2	-	13.2
13	Rosario Bridge	1.3	13.7	-	13.7
14	Marcos Bridge	1.5	15.1	-	15.1
15	Marikina Bridge	1.5	16.0	-	16.1

11.4 PREVENTION SYSTEM AGAINST VESSEL COLLISION

11.4.1 Administrative Measures

Vessel collision with bridges could be classified into accidental collision and collision caused by reckless passing under the bridge. To prevent vessel collision with bridges, the enforcement of administrative measures is indispensable, practical and economical for the Pasig-Marikina River, as specified below:

- **No Passing Zone:** Vessels should not pass together or at the same time with other vessels under a bridge.
- **No Ovetaking Zone:** Vessels should not overtake other vessels under a bridge.
- **Warning Tone:** Vessels should blow a warning tone before passing under a bridge, especially at the corner of a meandering river course.
- **Clearance Gauge:** Gauges are valuable to vessel operators to indicate the vertical clearance.
- **Warning Buoy:** Buoys are valuable to indicate the navigation area to vessel operators and avoid accidental vessel collision with bridge piers/abutments.

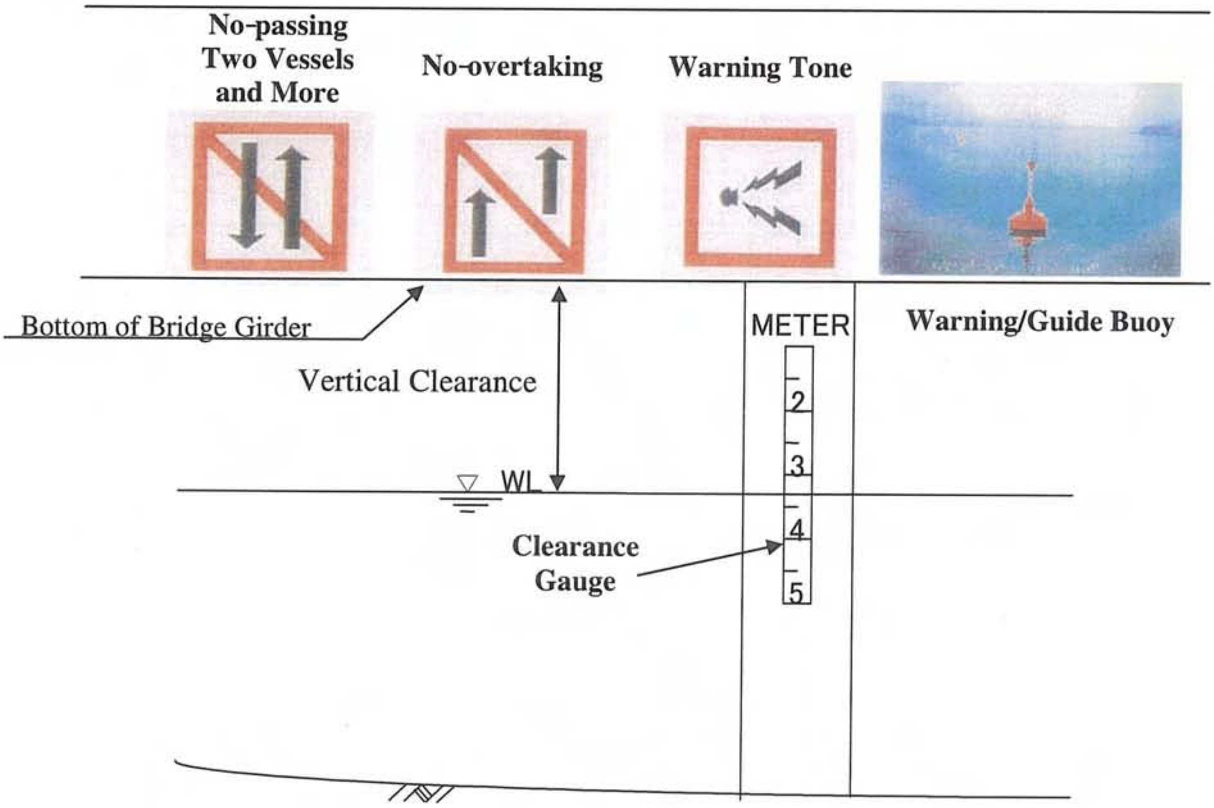


Figure 11.4.1-1 Signs and Markers for Safety Navigation

Damage Protection of Bridge Pier/Abutment

Warning Buoy is effective for seven (7) bridges with high risks of vessel collision with bridge pier/abutment such as the Jones, McArthur, Nagtahan, Lambingan, Guadalupe, C-5, Bambang. The installation on **Warning Buoy** and use of **Warning Tone** should be given very high priority for the bridges located at the meander of river channel such as McArthur Bridge, Nagtahan Bridge, Lambingan Bridge, and C-5 Bridge.

Damage Protection of Bridge Girder

Markers for **No Passing Zone**, and **No Overtaking Zone** together with **Clearance Gauge**, are effective for seven (7) bridges with lower girder elevation such as Delpan, Jones, McArthur, Ayala, Nagtahan, Lambingan and Bambang bridges. Especially, Ayala Bridge and Jones Bridge should receive the highest priority for adoption of these measures immediately.

11.4.2 Technical Measures

Based on the above investigation and data collection, some alternative plans to prevent damage to bridge structures by ship collision are proposed, as follows:

- To install fenders in front of or around the pier/abutment to mitigate or protect it from damage.
- To install guidepost to identify the vertical clearance. The height of barge would vary from 1.5 m to 2 m due to the volume or weight of load.

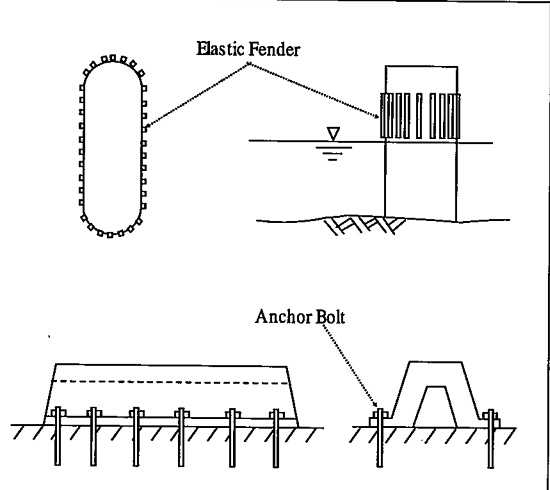
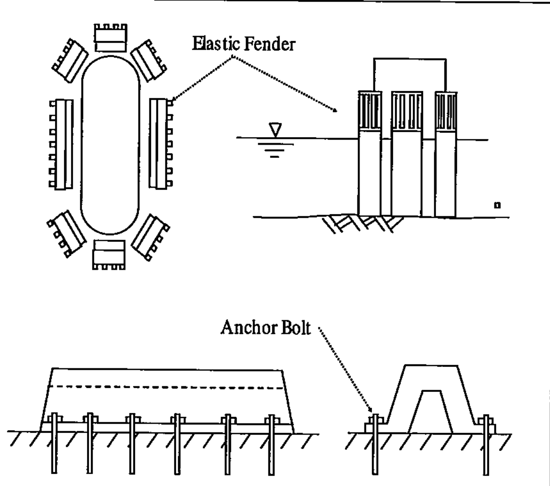
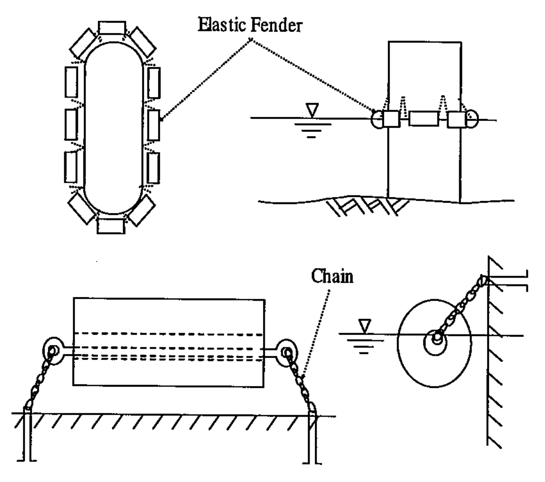
(1) Fenders for Bridge Pier/ Abutment

Fenders are generally classified into three (3) categories; attached fender, dolphin fender and floating fender. The features and a comparison of these fenders are given in **Table 11.4.2-1.**

From the comparative study, floating fender is the most recommendable option in view of river encroachment and navigation. The target bridges and the priority of installation of fenders should be decided based on the survey results of damage caused be vessel collision. **Section 11.5** gives the recommendation of countermeasures against vessel collision for each bridge.

All of these types of fender would require investment for maintenance as well as replacement and repair. If the existing pier/abutment would not be damaged seriously by vessel collision, it is preferable not to install fenders in view of the financial burden for maintenance and the adverse effects like obstruction of flood river flow and navigation.

Table 11.4.2-1 Comparison of Protection Types of Pier

Item	Type I (Attached Fender)	Type 2 (Dolphin Fender)	Type 3 (Floating Fender)
Plan and Cross Section			
Fender Structure	Elastic fenders are attached to bridge pier/abutment by anchor bolts.	Independent Dolphin fenders are installed around pier/abutment	Floating fenders are attached to pier/abutment by chains.
Effect to the Bridge Structure	This type of fender has slightly less energy absorption than Type 3 because the fenders are attached directly to the bridge structure.	This type of fenders protects the bridge most effectively among the 3 types, because the fender structures are independent from the bridge structure.	This type has a slightly higher energy absorption properties than type 1, because the fenders are attached by chains.
Effect to the Vessel	Due to the same reason as above, it gives a slightly higher reaction to vessels than type-3	Based on actual PCG's experience, this type of fender was not immediately repaired and sometimes buried under water when damaged. The unrepaired fenders, especially buried ones, are quite dangerous to navigation. Due to this reason PCG does not recommend this type of fender.	Due to the same reason as above, it gives a slightly lower reactions to the vessel than type-1.
Effect to the River Flow	The effect to the river flow is negligible. However, its structure slightly disturb the river flow compared with Type 3, as it is fixed to piers/abutments.	This type of fender disturbs river flow and increases water level in case of flood.	The effect to the river flow is negligible.
Construction Cost	US$50,000 per linear meter including installation	US$100,000 per 50 linear meter including installation and foundation.	US$50,000 per 50 linear meter including installation.
Maintenance	Replacement of damaged fenders/anchor bolts	Replacement of damaged fenders/anchor bolts and rehabilitation of the supporting structures.	Replacement of damaged fenders/chains.
Rating and Remarks	2 This type of fenders mitigates the impact of vessel collision and prevents major damages to pier/abutment. However, this type is slightly less effective to the collision impact and affects river hydraulics/navigation.	3 This type of fender is the most effective for the protection of pier/abutment against vessel collision. However, this is not recommendable from the viewpoint of navigation and flood control. Besides, the cost of installation and maintenance is the highest among the three (3) types.	1 This Type is recommendable, because this type is most effective to collision impact and slightly affects river hydraulics/navigation.

(2) Protection for Bridge Girder

Table 11.4.2-2 provides three (3) types for comparative study on protection measures for bridge girders; Type 1 is a frame type with a steel fender beam; Type 2 is an arch type with hanging wires; Type 3 is a detector type with infrared radiation.

From the comparative study in **Table 11.4.2-2**, Type 3 is recommendable for the bridge girder protection system to vessel collision.

Figure 11.4.2-1 illustrates the Type 3 option with the following features:

- The speakers automatically give a warning against vessels having illegal height.
- This type inflicts no damage on vessels
- Impairing ambient landscape is to be minimized
- Installation costs of the system are considerably cheaper than the others.

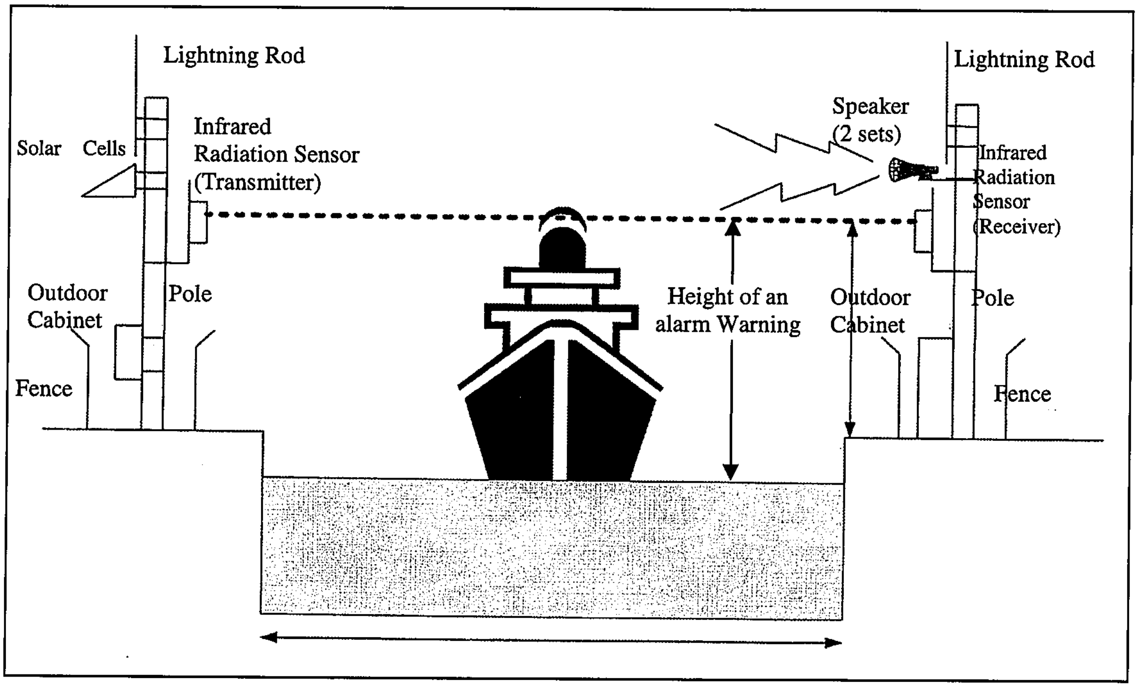
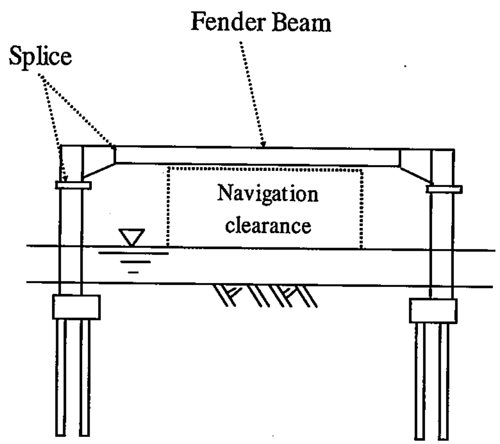
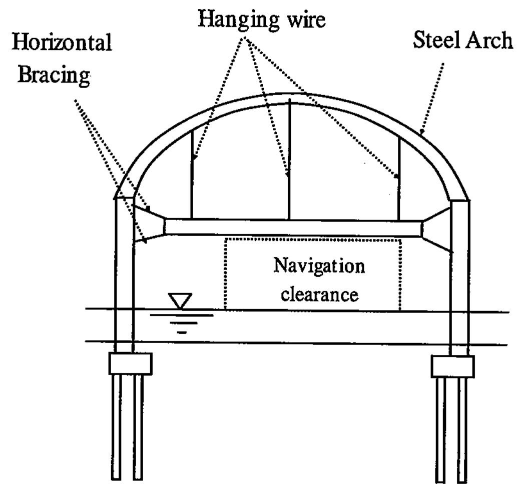
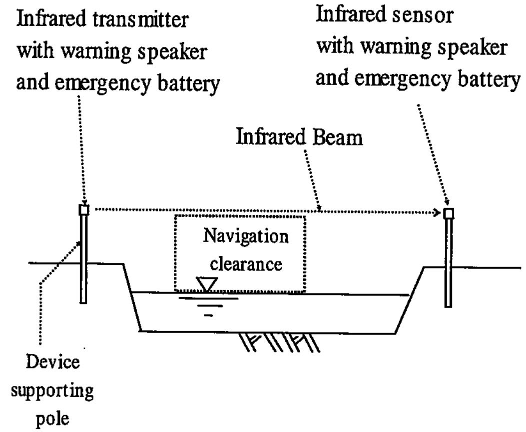


Figure 11.4.2-1 Bridge Collision Avoidance System with Infrared Radiation

Table 11.4.2-2 Comparison of Protection Types for Bridge Girder

Item	Type I (Frame Type)	Type 2 (Arch Type)	Type 3 (Detour Type)
Cross Section			
Structure / Effect	Structure: Two steel columns support a fender beam. The beam is connected by splices as to minimize damage on vessels. Effects: This type of fender has strong impact on vessel. Possibility of inflicting damage to vessels is slightly higher than Type 2. This system can partially absorb collision impact of accidentally drifting vessels.	Structure: Two steel columns support a steel arch. The columns and arch support a fender beam with wires to minimize damage to vessels. Effects: This type of fender has strong impact on vessels. Possibility of inflicting damage to vessels is slightly lower than Type 1. This system can partially absorb collision impact of accidentally drifting vessels.	Structure: The transmitter and sensors are supported by supporting poles on the river banks. The speaker automatically gives warning against vessels having illegal height. Effects: There is no possibility to inflict damage to vessel. However, this system cannot prevent collision in case of accidentally drifting vessels during typhoon. The speaker automatically works when the sensor detects an illegally navigating vessel.
Appearance	Impair Landscape	Impair Landscape	Not Impair
Cost	5.5MP per frame	6.5MP per frame	1.2MP per whole system
Maintenance	Repair works needed after collision	Repair works needed after collision	Routine system maintenance (including electricity)
Rating	2	3	**1 (Recommendable)**

11.5 RECOMMENDED PREVENTION MEASURES

The causes of vessel collision with the bridge are taken as follows:

- Physical conditions of the bridge such as insufficient horizontal and vertical clearances.
- Geometrical conditions of the river such as meandering river section.
- Maneuver of vessel operation such as reckless passing and overtaking of vessels under bridges.

The recommendations on countermeasures against vessel collision are summarized in **Table 11.5-1** in terms of the physical conditions of each bridge, the geometrical conditions of the river section where the bridge is located, and the present damage conditions caused by vessel collision.

As far as maneuver of vessel operation is concerned, the rules and regulations on the passage of vessels under bridges should be strictly enforced.

Table 11.5-1 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 be not 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

* : Refer to the Type 3 in **Table 11.4.2-2**
: Refer to the Type 3 in **Table 11.4.2-1.

CHAPTER 12

OVERALL IMPLEMENTATION PLAN

CHAPTER 12

OVERALL IMPLEMENTATION PLAN

12.1 IMPLEMENTATION STRATEGY

Bridge condition survey and structural analysis were conducted for the twenty (20) bridge structure under the study. The results revealed that based on technical judgment, thirteen (13) bridge structure were evaluated to require urgent improvement measures.

In consideration of such technical urgency and the financial aspects, the following strategies were 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

- Major and minor scale rehabilitation works are given the highest priority of urgency. (13 Bridges)
  Delpan Bridge (Upstream side), Jones Bridge, Mc Arthur Bridge, Quezon Bridge, Ayala Bridge, Nagtahan Bridge, Lambingan Bridge, Guadalupe Bridge (Central), Guadalupe Bridge (Both sides), Vargas Bridge (Upstream side), Vargas Bridge (Upstream side), Vargas Bridge (Downstream side), Rosario Bridge and San Jose Bridge.

- Repair works are given the second priority of urgency. (7 Bridges)
  Delpan Bridge (Downstream side), Pandacan Bridge, Makati-Mandaluyong Bridge, C5 Bridge, Bambang Bridge, Marcos Bridge and Marikina Bridge.

Measures against Vessel Collision (Fender)

- Ruptured girder of the Jones Bridge were caused by vessel collisions. The measures against vessel collisions with girders shall be undertaken together with the bridge improvement project as well as the Ayala Bridge, accordingly. Otherwise the rehabilitation for the Jones Bridge will be insufficient.

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

Retrofitting to Earthquakes

- The implementation timing of retrofit to earthquakes is to be considered to be separate 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

- The Ayala Bridge, Jones Bridge and Guadalupe bridge (Both sides) shall be improved at the soonest possible time because of the deteriorated condition.

- The Second Ayala Bridge shall be constructed at the most economical timing, as recommended in **Chapter 19**.

12.2 PROPOSED IMPROVEMENT WORKS

The proposed improved work are shown in **Table 12.2-1** 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 were determined based on the rehabilitated or repaired bridges that would require further repair works of other members remaining unrepaired about every ten (10) years.

Table 12.2-2 presents roughly the estimated construction cost of the proposed improvement works.

The rehabilitation works, such as replacement of floor system, replacement of rivets and heavily corroded joint connections, rehabilitation of corroded steel members etc. call for ₱ 757.94 M (except Ayala improvement works). The repair works needs only ₱ 111.50 M.

12.3 OVERALL IMPEMENTATION SCHEDULE

Table 12.3-1 illustrates the overall implementation schedule of the project, showing the annual fund requirement.

The total cost of the project is estimated as follows:

- 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 : ₱ 941.30 M

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

The following improvement works are not included in the project:

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

Table 12.2-1 Proposed Improvement Works

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

Table 12.2-2 Proposed Improvement Works and Construction Cost

No.	Ref. No.	Bridge Name	Superstructure Type	Main Damage	Improvement Works				Pier Protection to vessel collision	Retrofitting to Earthquakes			Vertical Clearance	
					Strengthening	Rehabilitation	Repair	Total Cost		Protection for fall-down	Pier Body	Foundation for piers abutment	For Truck	For vessel
1	Pa 1.1	Delpan Bridge (Upstream)	PC Gerber Box Girder (5span)	Truck Collision	-	23.70	-	23.70	-	▽	⊗	⊗	⊛	⊛
	Pa 1.2	Delpan Bridge (Downstream)	PC Gerber Box Girder (5span)	Minor Cracks	-	-	11.40	11.40	-	▽	⊗	⊗	⊛	⊛
2	Pa 2	Jones Bridge	3-Span Continuous Steel Plate Girder	Ruptured Girder	-	161.80	-	161.80	13.60	▽	®	®	-	⊘
3	Pa 3	McArthur Bridge	3-Span Continuous Steel Plate Girder	Loss of Rivets	-	50.70	-	50.70	4.50	▽	®	®	-	⊛
4	Pa 4	Quezon Bridge	Single Steel Arch	Corroded Floor System	-	119.60	-	119.60	-	-	-	®	-	⊛
6	Pa 6	Nagtahan Bridge	3-Span Continuous Steel Truss Bridge	Pier Inclination	-	124.74	-	124.74	1.70	▽	®	®	⊛	⊛
7	Pa 7	Pandacan Bridge	PC I Girder (5span)	Minor Cracks	-	-	12.20	12.20	-	-	⊗	⊗	-	⊛
8	Pa 8	Lambingan Bridge	PC I Girder (3span)	Corroded Uplift Device	-	48.90	-	48.90	12.20	▽	®	⊗	⊛	⊛
9	Pa 9	Makati-Mandaluyong Bridge	PC Box Girder with Gerber I Girder (3span)	Horizontal Cracks	-	-	9.40	9.40	-	®	®	®	-	⊛
10	Pa 10.1	Guadalupe Br. (Central)	3-span Continuous Steel Truss Bridge	Corroded Steel Members	-	94.80	-	94.80	-	⊗	⊗	⊗	⊛	⊛
	Pa 10.2	Guadalupe Br. (Both Sides)	PC Gerber Girder (3span)	Gerber Hinge Cracks	-	20.40	-	20.40	4.50	▽	®	®	⊛	⊛
11	Pa 11	C-5 Bridge	PC I Girder (10span)	Cracks	-	-	32.90	32.90	5.70	⊗	®	®	-	⊛
12	Pa 12	Bambang Bridge	PC I Girder (9span)	Diagonal Cracks	-	-	7.50	7.50	4.50	▽	▽	▽	-	⊛
13	Ma 1.1	Vargas Bridge (Upstream)	PC Gerber Girder (4span)	Deflection/Gerber Hinge Cracks	-	24.31	-	24.31	4.50	▽	⊗	▽	-	⊛
	Ma 1.2	Vargas Bridge (Downstream)	Steel Plate Girder (4span)	Steel Corrosion	-	18.64	-	18.64	-	▽	⊗	⊗	-	⊛
14	Ma 2	Rosario Bridge	PC I Girder (6 span)	Deck Slab Cracks	-	36.35	-	36.35	-	▽	®	®	⊛	⊛
15	Ma 3	Marcos Bridge	PC I Girder (11span)	Minor Cracks	-	-	25.70	25.70	-	▽	▽	⊗	-	⊛
16	Ma 4	Marikina Bridge	PC I Girder (5span)	Minor Cracks	-	-	12.40	12.40	-	▽	▽	▽	-	⊛
17	Ma 5	San Jose Bridge	PC I Girder (8span)	Expansion Joint	-	34.00	-	34.00	-	®	®	®	-	⊛
TOTAL CONSTRUCTION COST					-	757.94	111.50	869.44	51.20	-	-	-	-	-

Legend:

▽ – Already installed/retrofitted

® - Retrofitted Necessary

⊗ - Retrofit not Necessary

⊛ - Sufficient Vertical Clearance

⊘ - Insufficient Clearance

Table 12.3-1 Overall Implementation Schedule

Bridge No.	REF.	Bridge Name (Construcion Year)	Short Term (Year 2004 - 2013) 04	05	06	07	08	09	10	11	12	13	Medium Term (Year 2014 - 2023) 14	15	16	17	18	19	20	21	22	23	Long Term (Year 2024 - 2033) 24	25	26	27	28	29	30	31	32	33	Protection of Piers	Retrofitting to Earthquake
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

12.4 SELECTION OF BRIDGES FOR FEASIBILITY STUDY

12.4.1 Selection Criteria

A selection criteria was established and applied to all bridges to identify bridges to be subjected to further technical and environmental and economic studies during the next phase of the Study.

① Urgency

Improvement works will be in urgent need for implementation in terms of structural safety.

② Positive Environmental Impact

Projects should be selected to improve the natural and social environmental aspect in the vicinity area and to provide positive impacts to environment.

③ Project Maturity

Project should have the readiness for implementation while those involving the acquisition of right of way and relocation of residents are given the low priority.

④ Study Example

A study with technical, economic and environmental depth is expected to show an example of solving similar problems involving a new technology.

⑤ Project Scale

High priority projects are preferable to have the big scale in terms of impacts so that the realization of the Master Plan will be accelerated.

12.4.2 Selected Bridges

Under the criteria established in **Section 12.4.1**, the following bridges were selected as the projects with highest priority for further detailed studies in the next phase of the Study.

1. Jones Bridge
2. Quezon Bridge

3. Lambingan Bridge
4. Guadalupe Bridge (Both Sides)
5. Vargas Bridge (Upstream side)
6. Second Ayala Bridge

Bridges above were evaluated as shown in **Table 12.4.2-1** corresponding to the criteria established in **Section 12.4.1.**

The second Ayala Bridge was included in the bridges for the Feasibility Study according to the following reasons.

- The role of the Second Ayala Bridge is to complement the traffic function of the existing Ayala Bridge, the traffic volume of which was forecasted to be beyond its capacity in the near future. This means that construction of the second Ayala Bridge shall be considered as part of the improvement project of the existing Ayala Bridge.

- The second Ayala Bridge will be conducive to the improvement of the traffic function in the vicinity areas revealed in **Chapter 19.**

Table 12.4.2-1 Evaluation on Bridges for Feasibility Study

Bridge Name	① Urgency	② Positive Environmental Impact	③ Project Maturity	④ Study Example	⑤ Project Scale	Main Study Items Under F/S
1. Jones Bridge	• RF_1 = Negative (an exterior girder is ruptured) • RF_0 = 0.76 (Very Urgent)	• Vibration of the bridge may be reduced • Ridability will be improved • Structural safety will be improved	• No right of way acquisition	• 3-span continuous steel plate girder bridge	• Major rehabilitation	• Replacement method and analysis of the ruptured girder • Construction planning
2. Quezon Bridge	• RF_1 = 0.92 • RF_0 = 1.59 • Included in the short-term plan (Very Urgent)	• Vibration of the bridge may be reduced • Better scenery will be given to users by the painting • Structural safety will be improved	• No right of way acquisition	• Single steel arch bridge	• Major rehabilitation	• Survey on the degree of corrosion of the floor system • A study on rehabilitation methods, analysis and design.
3. Lambingan Bridge	• RF_1 = 0.63 • RF_0 = 1.06 • Included in the short-term plan (Very Urgent)	• Vibration of the bridge may be reduced • Ridability will be improved • Structural safety will be improved	• No right of way acquisition	• PC I Girder Gerber Bridge	• Major rehabilitation	• Analysis of up-lift mechanism at the supporting part of gerber hinge • Establishment of counter-measures
4. Guadalupe Bridge (Both sides)	• RF_1 = 0.44 • RF_0 = 074 • Included in the short-term plan (Very Urgent)	• Vibration of the bridge may be reduced • Ridability will be improved • Structural safety will be improved	• No right of way acquisition	• PC I Girder Gerber Bridge	• Major rehabilitation	• Analysis of concrete cracks at the supporting part of gerber hinge • Rehabilitation method for gerber hinge • Establishment of counter-measure.
5. Vargas Bridge (Upstream)	• RF_1 = 0.83 • RF_0 = 1.39 • Included in the short-term plan • Remarkable deflected center span (Very Urgent)	• Ridability will be improved • Structural safety will be improved	• No right of way acquisition	• PC I Girder Gerber Bridge	• Major rehabilitation	• Rehabilitation method for gerber hinge • Establishment of counter-measures.
6. Second Ayala Bridge	• New Construction • Shall be constructed within 10 years because of less traffic capacity of Ayala Bridge	• Social and economic activities will be enhanced • Pollutant emitted from motor vehicles will be mitigated	• Need for right-of –way acquisition • Relocation of residents will be minimized by going through relatively vacant areas	• New Construction	• New Construction	• Preliminary design of the bridge and approach road.

RF_1 : Rating factor of the Inventory Level
RF_0 : Rating factor of the Operating Level